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Design and Development of BRRI Solar Powered Light Trap

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Abstract*: This research intends to design, assemble and evaluate the performance of an eco-friendly solar light trap to reduce the insect population in rice fields as well as to minimize the use of harmful chemical pesticides. An AutoCAD drawing tool 2016 was used to sketch the design of solar light trap. The main component of this light trap was bulb, solar panel and battery. Design of solar panel and battery was done considering by 5W LED bulb. A total of five bulbs with different colors were selected to test the insect's reaction by visible light. Study indicated that ultra violet-blue bulb showed the best performance compare to others based on the high percentage of insect trap (31.22%). A 20-watt solar panel and two 4.5 ah batteries of 6 volts were used to operate the solar light trap. The current, voltage, solar intensity was recorded to check overall performance of solar panel. The solar panel generated more power in April than May due to higher solar radiation in the study area. Study suggested that only 4.26 sunshine hours were required to full charge the battery. The solar light trap was operated 5.5 hour in night which was sufficient to reduce the insects in rice field. Moreover, the light sensor was showed 100% functional for ON/OFF purposes. The dominant insects like yellow stem borer (YSB), green leafhopper (GLH) were mostly observed. The average largest numbers of YSB and GLH were 900 and 600 respectively. In conclusion, the solar light trap is eco-friendly, low cost, easy and self-sufficient in term of solar energy. Finally, the newly developed light trap could be helpful for manufactures, decision makers, and engineering community as well as farmers as a best tool to protect nature in comparison to other pesticide using practices.

Keywords: Solar Radiation, UV Blue Light, Insects, Solar Light Trap, Eco Friendly.

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I. INTRODUCTION

Rice is a staple food of nearby 150 million inhabitants of Bangladesh. It accounts for closely 48% of all rural employment, provides around two-third overall calorie, and one-half of total dietary protein for the average citizen in the nation. corner of the paper. Among the cereal crops, rice sector contributes around one-half of the agricultural GDP

and one-sixth of national revenue [1]. Rice production is severely hampered by insect pests and total 267 insect pest species reported to exist in Bangladesh rice environments [2]. The rice plants are so much sensitive to insect feeding during their life cycle (seeding to harvest). The rice plants are injured by insects due to chewing of leaf, leaf tissues, tunneling and boring into stem and sucking fluid from grains [3]. In 2014, agricultural sectors utilized about 39,464 tons of pesticides to manage insect pests [4], with over 80% of them being used in rice fields to protect insect pests. The fast consumption rate of pesticide use raises concerns about its probable effect on farmers' health, animal, biodiversity and environment. The use of chemical pesticides need to stop now from agricultural practices to protect our civilization. However, focus on this issue, the advanced insect management tool like solar light trap need to introduce that could help farmers to reduce the use of chemical pesticides in rice as well as all agricultural practices.

Different types of methods like biological, plant resistance, cultural, mechanical and physical methods, legal control, chemical control, integrated pest management (IPM) and natural or organic farming are used to reduce the damage from insect pests [5]. Traditionally, survey of damage estimation, insect population study and sweeping, poison bait, pheromone trap and light trap (electrical) mostly used to monitor and protect the crop from insect pests. These techniques are time consuming, costly and sometimes unsafe for environment. The available light traps are commonly designed based on the power sources like fossil fuel (gas and oil) and electricity. The drawback is that the fossil fuels are limited and electrical light trap is not possible to set in all rural agricultural fields due to electricity facilities. The supply of electricity in entire agricultural fields is the main challenge task. The alternative power sources (e.g. solar and wind) need to introduce which play a vital role in this aspect. Solar light trap is considered one of the suitable tool to control the insect populations without any use of pesticides. In regions, where power is not accessible, solar cell create solar energy directly from sunlight [6]. The solar light trap didn't depends on any other power source which is makes the light trap more acceptable than the others type light trap [7].

The solar light trap is eco-friendly, energy-saving, easy to use and liberated of the electricity.

Solar light trap decrease power consumption and save energy which spreading the operational hours in the bad weather (Rain) days. In Bangladesh, solar electric systems are mainly being used to provide electricity for lighting, battery charging, small motors, and water pumping. Now a day, the number of solar energy collecting systems have been developed and analyzed for agricultural applications such as solar dryers, solar water pumps, solar greenhouse heating, ventilation for livestock, etc. But so far, the number of research regarding solar power light trap is quite missing in the country. Besides, with the decrease of value of solar panel and electronic apparatuses the solar light trap is now an economically viable option for insect management in agricultural fields. To address the above-mentioned point of views this investigation was undertaken to develop, assemble and evaluate performance of the solar powered light trap.

II. MATERIALS AND METHOD

A. Study area

The study was performed under the Farm Machinery and Post-Harvest Technology (FMPHT) Division of Bangladesh Rice Research Institute (BRRI), Gazipur, during the year 2017 to 2018.

B. Design consideration

The solar light trap is an experimental research and conducted to develop, assemble, and evaluate the performance based on the various color of light sources. The overall methodology is shown in Fig. 1. Next section will be described the details of design consideration. A total of 5 LED bulbs (5 watt) with different colors like as white, blue, yellow, green and ultra violet-blue were collected from local market. The solar panel and battery were selected to provide the lighting at least 8 hours from evening to night [8], [9].

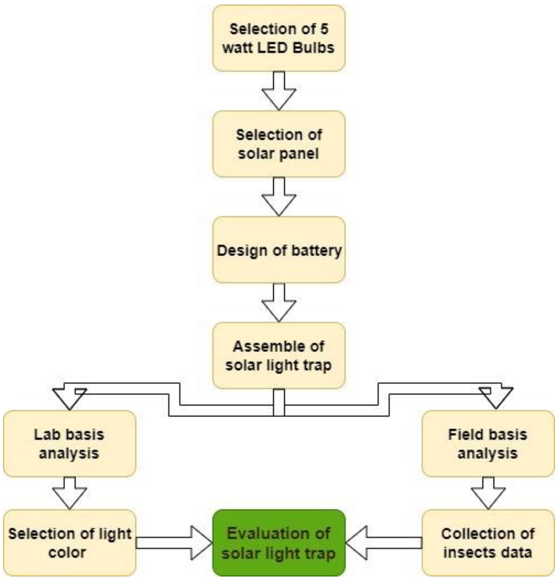

Fig. 1. Flow diagram of the research

Solar radiation is significant factor for solar panel in terms of current, voltage and power. The 10 days' interval hourly solar radiation data was recoded from 7:00 to 17:00 during the month of April and May 2017. Finally, the monthly average data was prepared for the analysis of the variation of current, voltage and power of solar panel.

C. Solar panel size calculation

The solar panel size calculated in four steps. Firstly, the total load was computed by multiplying the actual load demand by their consumption period (hour) using the equation (1). Secondly, after the calculation of total load, it was multiplied by energy loss factor 1.3 to get the total required energy of solar panel using the equation (2).

$$Total\ load = Load(Watt) \times Hour(hr) \text{-------------(1)}$$

$$Panel\ energy\ needed = Total\ load \times 1.3\frac{Wh}{day} \text{-------- (2)}$$

Where, Wh is required watt-hours per day. Thirdly, the daily required power was divided by panel generation factor 3.4 to get the panel capacity by using the equation (3). Finally, required number of solar panel was calculated using the formula (4).

$$Panel\ capacity = \frac{Daily\ required\ energy}{panel\ genertaion\ factor} \text{------------- (3)}$$

$$Number\ of\ solar\ panel = \frac{Generated\ power\ from\ the\ panel}{Panel\ rated\ watt} \text{---------- (4)}$$

D. Battery sizing

According to the Ohm's law, the current through a driver between two points is directly relative to the voltage among the two points. Counting the constant of proportion, the resistance, the mathematical relationship is completed by applying below formula (5):

$$Power = V \times I \text{---------(5)}$$

Where, V and I indicated the battery voltage and current.

The total required power was considered as bulb required power (Watt) and power loss (Watt) in the circuit system. The total consumed energy of the light trap was calculated using the formula (6):

$$Energy\ (Watt) = Actual\ power + power\ loss \text{------(6)}$$

It was necessary to identify the operating hours of the light. The operating time (t) of the battery was calculated by applying the below equation (7):

$$Time\ (hrs.) = \frac{Total\ input\ energy}{Total\ output\ energy} \text{---------- (7)}$$

E. Charging time (hour) of battery

The operation principle of solar light trap mainly depends on the battery. The battery should be fully charge in the presence of sunshine and discharge at night. It was necessary to know the charging time of battery of the solar light trap. The performance of the solar system normally depends on the charging point and the capacity of the battery. The required charging time of the battery was calculated in 2 step: Firstly, the hourly required power (watt) was calculated using the following formula (8):

$$Power\ (watt) = Current\ (I) \times Volt\ (V) \text{-----------(8)}$$

Where, I is the total uses solar panel rated current and V is the maximum power point of solar.

Secondly, the total power (watt) of the battery was divided by total required energy (watt) to calculate the charging time of battery. The mathmatical formula for the charging time (t) of battery is given below (9):

$$t = \frac{Total\ required\ power\ of\ battery\ (watt)}{Total\ required\ power\ (watt)} \text{----------(9)}$$

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F. Drawing and assembly of light trap

Fig. 1 shows the AutoCAD view of the solar light trap. Solar panel size was 54.60 cm long and 34.5 cm wide respectively. The panel module was inclined with the angle of 23^0 at [10] north-south direction on the top of stand with the help of 43 cm MS flat bar. However, Fig. 2 illustrates the complete view of solar light trap at study field condition. The light trap was assembled with the combination of solar panel, electric cable, battery, charge controller, bulb, and a versatile framework. The locally existing materials like MS rod, MS flat bar, plastic-bowl, nuts and bolts were used to fabricate the frame. However, 5 watt LED bulb was trimed under the solar panel and covered with a transparent plastic to protect the bulb against rain and other stormy weather conditions. MS flat bar of 49.5 cm diameter used to fit bowl with stand purpose of providing extra support to plastic bowl when half of bowl filled with water.

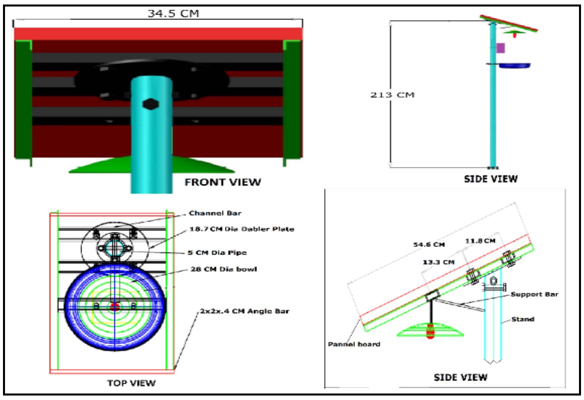

Fig. 2. An AutoCAD view of solar light trap

Fig. 3. Field view of solar light trap

G. Performance Test

The lab and field experiment was carried out to check the overall performance of solar light trap. At lab basis, variation of solar intensity (w/m^2) with power (watt) and solar voltage (V) with current (I) were investigated with time (hr) at FMPHT Division workshop of BRRI. However, five light traps with different color of bulbs [8] were settled at research plot (West Bayed) of BRRI. The bulb was selected based on the visible light reaction of insects. Normally, the insect population are flying or travel at the night for feeding or mating purposes [9]. During opeartion, the insects were flew around the bulb and has flown into the bowl. The bowl was filled with a 1/4 portion of water with several drops of fuel or hand soap so that the trapped insects do not run away from the bowl. In this research, two months of insect's data was collected from selected farmers field. Farmers opinion were collected by an open questionnaire to evaluate the effectiveness and sustainability of the solar light trap. Finally, the monthly average number of insects were counted and categorized them in respective order.

II. RESULTS AND DISCUSSION

A. Selection of solar panel

The solar panel size was selected based on the required energy of 5 watt LED bulb. Table I shows the panel size of light trap for 8 hours lighting. The required loaded power was found 40 Wh and required loaded was enlarged by 1.3 which is the energy lost factor of this circuit system of solar light trap. The total loaded energy was found 52 watt-hours per day including the energy loss factor. The 15.29 W solar panel is required to operate the light trap. However, omitting the fraction value of solar panel, one (1) 20 W panel was chosen for this experiment.

Table- I: Calculation of solar panel size

Serial no.	Functional activity	Output
1.	Loaded power	40 Watt-hour
2.	Total energy need	52 Watt-hour/day
3.	Panel capacity	15.29
4.	Number of solar panels	1

B. Design analysis of battery

Table II shows the distribution of input and output energy of battery. A total of two 4.5 Ah of 6 volt batteries were parallel connected to store the energy from solar panel. The over voltage (16.98 volt) of solar panel was synchronize to 6 volt by using Buck converter which is popularly used to reduce the over voltage [11]. The size of battery was calculated considering the lighting hours by using the following equation (5) to (7). The battery stored energy was found 54 watts which was sufficient to operate the bulb at night. The loss of energy in the circuit system was found 0.5 watt which was added with the bulb energy to get the total required energy of this system. The result showed that the battery was able to operate the solar light trap around 9.82 hours at night which indicated the best performance of the battery. It was necessary to protect the battery from over discharging issue.

We fixed our battery at least 60% discharge condition which implies that after 60% discharged of the battery the circuit system would be stop automatically. In this research, the light trap was used only 5.5 hours from the evening to night and other energy was utilized for next night in case of bad weather or rainy-day.

Table-II: The input and output energy of the battery

Input Energy	Output Energy	
	Item	***Description***
54 watt	Bulb energy	5 watt
	Loss of energy	0.5 watt
	Total power needed	5.5 watt
	Bulb lighting hours	9.82 hours

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The calculation of charging time of battery is shown in the Table III. The voltage and current of panel was rated by 16.8 volt (V) and 1.19 ampere. The study suggested that the selected solar panel was able to generate the sunshine to electricity approximately 11.26 watt in an hour. The total charging hours of the battery was found 4.26 hours.

Table III: Optimum charging time of the battery

Items	Value
Panel rated power (watt)	20
Voltage (V)	16.8
Current (I)	1.19
Total power (watt) in hour	11.26
Charging time (hours)	4.26

C. Performance evaluation of the light trap Bulb Selection

The percentage of trapped insects at different light colors shown in Fig. 3. Ultra violet light was showed the highest number of insects (33.22%) compared to other light colors. This result was strongly agreed with the findings of [8]. The yellow and green color bulbs were showed better performance compared to the white and blue color bulbs. The lowest trapped number of insects were found in white color bulb (10.92%). The results of light sensor showed 100% working ability with the presence or absence the sunlight on the sensor.

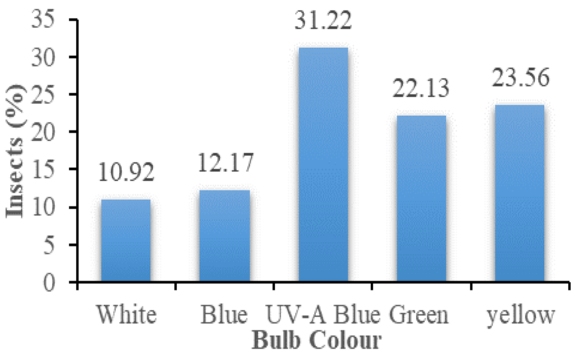

Fig. 4. Bulb performance based on color and insects

D. Performance of solar panel

The variation of solar intensity with power, current with voltage corresponding to time was recorded in 10 consecutive days from April to May 2017 at FMPHT division, BRRI. Fig. 4. shows the monthly average frequency of solar radiation and power with time in hour. The solar photovoltaic (SPV) panel generated power was increased with increasing the solar radiation at both of the month April and May. The SPV panel generated more power between 10:00 to 15:00 and peak at 12:00 to 13:00. The solar intensity and power frequency was observed more in April compared to May due to high solar radiation.

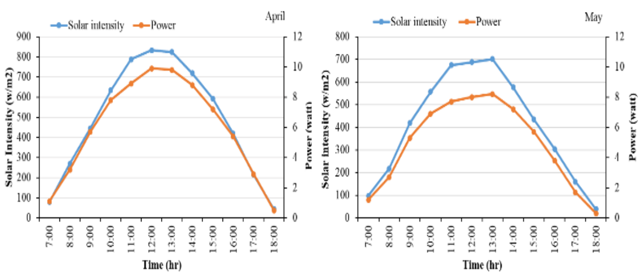

Fig. 5. Variation of solar intensity (w/m2) and power (watt) with time (hr)

The frequency of the current and voltage characteristic curve of solar panel for April and May shown in Fig. 5. It was shown that, the selected panel was suitable in terms generating of current, voltage and power supply to the bulb.

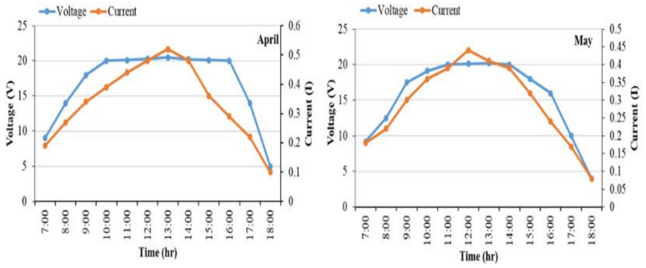

Fig. 6. Variation of solar voltage (V) and Current (I) with time (hr)

E. Fields performance

The field views of solar light trap are shown in Fig. 6. The insects were collected from each light trap and stored in a plastic jar. The insects were categorized based their respective order.

Fig. 7. The installation of solar light trap at Gazipur Sadar

The dominant insect pests such as Yellow Stem Borer (YSB), Green Leafhopper (GLH), White Leafhopper (WLH), Leaf folders (LF), Caseworm (CW) and Rice Bug (RB) which were found in each light trap. According to the findings, largest numbers of insects were trapped in the month of May compared to April. The average largest numbers of YSB and GLH were found in 900 and 600 respectively (Figure 7). However, most of the harmful insects were seen in surrounding the light trap which may affect the rice field.
It is recommended that light trap should be fitted at least 1 meter away from the rice fields. This result demonstrates that solar light will be a promising technology in crop fields in terms of pest control management tool.

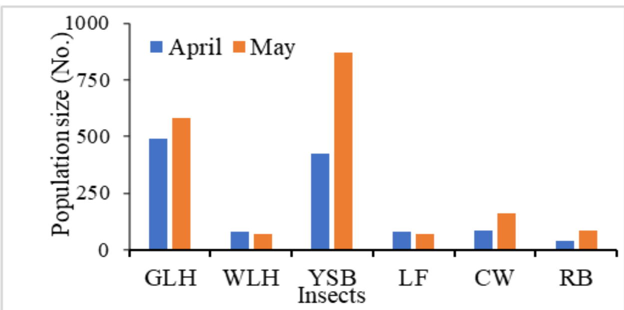

Fig. 8. Average number of trapped insect population

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III. CONCLUSION

The developed solar light trap is an alternative tool instead of using the harmful chemical pesticides. The 5-watt ultra violet bulb indicated the highest performance compare to other bulbs in terms of insect's attraction. The size of solar panel and battery was properly designed to provide the required power to the bulb. The battery was able to provide sufficient energy to bulb. The solar light trap was operated 5.5 hours by discharge of battery 60%. The sensor of the light trap was 100% functional for ON/OFF purposes which reduced the human labor. This light trap is beneficial in the agricultural sector, due to its eco-friendly activity. The manufacturers would take necessary steps to disseminate and implement this sustainable tool at farmer's field to protect nature. Finally, this light trap will be preferred technology in terms of insect pest management in the field of agriculture.

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