Optimization of a solar light trap for controlling the pest in rice field

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Abstract: The use of chemical pesticides in the agricultural field is a common practice for pest control. It is hazardous to human health with the environment and is often used more than the prescribed amount. The solar light trap is a popular renewable and environment-friendly device. The purpose of this research was to determine the light color, installation height, and operating power for a solar light trap that uses light-emitting diode (LED) bulbs. Three solar light traps using three colors of bulbs (white, blue and yellow) were operated at three different power levels of 1, 2, and 2.5 W, and each of them was set at three height levels of 1, 1.25, and 1.5 m in the light traps to find the best color, height, and power by counting the number of friendly and harmful insects trapped. A 3 W white color bulb was used for validation. With the increase of light power and height, the number of insects increased. The white color bulb showed the most efficient result at 1.5 m height in all power treatments. The 3 W white bulb significantly increases the number of friendly insects but has no effect on the number of harmful insects or the total number of insects. In comparison, the power level of 2.5W produces a smaller change in friendly insects while significantly increasing the number of harmful and total insects. The optimum light power for trapping harmful and friendly insects was 2.5 W at 1.5 m height for white color based on the number of trapping harmful and friendly insects.

Keywords: bulb color, optimum height, pest control, solar light trap

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1 Introduction

Disease management is crucial in the crop growing cycle to improve crop yield, whereas pesticide is viewed as a tool for pest control. As an agricultural country with limited land and a large population to feed, Bangladesh relies heavily on pesticides to increase crop yields. In Bangladesh, farmers habituated to using more pesticides to prevent crop losses from pest attacks. A dramatic increase in pesticide use has been observed over the past few decades. Shammi et al. (2020) indicated that approximately 77% of Bangladeshi farmers used pesticides at least once (37% applied once, 31% applied twice, and the remainder applied 3-5 times) during a crop season (Shammi et al., 2020). A report from Bangladesh Rice Research Institute articulates that the use of toxic pesticides by farmers in Bangladesh increased by 328 percent over the past ten years, posing severe health hazards to human health and the environment due to long-term residual consequences (BRRI, 2021). Most farmers of Bangladesh spray pesticides without wearing masks, gloves, and other proper protection. More than 87% of farmers use little or no protective measures while applying pesticides, and 92% of them do not take any protective measures at the time of using, storing, transportation, etc. (Dasgupta et al., 2007). Besides, inhalation and absorption of chemical pesticides lead to severe health problems for farmers who handle the chemicals, such as abdominal pain, dizziness, headaches, nausea, vomiting, and skin and eye problems (Salazar and

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Rand, 2020). The excessive quantities and ineffective use of applied and sprayed pesticides by farmers that result in waste ultimately increase disease management costs.

Besides the chemical pesticide methods, a less hazardous method was derived called light trap. It is an electronic device using the phototaxis (light rays) and chemotaxis (energy trap) to induce pests to touch the high-voltage power grid, thus killing or collecting them in the bag or bowl (El-Shafie, 2020). Most light traps used in agriculture to monitor and control pests of different crops are operated electrically and are stationary due to their dependence on electricity (Erler and Bayram, 2022). Besides, there is no opportunity to supply electric connections in the entire area of any field crops for the smooth operation of the light trap, especially where electricity is not abundant. Hence, the solar light trap can be considered a substitute solution with several advantages over the electrical light trap. Solar light traps were designed to meet the necessity of electricity in remote areas, securing their portability property. Solar traps can easily be installed at any field position by supporting two bamboo poles or one concrete column that can be accessible in the locality (Meshram et al., 2018). In Bangladesh, different types of solar light trap were introduced to farmers by different organizations (Ali et al., 2020). However, there is essential to specify the bulb's color, the optimum power for attracting insects, and the height of the light bulb from the plant surface. Therefore, the objective of the study is to determine the perfect color of the bulb, optimum height, and power to operate the bulb of solar light trap and evaluate the overall performance of the solar light trap.

2 Materials and methods

The research work was conducted at the University farm, Bangladesh Agricultural University, Mymensingh, to evaluate the performance of solar light trap in rice during the period from March 2019 to May 2019 for the rice variety of BRRI *dhan* 28. The experimental site was at 240 75' N latitude and 900 50' E longitude at 18 m above sea level.

2.1 The Solar light trap

The solar light trap consists of solar panel, battery, lamp, and frame. Figure 1 shows the pictorial view of the solar light trap.

Figure 1 The solar light trap

2.1.1 Solar panel

A solar panel was used for supplying electricity. The specification of the solar panel is shown in Table 1.

Table 1 Specifications of solar panel

Parameter	Value
Manufacturer	CNPV Dongying Solar Power Company Limited
Model	CNPV-10M(P)
Origin	China
Maximum Power (Pmax)	10W
Maximum voltage (Vmp)	18.0 V
Maximum current (Imp)	0.56A
Open circuit voltage (Voc)	22.5V
Short circuit current (Isc)	0.62A
Nominal operating cell temperature	45±2℃
Maximum System Voltage	1000VDC
Minimum bypass diode	10A
Maximum series fuse	1A

2.1.2 Battery

In this system, a battery was used to restore energy. It was a sealed lead-acid rechargeable battery. The battery saves the solar panel energy and helps lighten the bulb at night. The specification of the solar panel is given in Table 2.

Table 2 Specifications of the battery

Parameter	Value
Manufacturer	Sun Electric Production (Int'l) co. Ltd.
Model	SUNCAMAX®
Origin	China
Maximum voltage (Vmp)	6 V
maximum current	4.5 Ah
Cycle use	7.20-7.50 V
Standby use	6.75-6.90 V
Maximum charging current	1.35 A

2.2 Experimental setup

The incandescent lamp produces long-wave radiation, including a large proportion of infrared radiation that contributes relatively low to attract insects (Cowan and Gries, 2009), while the lifespan of such lamps is somewhat limited (Infusino et al., 2017). Mercury vapor (MV) self-ballasted lamps emit a more favorable radiation spectrum, but the endurance of the commonly used self-ballasted type is equally limited to incandescent lamps (Infusino et al., 2017). The use of LEDs is now common in light trapping, and the use of LEDs is increasing in light traps (Green et al., 2012; Price, 2016; Infusino et al., 2017). It produces a wavelength of 360 to 950 nm, which performs better in attracting insects. The experiment was conducted using a simple LED light trap model with three LED bulbs as blue, yellow, and white in color operated at three different powers (1, 2, and 2.5 W). The power of the battery was measured using an ammeter and voltmeter. All the light traps were installed at different heights (1, 1.25, and 1.5 m) above the soil level. The heights were chosen to keep the light trap at a level of easy human reach. Besides, insects are most dense to fly over rice plants in this range. For validation, treatment with a white color bulb of 3W was also conducted. The distance between the solar light traps was 112 m so that each of the lights could cover the 0.4 ha of the rice field. Light traps were operated from 6 p.m. to 6 a.m. daily, and the number of trapped insects (friendly and harmful) was recorded. The design of the experiment can be shown as follows (Figure 2). There were nine treatments of three different power, color, heights, and each treatment were replicated three times. For each treatment, three-light traps were used as replications.

2.3 Performance of the light trap in varying conditions

The number of insects was identified and counted manually by separating friendly insects, harmful insects, and mosquitos. The performance of catching insects was determined according to operating powers, bulb colors, and the bulb heights from the ground. Insects were identified, according to Shepard et al. (1995).

2.3.1 Friendly insects

Friendly insects are the species of insects that perform valued services like pollination and pest control. Insects that were considered friendly in this experiment were Lady beetle, Ground beetle, Cricket, Water bug, Plast bug, Damselfly, Dragonfly, Bee, Node spider, and Orb spider.

2.3.2 Harmful insect

Harmful insects are the species that cause damage to humans and their livestock, crops, and possessions worldwide. Harmful insects considered in this experiment were yellow stem borer, rice gall midge, rice leaf fly, rice case worm, rice leaf roller, ear cutting caterpillar, rice cricket, grasshopper, rice hispa, rice bug, rice short-horned grasshopper, rice thrips, mealybug and red flower beetle.

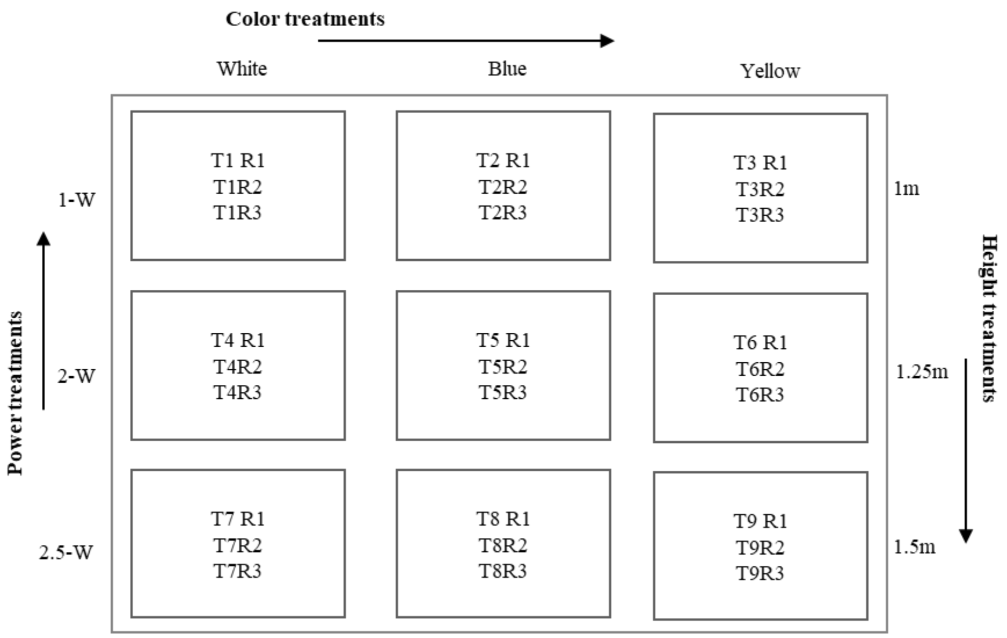

Figure 2 Design of experiment

2.4 Statistical analysis

The collected data were compiled and analyzed statistically using the analysis of variance technique with IBM SPSS Statistics 25 software and Microsoft excel-2019. The selection of color was made using the general linear model and data plotting. The optimum power was selected from insects' significant attracting performance, which was determined by the generalized linear model (GLM) and one-tailed *t*-test.

3 Results and discussion

3.1 Performance of light trap for varying power of the bulb

3.1.1 Bulb power (1 W)

The 1 W bulb was used as the lowest bulb power for the experiment. The number of insects for the 1W bulb at different heights is shown in Table 3. From the table, the maximum number of friendly insects was trapped for blue color at 1.5 m height, whereas the minimum number of friendly insects was 16 for yellow color at 1 m height. The highest number of harmful insects was 143 for the white color bulb at 1.5 m height, and the lowest number of harmful insects was 116 for the blue color LED at 1 m height. For the 1 W bulb, only the white color shows significantly good performance in total insect collection at 1.5 m height. So, this color and height (white and 1 m) can be selected as optimum for 1 W power.

Table 3 Number of friendly and harmful insects in different heights and colors of light for the 1 W bulb

Light Color	Height (m)	Friendly insects	Harmful insects	Mosquito	Total insects
White	1	17±2.65	135±5.29	19±2.00	171±7.81[b]
	1.25	19±3.51	137±6.00	20±3.61	176±4.16[b]
	1.5	20±4.16	143±6.51	26±4.16	188±4.58[a]
Significance		NS	NS	NS	*
Blue	1	23±2.89	116±5.29	25±4.04	164±9.17
	1.25	23±4.51	119±9.29	28±6.43	170±9.24
	1.5	26±4.36	119±2.52	30±3.51	174±4.62
Significance		NS	NS	NS	NS
Yellow	1	16±5.03	125±11.14	18±3.61[b]	159±16.07
	1.25	18±4.58	124±6.11	24±3.00[ab]	166±3.79
	1.5	21±2.00	125±10.07	27±5.03[a]	173±15.87
Significance		NS	NS	*	NS

Note: *$p<0.05$, NS= Not Significant

Table 4 Number of friendly and harmful insects in different heights and colors of light for 2 W bulb

Light Color	Height (m)	Friendly insects	Harmful insects	Mosquito	Total insects
White	1	24±5.86	171±9.50	26±4.93[b]	221±18.56[b]
	1.25	25±6.03	176±10.41	30±4.04[ab]	231±2.52[ab]
	1.5	27±4.58	182±4.04	35±3.51[a]	245±4.04[a]
Significance		NS	NS	*	*
Blue	1	29±3.06[b]	142±8.14	35±7.77	206±9.50
	1.25	31±3.51[ab]	146±7.00	39±3.79	215±8.02
	1.5	37±3.51[a]	144±5.03	40±7.77	221±6.51
Significance		*	NS	NS	NS
Yellow	1	25±3.06	155±6.03	25±5.13	205±4.16[b]
	1.25	28±3.51	157±3.61	28±2.52	213±3.00[ab]
	1.5	29±2.65	159±4.16	29±4.16	218±7.09[a]
Significance		NS	NS	NS	*

Note: *$p < 0.05$, NS= Not Significant

3.1.2 Bulb power (2 W)

Table 4 represents the number of friendly and harmful insects for 2 W white, blue, and yellow colors at three different heights. Here, the maximum number of harmful insects was 182 collected at 1.5 m height for the white color bulb. However, the minimum number of harmful insects was trapped for a blue color bulb at 1 m height. The minimum number of friendly insects was 24 for the white color bulb at 1 m height, whereas the maximum number was 37 for blue at 1.5 m height. Results show that the white light different height has no significant difference in friendly and harmful insects but significantly high difference in 1.5 and 1.25 m height. There is a significant difference in friendly insects for blue light, and it is the lowest for 1 m height. A significant indifference was found in the total insect count for yellow light and maximum at 1.5 m height. So, 1.5 m height can be selected primarily for a bulb of 2 W power.

3.1.3 Bulb power (2.5 W)

An evaluation of the performance of the solar light trap 2.5 W bulb was used as the maximum power. According to Table 5, the highest number of harmful insects was 191 at 1.5 m height for the white color bulb, and the lowest number of harmful insects was 143 for blue color bulb at 1 m height. For the white and yellow color solar light trap at 1 m height, the lowest number of insects was trapped, whereas the maximum number of friendly insects was 39 for the blue bulb at 1.5 m height. With the increase in height, the number of friendly and harmful insects also increased. In Table 5, it is shown that the white bulb performs significantly well at 1.5 m height and for the blue and yellow bulbs, a significantly high count was found for friendly insects and total insects. So, for 2.5 W, 1.5 m can be selected primarily.

Table 5 Number of friendly and harmful insects in different heights and colors of light for 2.5 W bulb

Light Color	Height (m)	Friendly insects	Harmful insects	Mosquito	Total insects
White	1	27±4.04	179±5.00[b]	29±3.06	234±5.86[b]
	1.25	27±5.13	183±6.11[ab]	31±4.51	241±13.87[ab]
	1.5	29±1.53	191±6.43[a]	34±2.08	254±6.03[a]
Significance		NS	*	NS	*
Blue	1	30±3.21[b]	143±9.54	39±2.00	212±14.05
	1.25	31±3.06[b]	146±5.51	43±3.51	220±11.24
	1.5	39±3.06[a]	153±5.03	44±5.69	236±10.02
Significance		*	NS	NS	NS
Yellow	1	26±2.52[b]	158±3.51	25±2.08[b]	209±6.81[b]
	1.25	28±3.61[ab]	163±4.58	27±2.52[b]	218±9.02[ab]
	1.5	34±2.52[a]	163±4.73	34±2.52[a]	231±9.07[a]
Significance		*	NS	*	*

Note: *p<0.05, NS= Not Significant

3.2 Selection of light color

The selection of light colors was made based on the performance of lights in attracting insects. The minimum number of friendly insects and the maximum number of harmful insects were the considerations for selecting bulb colors. The number of insects caught in three different colors of the bulb is shown in Figure 3. The boxplots reveal that the maximum number of insects were attracted by white light. In the case of friendly insects, the maximum average number of insects was found in blue color. White color was also found more satisfactory than two other colors in trapping harmful insects. Yellow and white color traps comparatively fewer friendly insects. So, white light was selected as the most efficient light color for this light trap.

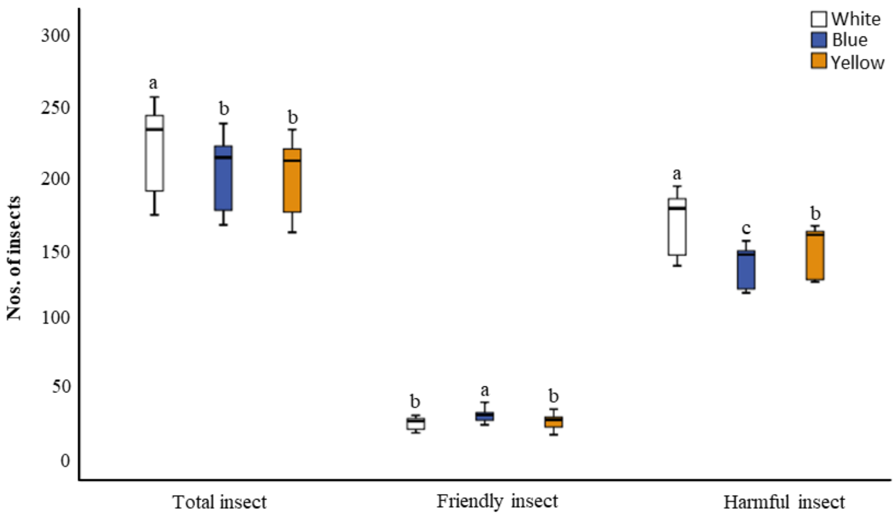

Figure 3 Number of total friendly and harmful insects in the different color of light

3.3 Selection of optimum light power and height

The maximum number of friendly insects was counted for the 2.5 W blue color bulb at 1.5m height, and the minimum number was trapped at 1m height for the color of the 1 W yellow bulb. At 1.5 m in height, the maximum number of harmful insects was counted for the white color bulb. Besides, the minimum number of harmful insects was collected for 1W blue color bulb at 1m height. The figure also revealed that the maximum number of insects for each color and power treatment was found when the light was set at 1.5 m height. The maximum insect was trapped by the white color 2.5 W bulb at 1.5 m height. The comparative insect trapping of the different color bulbs at different heights and power is illustrated in Figure 4.

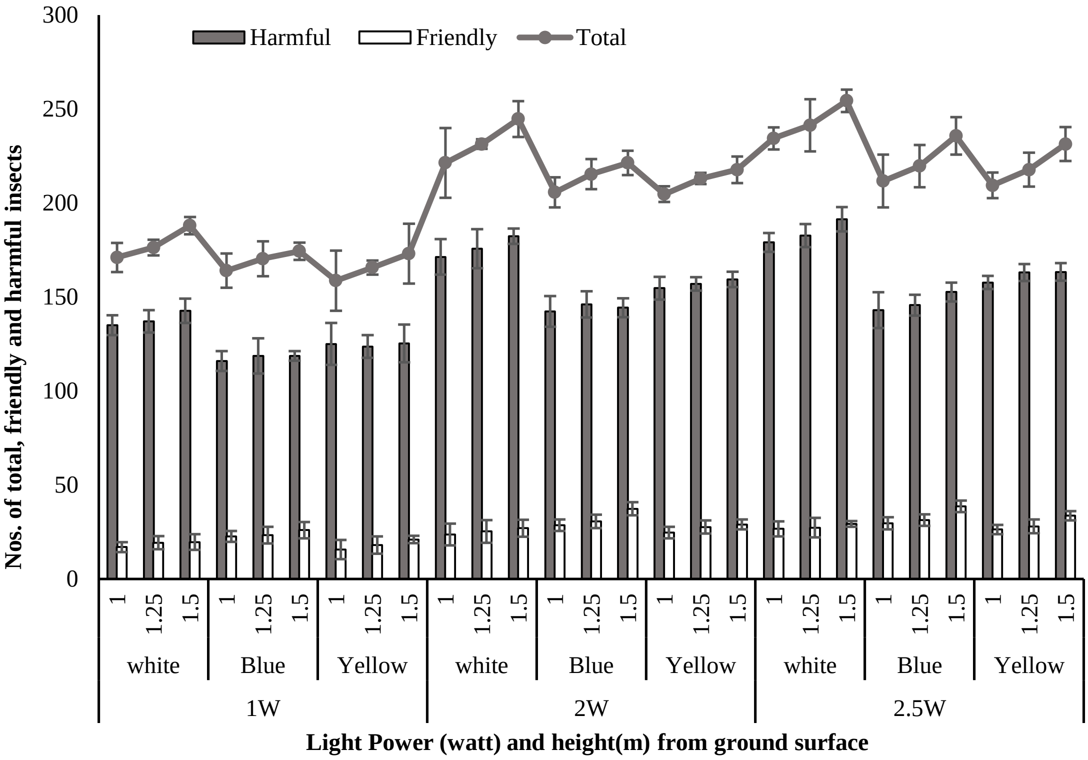

Figure 4 Number of friendly and harmful insects in different color and power of light at three different heights

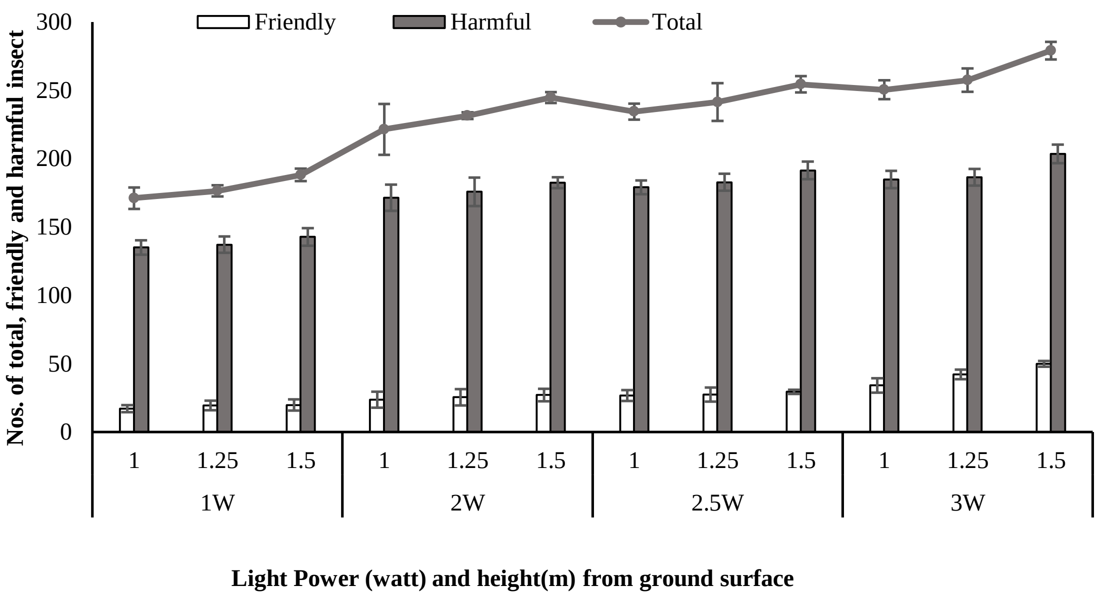

Figure 5 Comparison of nos. of insects in different power of lights in three different heights

Figure 5 shows that the number of insects increases with increased power, but the alarming point is that the number of friendly insects also increased tremendously, whereas the number of harmful insects did not significantly increase.

The number of total insects, friendly and harmful insects, is dependent on light power. The change in light power has an impact on insect numbers. Table 6 shows the significant change in the number of insects for varying powers. From Table 6, it can be said that the most efficient number for insects is found in 3 W, but the number of friendly insects has a significant increase in 3 W light from 2.5 W compared to that of 2.5 W and 2 W.

Table 6 Significance test of insect count in varying power for white bulb light at 1.5m height

Light power(W)	Friendly insect	Harmful insect	Mosquito	Total insect
1	20[c]	143[c]	26	188[c]
2	27[b]	182[b]	35	245[b]
2.5	29[b]	191[b]	34	254[b]
3	50[a]	203[a]	26	279[a]
Significance	*	*	NS	*

Note: *p<0.05, NS= Not Significant

Table 7 shows the significant level of pest attracting performances on average of all three heights at 2.5 W and 3 W powered white bulb. The *t*-test result shows that the difference is significant for friendly insects, but not significant for total insects and harmful insects. As the number of friendly insects trapped by the 3W white bulb is significantly high, the 2.5 W white bulb can be said to be optimum.

Table 7 One-tailed *t*-test for selecting optimum bulb power of solar light trap

	Total insect		Harmful insect		Friendly insect	
	2.5 W	3 W	2.5 W	3 W	2.5 W	3 W
Mean	243.33	262.22	184.33	191.50	27.78	41.96
Variance	103	223.37	40.11	108.58	1.93	62.97
P value		0.07		0.18		0.02
Significance at 95% confidence level		NS		NS		Significant
Significance at 99% confidence level		NS		NS		NS

Note: NS= not significant

4 Conclusion

The study shows an increasing trend in the number of trapped insects with the increasing power of the bulb. The most efficient power for this LED light trap was found at 3 W in terms of total and harmful insects, but it gives a significantly higher number of friendly insects than other power treatments, but 2.5 W was the optimum power to operate the bulb in terms of trapped harmful insects. The white color of the bulb shows significantly higher efficiency in trapping insects. White color attracts a higher number of harmful insects and less friendly insects. It also gives the most satisfying result regarding the total number of insects. The most efficient height of the bulb was found 1.5 m from the ground. At this height, the total number of insects is found higher than 1 m and 1.5 m height, but the change in height is not so significant in attracting friendly insects when operated with white color. This study showed that the 2.5 W white color bulb trapped a significant number of friendly and harmful insects at 1.5 m height for this light trap. As a light trap is an environmentally friendly, cost-effective, and sustainable pest control system, in order to motivate farmers to adopt a solar light trap, several measures need to be taken by major intervening agencies, such as governmental organizations and non-governmental organizations.

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