A Novel, Inventive, and Automated Solar-Powered Pest Light Trapping Machine with a GSM-based Monitoring System Using Arduino Microcontrollers

Elaine Grace Q. Lariosa
Department of Electronics Engineering, Caraga State University

Jetro M. Juntilla
Department of Electronics Engineering, Caraga State University

Glenn V. Villafuerte
Department of Electronics Engineering, Caraga State University

Isagani M. Roma
Department of Electronics Engineering, Caraga State University

他

https://doi.org/10.5109/7323321

出版情報：Proceedings of International Exchange and Innovation Conference on Engineering & Sciences (IEICES). 10, pp.590-596, 2024-10-17. International Exchange and Innovation Conference on Engineering & Sciences
バージョン：

A Novel, Inventive, and Automated Solar-Powered Pest Light Trapping Machine with a GSM-based monitoring system using Arduino Microcontrollers

Elaine Grace Q. Lariosa[1,2], Jetro M. Juntilla[1,2], Glenn V. Villafuerte[1,2], Isagani M. Roma[1,2], Jeffrey T. Dellosa[1,3], Re-Ann Cristine O. Calimpusan[1,2]
[1]Department of Electronics Engineering, Caraga State University, Butuan City, Philippines
[2]Center for Renewable Energy, Automation, and Fabrication Technologies (CRAFT)
[3]Mindanao Renewable Energy Center, Ateneo de Davao University, Davao City, Philippines
Corresponding author email: jtdellosa@carsu.edu.ph

Abstract: *This study introduces an innovative automated solar-powered rice black bug light trapping machine to address farmers' challenges in manual pest management, such as installation, collection, and electricity costs. The machine features self-operating electronic circuitry, an automated packing system for sealing full sacks, and a GSM-based remote update and control monitoring system. It operates from 8 pm to 12 midnight, with an extension option until 3 am, powered by a solar photovoltaic system, ensuring sustainability, and reduced operational costs. Prototype testing demonstrated its efficiency in automated trapping, packing, and remote monitoring. The GSM system provided reliable updates. Further field testing is recommended, but initial results showed successful pest attraction and collection. Patent protection has been applied for, highlighting the invention's novelty and potential impact on sustainable pest management for rice farmers.*

Keywords: Pest management; Black bug light trapping machine; Arduino microcontrollers; GSM-based communication system.

1. INTRODUCTION

Rice is the main source of food for Filipinos. It has always been a part of every Filipino meal, so its production is vital to food security. The increasing Philippine population equates to an increasing demand for rice production [1]. Approximately about 2.3 million hectares in the Philippines are rice cultivated lands. Many factors influence crop yield, such as farming practices, use of fertilizers, pest infestation, and crop diseases [2]. Among these factors, pest infestation and crop diseases directly affect crop productivity as they directly damage the crop, thus resulting in a decrease in crop yield. This calls for researchers and scientists to find effective methods and measures to improve crop protection strategies. However, attention and efforts should be directed towards developing an environment-friendly pest management strategy. Prevention of damages to crops can prevent crop losses and increase production. Pest infestation is one of the most challenging tasks for farmers to manage. Improper pest management could result in production losses and affect farmers' income [3]-[6].

One of the rice pests that has continuously destroyed the rice fields in the Philippines is the Rice Black Bug (RBB.) Its first outbreak was recorded in June 1982 in Palawan Province [7], and it continued to invade the Philippine rice fields until now. An IRRI study in 1981 shows that this pest feeds on the different parts of the rice plant during different growth stages of the plant [8]. It was found out in a study conducted at the PhilRice in North Cotabato from 1996 to 1999 that a single female rice black bug can lay eggs in masses with 20-59 eggs per mass [9], and it can lay up to 200 eggs during its lifetime [10]. Ten adult black bugs per rice hill can cause up to 35% loss to crop production per hill [11]. Uncontrolled pest outbreaks could result in 60 to 80% yield reduction up to zero harvests when the infestation is exceptionally high [12].

The most conventional way to control RBB among farmers is using pesticides. The continuous use of pesticides results in the buildup of pest resistance. Massive application of pesticides kills the pest's natural enemies and can bring "catastrophic synchronization" [13]. This phenomenon results in pest outbreaks rather than control due to the absence of natural predators in the field. An example was the outbreak in Palawan in 1982 and Zamboanga in 1992 [14]. The use of pesticides also results in acute and chronic health problems [15]-[21]. Pesticides leave toxic residues on treated grains, which harm human consumers and pose a danger to pesticide applicators and the environment [21]. Due to numerous downsides associated with the use of pesticides, PhilRice and the International Rice Research Institute encourage the use of light traps to manage the RBB population [10]-[11], [22]-[23]. Researchers have recommended light trapping to control RBB [24]-[25]. In the 1970s', China set up over one million light traps at a rate of one trap per 2.3. hectares for rice stem borer control [26]. Light trap was also used to suppress other rice pests such as stem borer, leafhopper, and planthopper [27].

The researchers searched the patent to determine the closest prior art for the proposed technology using the patent databases available from the World Intellectual Property Organization's (WIPO) Espacenet and other relevant journals or articles. The closest prior art identified was research funded by DOST ERDT in 2013, which aimed at creating a prototype of an alternative digital pest controller to eliminate the use of pesticides in pest management [28-30]. The prototype was a light-trapping machine that collects rice pests (see Fig. 1). At the end of the research, more pests were collected in white light at higher light intensity and in ultraviolet light. However, this lacks the mechanism to pack the pests when the device or system captures them.

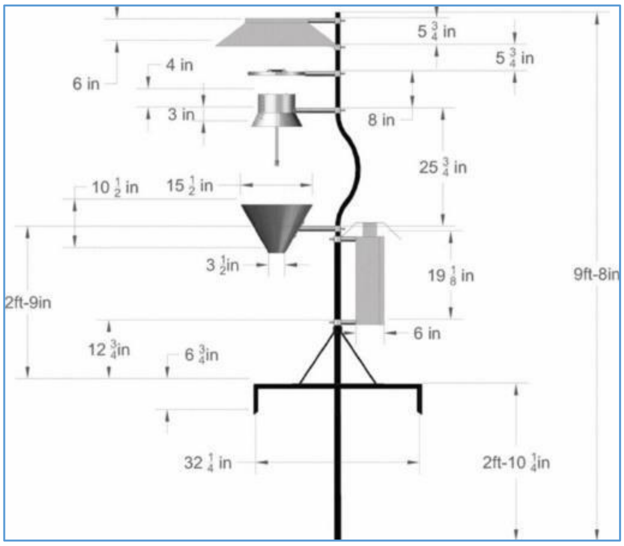


Fig. 1. Alternative digital pest controller.

Making a good trap and finding electrical connections, especially in rural areas, are often the limitations of using light traps [23]. High electricity costs often concern farmers. Farmers also complain about skin itchiness, irritations, and a stinky smell when contacting RBB during packing. Farmers are usually unaware when an infestation has already become an outbreak, resulting in improper pest management.

The main objective of this study is to make an automated light-trapping machine for RBB to reduce the use of pesticides. To address farmers' problems with manual light traps, the machine has an automated packing system and a GSM-based monitoring system that will give updates, especially during outbreaks. A stand-alone photovoltaic power system also powers the whole system.

2. METHODOLOGY

This chapter outlines the detailed methodology used in designing, constructing, and evaluating the automated solar-powered light trapping machine to manage the Rice Black Bug (RBB) in Philippine rice fields. The chapter is structured to provide a comprehensive understanding of the steps and processes undertaken in developing the machine, including the system design, implementation, and testing procedures.

This part of the study focused on the construction of the light trap machine, the mechanisms for collecting and packing collected RBB, and the monitoring system used. It also includes the control system's program flow, the machine's overall circuitry, and its physical construction. This part of the study also discusses how the necessary data was obtained.

The primary objective of this study is to create an innovative solution that addresses the challenges farmers face in pest management. Traditional methods, such as manual light traps and pesticide application, have proven labor-intensive, costly, and potentially harmful to human health and the environment. Therefore, this study aims to develop a machine that reduces manual labor and promotes sustainable farming practices through renewable energy sources and automated systems.

The methodology section begins with an overview of the overall system design and implementation, detailing the construction of the light-trapping machine and the mechanisms for collecting and packing the trapped pests. This is followed by a description of the control system's program flow, the electronic circuitry involved, and the physical construction of the machine. The chapter also explains the data-gathering methods employed to test the machine's efficiency and effectiveness, including the testing of weight sensing systems, battery performance, solar charging capabilities, and the reliability of the GSM-based monitoring system.

Additionally, the methodology includes a discussion of the testing environment and conditions and the parameters used to evaluate the machine's performance. The results obtained from these tests are crucial in determining the machine's practicality and potential impact on pest management practices. By providing a detailed account of the methodology, this chapter offers a clear and replicable framework for future research and development in automated pest management systems.

First, the actual figure of the constructed light-trapping machine was presented. The data gathered from the series of experiments measured the prototype's effectiveness.

2.1 Overall system design and implementation

The process flow of the whole operation is described below (see Fig. 2). The machine operates only at night.

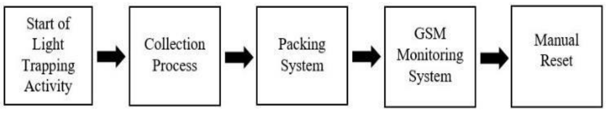


Fig. 2. Process flow of the whole operation

When the light-activated sensor (LDR) can no longer detect ambient light from its surroundings, it activates and sends a signal to Arduino to start the timer. When the timer reaches one hour, probably between 7 pm to 8 pm, the Arduino turns on the bulb and fan. A one-hour delay was set before turning on the bulb and fan at the approximate operation time. The bulb serves as an attractant to pests. The fan pushes the pests towards the entrapment container for collection.

When the weight of collected RBB reaches around 5 to 6 kg, a weight sensing system mainly composed of a pushbutton switch connected to the Arduino activates and sends a signal to Arduino to move the pipe that serves as an arm driven by the wiper motor. The wiper motor rotates and stops moving when it reaches a capacitive sensor. This capacitive sensor is placed beside the sack's opening to ensure that the arm pipe stops in the opening of the next sack. Afterward, Arduino activates another mechanism driven by a DC-geared motor to lock the full sack.

The operation stops after 4 hours, the desired duration between 11 pm and 12 pm. However, the user or farmer can add up to 3 more hours of operation. The system's Arduino connections (see Fig. 3) and the machine's sketch are shown in the succeeding page (see Fig. 4).

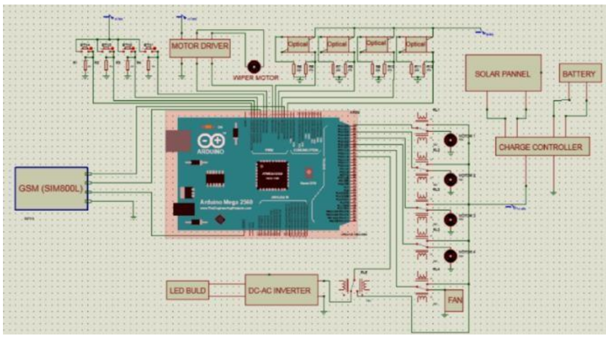


Fig. 3. Diagram of Arduino microcontroller connections.

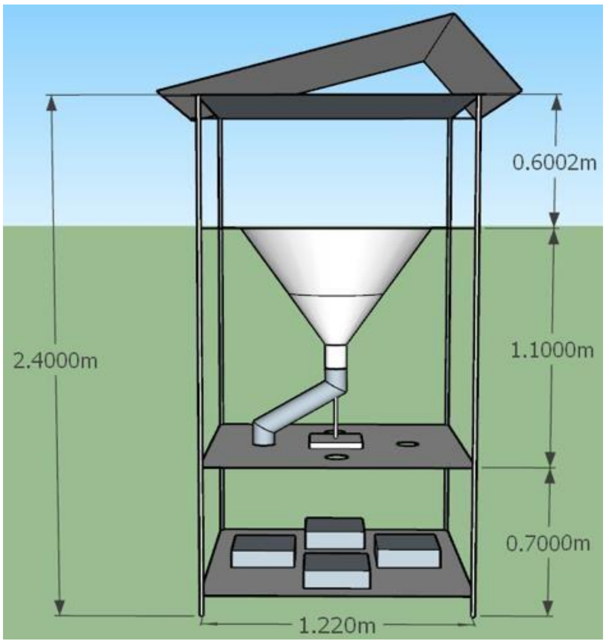


Fig. 4. Design of the light trapping machine.

2.2 GSM Communication

The mechanism of the GSM monitoring system is shown as follows (see Fig. 5). The main operation of the device starts when the bulb and fan turn on. As soon as the bulb and fan turn on, an SMS generated by a GSM module will be sent to the mobile phone of the user as well as when it turns off after four hours of operation.

Furthermore, every time the weight sensing circuit activates, a GSM module sends an SMS to the farmer's mobile phone, notifying them that a sack is already full. This monitoring system is a great help to the farmers, especially during the outbreak. Since the prototype is only capable of four sacks and requires a manual reset, a monitoring system is important for the farmers to be updated with the number of sacks that are already full. Through GSM technology, a farmer can also override the operation of the machine by remotely turning on and off the machine just by sending an SMS.

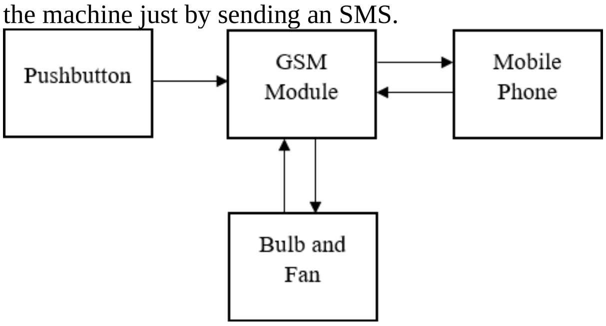


Fig. 5. Block Diagram of GSM Monitoring System.

2.3 Data gathering methods

A series of experiments were conducted to test the efficiency of the machine. Each weight sensing circuit for each sack was tested ten times using 6 kilograms of cracked corn to get the approximate weight that the weight sensing circuit could detect. Cracked corns were used as a representation of pests due to the unavailability of RBB during testing. Six (6) kilograms of cracked corn were used since the target weight was five (5) to six (6) kilograms of pest to be packed.

The sensitivity of the capacitive sensors and light-activated sensors used were also tested by running a program on Arduino that reads the input of the sensors. Binary output is obtained from the capacitive sensor, while analog data is the displayed output of the LDR.

The battery's charging rate through the solar panel was also tested, and data such as voltage and current were logged every 30 minutes until the battery was full. The testing and logging were done for four days with different weather conditions. The machine's maximum operation time was also tested by imitating the real operation scenario for two days, and the battery's voltage was recorded every 30 minutes. The reliability of the GSM module was also tested by imitating situations wherein an output message from GSM is necessary during machine operation. The machine was employed in the nearest rice field to test its capability to attract and collect pests.

3. RESULTS AND DISCUSSIONS

This chapter presents the results of the experiments and development conducted on the automated solar-powered light-trapping machine and discusses their implications for pest management in rice fields.

The results highlight the machine's performance in various aspects, including the effectiveness of the weight sensing system, battery performance, solar charging capabilities, and the reliability of the GSM-based monitoring system. Each component's performance is assessed based on data gathered from controlled experiments and initial field tests.

The weight sensing system's ability to detect the desired weight range (5-6 kg) is crucial for efficient pest collection and packing, ensuring that the machine operates effectively without manual intervention. Battery performance tests indicate that the machine can operate efficiently within the desired 4-hour duration, with sufficient capacity even after extended operation periods. The solar photovoltaic power system's reliability is demonstrated by its ability to charge the battery under various weather conditions, confirming its suitability for use in remote areas.

The GSM communication system's reliability in sending updates and commands is crucial for remote monitoring and control. It provides farmers timely information on the machine's status and progress of pest collection. Initial field tests validate the machine's design and operation, showing successful pest attraction and collection.

This chapter also discusses the machine's potential impact on sustainable pest management practices, emphasizing its ability to reduce manual labor, enhance monitoring capabilities, and promote using renewable energy sources. The results suggest that the automated light trapping machine offers a viable alternative to

traditional pest management methods, with significant benefits for rice farmers.
The chapter addresses the current study's limitations and provides future research and development recommendations. These include further field testing throughout the rice plant growth stages, reducing the machine's size for easier transportation, implementing an early monitoring system, and exploring additional features such as ultraviolet light bulbs for better pest attraction and a voltage logging system for battery monitoring. Overall, the results and discussions presented in this chapter underscore the machine's potential to transform pest management practices in rice farming.

3.1 Construction of the Light Trapping Machine

The constructed actual light trapping machine is shown as follows (see Fig. 6). The bulb is hung from the roof. The funnel is supported by four flat bar metals attached to the machine's main metal structure. Inside the funnel, the fan is attached to the opposing side of the funnel. Below the funnel is an arm attached to a wiper motor inside the big wooden box. The battery and other electronic components were also housed inside the box. The packing system is found below the box. Each sack is placed inside the small boxes, which serve as a supporting structure to each sack.

Fig. 6. Actual Light Trapping Machine developed or assembled by the project team.

3.2 Machine system testing

Table 1 shows the average weight of each weight sensing system. Each system can detect the desired weight, 5 to 6 kilograms.

Table 1. The average weight of each weight sensing system.

Sack	Average weight (kg)
First sack	5.425
Second sack	5.215
Third sack	5.100
Fourth sack	5.210

It is important that the weight sensing system can detect the desired weight because it is necessary for the next step of operation, which is packing. If the weight exceeds the desired weight, there is a possibility of pest overflow from the container, thus resulting in inefficient packing.
The results for both trials in Table 2 have shown that the machine can function appropriately for the desired duration of operation, which is 4 hours.

Table 2. Monitoring the battery voltage during operation

Trials	Hours of operation (Hrs)	Initial battery voltage (V)	Final battery voltage (V)
1	7	13.6	12.15
2	6	13.45	12.17

When comparing the two outputs, the starting battery voltage at the first trial is higher than that at the second trial, which is why the first trial has more hours of operation than the second trial.
Table 3 shows that the machine's designed solar photovoltaic power system was able to fully charge the battery not just on sunny days but even on cloudy days. Therefore, the system can support the machine's operation.

Table 3. Solar PV System charging the battery

Trials	Hours of Charging (Hrs)	Starting Time (AM)	Time at full Charge	Weather Conditi on
1	3	8:50	11:50AM	Sunny
2	6	9:50	3:50PM	Cloudy
3	7.5	10:00	5:30PM	Cloudy
4	3	9:00	12:00PM	Sunny

The user's messages sent to the GSM were "ON," "1HR", "2HR, "3HR", and "OFF" are show below (see Fig. 7 and Fig. 8). Upon execution of the commands received from the user, the GSM was able to send updates to the user. The figure above has shown that the GSM monitoring system used in this study is reliable enough. The machine was tested in an open area where black bugs were spotted, and the experiment captured more than 20 black bugs.

Fig. 7. Some commands sent to the GSM.

The photovoltaic power system employed in the study has shown great importance for implementing the machine in remote areas. The results show its efficiency in supplying the necessary power for the machine to continue operating. This not only helps the farmers with electricity costs in the long run but also conserves non-renewable energy resources and lessens greenhouse gas emissions.

Finally, the device developed was applied for patent protection at the Intellectual Property Office of the Philippines (IPOPHL) with patent application number Invention 1/2021/050406, and it has been found to be novel and inventive (see Fig. 9).

This patent application at the IPOPHL also satisfies all the requirements of Caraga State University's Intellectual Property (IP) Policy [31], including novelty, inventiveness, and industrial applicability requirements.

The study successfully developed an automated solar-powered light-trapping machine to manage the Rice Black Bug (RBB), a significant pest in Philippine rice fields. The machine features several key components: a high-intensity luminous trap for attracting pests, an automated packing system that seals sacks when full, a GSM-based monitoring system for remote updates and control, and a solar photovoltaic power system to enhance sustainability and reduce operational costs.

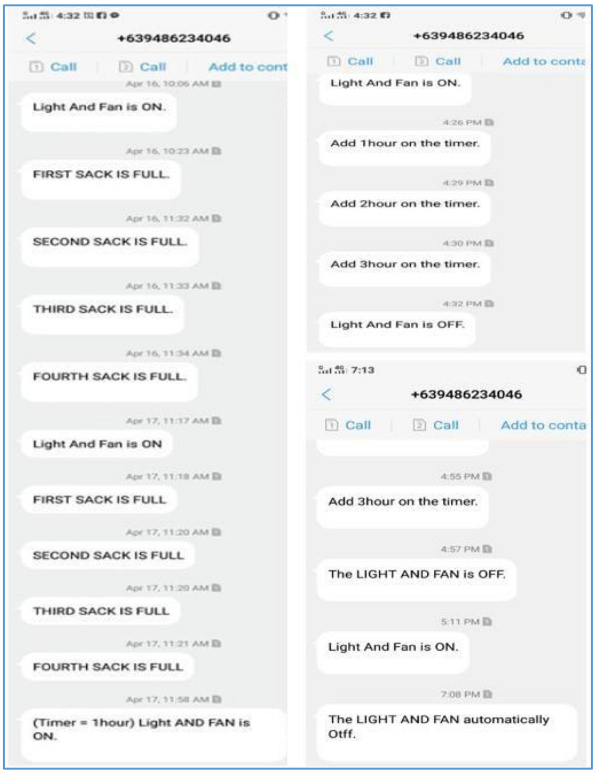
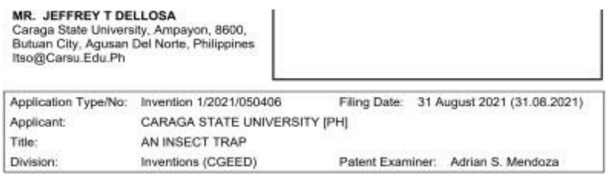


Fig. 8. GSM updates to the user.



MR. JEFFREY T DELLOSA
Caraga State University, Ampayon, 8600,
Butuan City, Agusan Del Norte, Philippines
Itso@Carsu.Edu.Ph

Application Type/No:	Invention 1/2021/050406	Filing Date:	31 August 2021 (31.08.2021)
Applicant:	CARAGA STATE UNIVERSITY [PH]		
Title:	AN INSECT TRAP		
Division:	Inventions (CGEED)	Patent Examiner:	Adrian S. Mendoza

Fig. 9. Screenshot of the patent application status with confirmed novelty and inventive aspect from the Intellectual Property Office of the Philippines.

Various experiments were conducted to evaluate the machine's effectiveness. The weight sensing system effectively detected the desired weight range of 5-6 kg, which is crucial for efficient packing and preventing overflow. Battery performance tests showed that the machine could operate efficiently for the desired 4-hour duration, with sufficient battery capacity even after extended operation. The solar photovoltaic power system successfully charged the battery under different weather conditions, proving its reliability in remote areas. The GSM communication system reliably sent updates and commands, facilitating remote operation and monitoring by farmers.

The prototype demonstrated effective pest attraction and collection. The automated packing system efficiently packed collected pests, reducing farmers' physical effort. The GSM system provided timely updates, enhancing pest management during outbreaks. Initial field tests indicated successful pest trapping and collection, validating the machine's design and operation.

The machine's innovative features and positive testing outcomes led to a patent application, signifying its potential impact on sustainable pest management. Operating autonomously, monitoring remotely, and reducing manual labor benefit rice farmers significantly. The study recommends further field testing throughout the rice plant growth stages to gather more accurate data for future work. Additional suggestions include reducing the machine's size for easier transportation, implementing an early monitoring system to alert farmers of pest presence, using ultraviolet light bulbs for better pest attraction, and adding a voltage logging system to monitor battery status. The results demonstrate the machine's potential to automate and enhance pest management practices, providing a sustainable alternative to conventional methods.

4. CONCLUSION

In this paper, the researchers presented several works and studies that became the basis for constructing the current study. Preliminary works were also presented towards developing an electric light trap to manage RBB. The researchers constructed an electric light trap that uses a high-intensity light luminous trap. It also has an automated packing system that seals the container once full. Additional features were also added, such as a GSM-based monitoring system. The machine can also be remotely accessed by the users or farmers, especially at night, which is the machine's operating time. The machine's duration of operation was set to 4 hours, 8 pm to 12 midnight, which was based on the previous studies regarding insect light trapping activities. However, using GSM-SMS technology, the researchers added another feature to remotely add up to 3 hours of operation time in case of severe infestation. The experiments' results show that the proposed automated electric light trap can potentially automate the laborious operations of manual light trapping, monitoring, and packing of RBB. With the added electronic circuitry, the machine will automatically start operating at night without any human intervention, thus reducing work efforts among farmers. The reliability of the GSM monitoring system used in the study implies significant advantages for farmers to easily monitor the population of RBB in their area and monitor the operation of the light trap with no physical interaction. The automated packing system used in the study was also tested. It had shown high efficiency in packing collected pests, thus highly decreasing the farmer's physical efforts to collect and pack pests, especially during outbreaks. Although the effectivity of the proposed electric light trap was not tested completely throughout the growth stage up to harvest time of rice plants, the light trap was able to attract and collect black bugs, proving that the machine could trap and collect pests. Moreover, many studies and research already supported the machine's effectiveness in attracting and collecting rice black bugs and other pests. Although previous studies and the results of the experiments have shown positive results regarding the current study's effectiveness, several issues need to be addressed. The researchers recommend testing the proposed electric light trap in the rice fields to get more accurate results and data. The constructed electric light trap can be reduced to a much smaller size to make it more portable for easy transportation and deployment. The researchers also recommended employing an early monitoring system in the machine that will count the RBB trapped to alert the farmers of the presence of the pest in their farms for early infestation prevention. Ultraviolet light bulbs can also be used as an attractant to pests for better attraction to RBB. The researchers also would like to recommend that a voltage logging system be added to the machine so that the farmers can monitor the battery voltage to be informed if the machine has reached full charge throughout the day of charging.

5. REFERENCES

[1] Tado, Neil Caesar M., and Reca S. Bautista. "Characterization of Mechanized Farming Operations in Butuan City, Philippines." Proceedings of International Exchange and Innovation Conference on Engineering & Sciences (IEICES). Vol. 8. 九州大学大学院総合理工学府, 2022.

[2] Liliane, Tandzi Ngoune, and Mutengwa Shelton Charles. "Factors affecting yield of crops." Agronomy-climate change & food security (2020): 9.

[3] Deguine, Jean-Philippe, et al. "Integrated pest management: good intentions, hard realities. A review." Agronomy for Sustainable Development 41.3 (2021): 38.

[4] Khan, Bilal Ahmad, et al. "Pesticides: impacts on agriculture productivity, environment, and management strategies." Emerging contaminants and plants: Interactions, adaptations, and remediation technologies. Cham: Springer International Publishing, 2023. 109-134.

[5] Bouri, M., Arslan, K. S., & Şahin, F. (2023). Climate-smart pest management in sustainable agriculture: Promises and challenges. Sustainability, 15(5), 4592.

[6] Berhe, M., Subramanyam, B., Chichaybelu, M., Demissie, G., Abay, F., & Harvey, J. (2022). Post-harvest insect pests and their management practices for major food and export crops in East Africa: An Ethiopian Case Study. Insects, 13(11), 1068.

[7] A.T. Barrion, O. Mochida, J.A. Litsinger, and N. Dela Cruz. The Malayan black bug, Scotinophara coarctata (Fabricius) (Hemiptera: Pentatomidae), is a new rice pest in the Philippines. Int. Rice Res. Newsl. Vol. 7, pp. 6-7, 1982.

[8] BK. Gyawali. Feeding behavior and damage of rice bug, Leptocorisa oratorius (Fabricius), on rice. MS thesis. UP Los Baños, Laguna, Philippines. p. 142, 1981.

[9] E.H. Batay-an, P.S. Torrena, and A. Estoy." Bioecological studies on rice black bug Scotinophara coarctata (Fabricius) in Cotabato, Mindanao, Philippines," p. 339-359. In: R.C. Joshi,

[10] A.T. Barrion, L.S. Sebastian (eds) Rice black bugs: Taxonomy, ecology, and management of invasive species. Philippine Rice Research Institute, Muñoz, 2007, p 787.

[11] Pinoyrice.com, 'Rice Black Bug (RBB): Handout Series', 2010. [Online]. Available: http://www.pinoyrice.com/wp-content/uploads/rice-black-bug.pdf. [Accessed: 25-Feb-24].

[12] PhilRice,' Control rice black bugs the natural way,' 2013. [Online]. Available: https://www.philrice.gov.ph/control-rice- black-bugs-the-natural-way/. [Accessed: 25-Feb-24].

[13] A.B. Estoy, E.H. Batay-an, FP.J. Tadle and P.S. Torrena. " Biological Control of the Rice Black Bug, Scotinophara coarctata (Fabricius) (Hemiptera: Pentatomidae)", p. 329-338. In: R.C. Joshi, A.T. Barrion, L.S. Sebastian (eds) Rice black bugs: Taxonomy, ecology, and management of invasive species. Philippine Rice Research Institute, Muñoz, 2007, p 787.

[14] G.O. Redondo, C.C. Launio, and R.G. Manalili. " Farmers' Knowledge, Perception, and Management Practices on Rice Black Bug," p. 287-305. In: R.C. Joshi, A.T. Barrion, L.S. Sebastian (eds) Rice black bugs: Taxonomy, ecology, and management of invasive species. Philippine Rice Research Institute, Muñoz, 2007, p 787.

[15] W.R. Cuatermo. " Current Status of Rice Black Bug and its Management in the Philippines," pp. 653-660 In: R.C. Joshi,

[16] A.T. Barrion, L.S. Sebastian (eds) Rice black bugs: Taxonomy, ecology, and management of invasive species. Philippine Rice Research Institute, Muñoz, 2007, p 787.

[17] A.C Rola, PL Pingali. "Pesticides, rice productivity, and farmers' health: an economic assessment." Los Baños (Philippines): World Resources Institute and the International Rice Research Institute. 1993.

[18] PL. Pingali, CB. Marquez, and FG Palis. "Pesticides and Philippine farmer health: a medical and economic analysis." Am. J. Agric. Econ. Vol. 76, pp. 587-594, 1994.

[19] PL Pingali, PA. Roger, editors. "Impact of pesticides on farmer health and the rice environment." Norwell, Mass. (USA) and Los Baños (Philippines): Kluwer Academic Publishers and the International Rice Research Institute. 1995

[20] Dalman, A. M., Aguhob, R. A., Buniel, R. J. N., Tado, N. C. M., Osoteo, M. R. B., & Belivestre, C. M. C. (2023). Assessment on the Level of Mechanization in the Rice Production and Post-Production Systems in Surigao Del Sur.

[21] S. Dasgupta, C. Meisner, D. Wheeler. "Is environmentally friendly agriculture less profitable for farmers? Evidence on integrated pest management in Bangladesh." Rev. Agric. Econ. Vol. 29, pp. 103-118, 2006.

[22] PI. Devi. "Pesticide use in the rice bowl of Kerala: health costs and policy options." South Asia Network for Development and Environmental Economics (SANDEE) Working Paper No. 20-07. Kathmandu, Nepal, 2007.

[23] A.T. Burdeos, and B.P. Gabriel. "Utilization of Green Muscardine Fungus (Metarhizium anisopliae) (Metsch.) Sorokin in the control of rice bug (Leptocorisa oratorius Fabr.) (Hemiptera: Alydidae". Philipp. J. Crop Sci. vol. 20, 1995.

[24] PhilRice, 'Intense light catches black bug,' 2011. [Online]. Available: https://www.philrice.gov.ph/intense-light-catches- rice-black-bugs/. [Accessed: 25-Feb-24].

[25] IRRI,2011.[Online].Available:http://www.knowledgebank.irri.org/training/fact-sheets/pest-management/insects/item/black- bug. [Accessed: 25-Feb-24].

[26] J. Sosamma, and N.R. Bai. "Black bug on rice in Kuttanad, Kerala". Insect Environ. Vol. 4, p. 79, 1988.

[27] E.R, Apao, A.A. Lulu, F.S. Sambulan, A.C. Esturas, T.N. Sobredo, and J.P. Arayal. "Integrated control strategies for the rice black bug (Scotinophara coarctata) in Western Mindanao." PhilRice Tech. Bull. Vol 3, pp. 49-54, 1998.

[28] NAS (National Academy of Sciences). "Insect control in the People's Republic of China: a trip report of the American Insect Control Delegation." Committee on Scholarly Communication with the People's Republic of

China (CSCPRC) Report No. 2. NAS, Washington, DC 1977

[29] Baba, M. C., Grado, J. J. B., Solis, D. J. L., Roma, I. M., & Dellosa, J. T. A multisensory Arduino-based fire detection and alarm system using gsm communications and rf module with an android application for fire monitoring. International Journal of Innovative Science and Research Technology (IJISRT), www. ijisrt. com. ISSN-2456-2165, PP:-964-968. https://doi. org/10.5281/zenodo, 6433836.

[30] I. A. P. Banlawe, R. G. Garcia and P. T. Sariego, "Aural and photonic spectrum based digital pest controller for Oryza Sativa (rice)," 2014 International Conference on Humanoid, Nanotechnology, Information Technology, Communication and Control, Environment and Management (HNICEM), Palawan, 2014, pp. 1-6. doi: 10.1109/HNICEM.2014.7016210.

[31] Dellosa, J. T. (2017, April). The impact of the innovation and Technology Support Offices (ITSOs) on innovation, intellectual property (IP) protection, and entrepreneurship in Philippine engineering education. In 2017 IEEE Global Engineering Education Conference (EDUCON) (pp. 762-770). IEEE.