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Development of solar powered insect trap

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Abstract

The stand alone solar powered insect trap was developed to evaluate the performance of solar powered insect trap with different colour lights (white, yellow and blue). The fabrication of three solar powered insect trap was carried out at Centre for Resource Conservation Technology, College of Renewable Energy and Environmental Engineering, S. D. Agriculture University, Sardarkrushinagar. The main components of solar trap were solar panel, D2D charge controller, battery, DC LED bulbs (white, yellow and blue), trapping device and supporting stand. The solar traps having dusk to dawns witch which automatically turn on bulbs in evening at 19:00 h and turn off at 6:00 h in morning. The observation was recorded from 26 June, 2019 to 11 July, 2019 at the interval of three days. It was found that the average solar intensity and power were varied from 154.5 W/m² to 843.9 W/m² and 4.45 W to 19.25 W, respectively. Battery was fully charged (13.9 V) by 20 w solar panel and reduces gradually up to 10.89 V. The total number of insects caught in white, yellow and blue colour light was 3148, 2166 and 949, respectively. The highest population of Coleopteran insects was found in all three lights. The highest numbers of insects were attracted towards white colour LED light i.e.50.26 per cent whereas the lowest numbers of insects were attracted towards blue colour LED light i.e.15.15 per cent.

Keywords: Insects, population, climatic factors, solar light trap, solar energy-based, solar cell

Introduction

Light trapping is one of the common and effective practices to attract and trap nocturnal insects by using different light spectrum e.g. mercury vapour lamps, black light lamps or fluorescent tubes.

Nocturnal Lepidoptera (moths), Trichoptera and Ephemeroptera are the insect groups which can be collected most efficiently by light-trapping but many nocturnal species in several other orders are rarely recorded with other methods, e.g. some Coleoptera. (Steiner and Hauser, 2009) ^[1]. Dubey *et al.* (1984) ^[2] was observed that the insect population was in increasing trend during ascending phase and yellow colour light was observed most effective as compared to other colours. Nag and Nath (1991) ^[3] studied the effect of moon light and lunar periodicity on the light trap. The response was higher in descending phase (full moon to no moon) as compared to the ascending phase (no moon to full moon). The effect of varying wavelengths of lights (blue, green, yellow, red, ultraviolet (black) and white) on different insect was studied and found that lowest number of insects was in the red light container and the highest number was in the ultraviolet light container Pate and Curtis *et al.* (2001) ^[4] and Ashfaq *et al.* (2005) ^[5]. Reducing and controlling the pest population using light

traps is an age old practice in India. It required electricity connection which is the major constrain and almost absent in remote villages (Bhamre *et al.* 2005) ^[6]. Hence, there is a need to develop stand-alone light trap which utilize renewable source of energy (Solar powered light trap).

Materials and Methods

The research methodology was divided into three components: preparation of conceptual design, development of insect trap and performance evaluation of developed trap. The fabrication of solar powered insect trap was carried out at Centre for Resource Conservation Technology, Renewable Energy and Environmental Engineering, S. D. Agriculture University, Sardarkrushinagar.

Geographical Location of study

Dantiwada taluka is near to Palanpur at 24° 31' north latitude and 72° 32' east longitude with altitude of 209 m. The experiment was conducted at the Agro- Tech. Park Sardarkrushinagar Dantiwada, Agricultural University, Sardarkrushinagar.

Development of solar powered insect trap

The trap system was mainly consisted of solar panel, sealed

lead acid battery, D2D charge controller, DC LED bulbs, trapping device, battery box and supporting stand. The major components of solar power insect trap were:

1. Solar panel
2. Lead Acid Battery
3. D2D Charge controller
4. DC LED bulbs
5. Trapping device,
6. Transparent polythene bag,
7. Three types of stands (Iron, PVC and Wood)

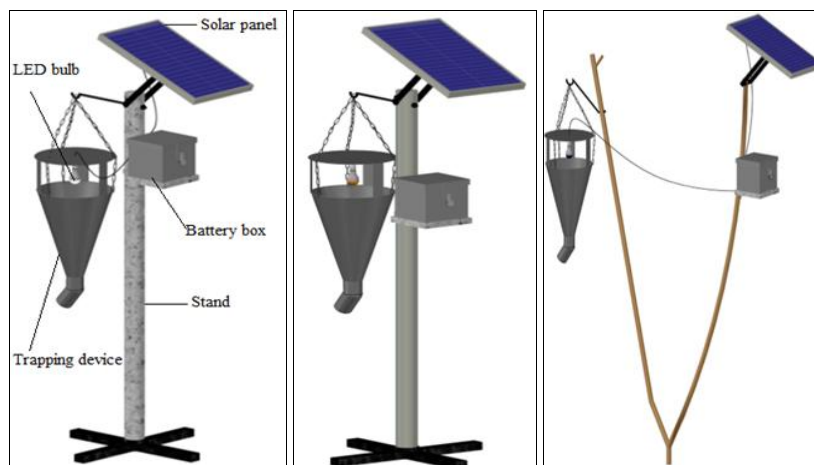


Fig 1: Schematic view of solar powered insect trap with different colored lights Selection of solar panel

The intense movement of insects are in night so this is the best time to trap them. Therefore, the LED pest control light was required to work for 10 h to 11 h in the night time (from 7 PM to 6 AM). Based on the above requirements and

availability of sunshine in the area during the monsoon, a polycrystalline silicon solar panel of 20 Wp capacity was selected.

Table 1: Specification of solar panel

Output power	20 W
Output current	1.17 A
Short-circuit current	1.32 A
Open circuit voltage	17.30 V
Output voltage	21.04 V
Size of panel	480×350×22cm
Average Daily Power Generation capacity during the monsoon	80 W

Selection of battery

The battery stores DC electric power during day time and supplies it to LED at night time. For the system, a 12 volt 7

Ah Sealed Lead Acid, solar grade battery was selected, whose depth of discharge (DOD) was up to 80 percent.

Table 2: Specification of battery

Constant voltage charge	27 °c
Voltage regulation cycle use	14.1 V-14.4V
Stand by use	13.6V-13.8V
Initial current	1.4 A max

Selection of dusk to dawn charge controller

Charge controller consists of automatic dusk to dawn (d2d) circuit for switching on/off the trap light without manual intervention. A charge controller was basically a voltage and/or current regulator to keep batteries from overcharging and over deep discharging. It regulates the voltage and current coming from the solar panels going to the battery. The 12 volt 7 Ah d2d charge controller was used to prevent

battery from overcharging and also prevent from reverse flow of current from battery to panel.

Selection of LED lights

Three different colours (White, yellow and blue) LED lights with 5 watts and 350 lumens were selected to know the insect to orient toward their most favorite colour.

**Fig 2:** White LED light**Fig 3:** Yellow LED light**Fig 4:** Blue LED light

Design of trapping device

It was made up of aluminum sheet consisting of a cone shape funnel 30 cm top diameter and 4.4 cm bottom diameter with the height of 39 cm. Small funnel stem (pipe)

was provided in place of collection chamber which was directly attached to collection transparent polythene bag. The funnel stem slightly bend which is enough to prevent the escape of the insects.

**Fig 5:** Trapping device

Collection bag for insects

The polythene bag was used for the collection of the insect. Insects could be easily visible and also dispose easily

through polythene bags. Cost of the polythene bags were comparatively low and it is easily available in market.

**Fig 6:** Polythene bags

Selection of supporting stand

Three supporting stands were selected to install the device. Supporting stands were selected according to locally available materials.

A. Stand for using Iron rod

Supporting stand was made up of iron rod (2.2 cm diameter, 180 cm height), solar panel is mounted at 27 cm above at top of the structure, trapping device hanging through chains at top 31 cm away from structure. Battery box is placed 36 cm from the top.

B. Stand for using PVC pipe

Supporting stand was made up of with PVC pipe (3.1 cm diameter, 191 cm height), solar panel is mounted at 27 cm above at top of the structure, trapping device hanging through chains at top 31 cm away from structure. Battery box is placed 55 cm from the top.

C. Stand for using Wood

Supporting stand was made up of by local available wood in V shape at one edge solar panel and battery box is place and at another one trapping device is hanging (bottom width 27 cm, top width 120 cm) height of the structure is 210 cm, battery box is placed 60 cm from the top of the structure.



Fig 7: Solar powered insect trap using different colored lamp

Table 3: Specification of developed solar powered insect trap

Specifications	Dimensions
Solar panel	20 watt
Battery	DC 12 V, 7 Ah Rechargeable battery
Charge Controller	DC 12 V, 7 Ah Dusk to down
LED bulb	5 watt DC
Colour of LED bulb	White, Yellow and Blue
Type of product	Eco friendly
Type of energy	Solar energy
Battery charging hours	10 to 12
Set up working hours	7 PM to 6AM
No of Stand	3 (wood, PVC pipe and iron rod)
Stands	2.2 cm diameter, 180 cm height (Iron rod), 3.1 cm diameter, 180 cm height (PVC pipe), 180 cm height (wood)
Total weight of device	15.23 kg
• Solar powered insect trap with iron stand	12.89 kg
• Solar powered insect trap with wood stand	10.92 kg
• Solar powered insect trap with PVC stand	

Evaluation of solar powered insect trap

The experiment was conducted by using solar powered insect trap with three different colored LED light viz. white, yellow and blue having 5 W rating All three light traps were installed at 3 feet above the crop height (green gram) and 30 meter apart from each other to let the insect to orient toward their most favorite colour. The solar panel of 20 watt was used to charge the battery. A battery of 12 V; 7 Ah was used

to store electrical energy produced by the SPV panel. The charging hours of the battery was 6 to 7 h. Solar insect light trap was operated from night 19:00 hrs to morning 6:00 h daily in the Agro Tech Park The performance of three LED light traps viz., white, yellow and blue were evaluate and number of insects caught was recorded. The experiment was conduct during June 2019 to July 2019.

Table 4: Cost of solar powered insect trap

Sr. No.	Item Name	Cost (Rs.)
1	Solar panel	700
2	Battery	600
3	Charge controller with relay circuit	300
4	LED light	150
5	Main pipe frame with battery box	650
6	Bulb holding funnel	50
7	Trapping device with chain & polyethylene bags	600
8	Labour charge	500
	Total	3550

Results and Discussion

Solar powered insect traps were installed in Agro-Tech Park, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar. The data was generated on the parameters of solar intensity, current, and voltage developed by panel and battery, order wise insect collection *etc.* an economic feasibility of developed system was evaluated in terms of net present worth, benefit-cost ratio and payback period.

Performance of solar powered insect trap

The variation of solar intensity and corresponding power from solar panel was recorded at the interval of three days during June and July, 2019. The solar powered insect trap was installed after first spell of rain on 25 June, 2019 and

the reading was recorded from 26 June, 2019.

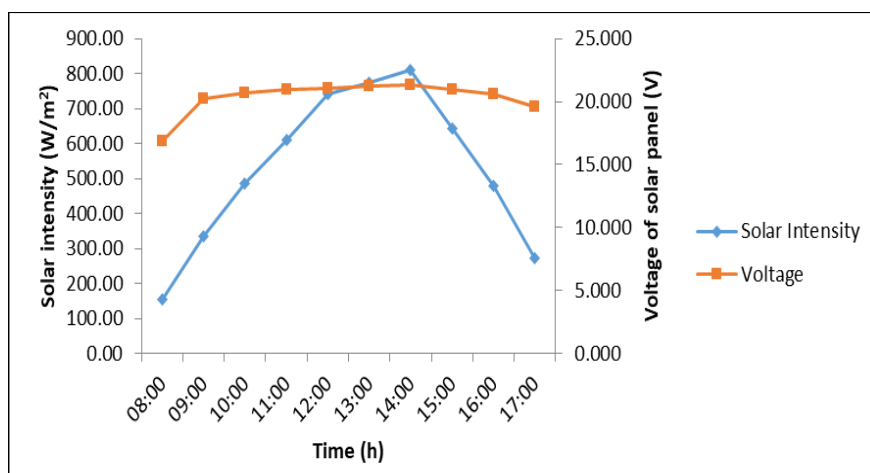
Performance of solar panel

From the Table 5 and Fig.8, the average solar intensity was varied from 154.5 W/m² to 843.9 W/m². The peak value of solar intensity was achieved at 14:00 h. The power developed by selected 20 W solar panel was varies from 4.45 W to 19.25 W. The peak value of power was achieved at 13:00 h.

From the above results it was observed that the power developed by SPV panel increased with respect to increase in solar radiation. It was revealed that, the power generated by selected solar panel was suitable for solar powered insect light trap.

Table 5: Average performance of solar panel for battery charging

Sr. No.	Time, h	Temperature (°C)	Solar Intensity, I (W/m ²)	Solar panel			Battery Voltage, (V)
				Voltage, (V)	Current, (A)	Power, (W)	
1	8:00	28.1	154.5	16.88	0.26	4.45	10.50
2	9:00	29.8	335.9	20.25	0.46	9.39	11.04
3	10:00	31.1	485.6	20.72	0.55	11.47	11.60
4	11:00	32.6	611.1	20.92	0.77	16.18	12.20
5	12:00	34.2	740.3	21.07	0.87	18.26	12.81
6	13:00	35.2	790.5	21.27	0.91	19.25	13.21
7	14:00	36.6	843.9	21.28	0.88	18.66	13.73
8	15:00	34.5	643.0	20.98	0.70	14.69	13.90
9	16:00	33.4	478.4	20.57	0.59	12.20	13.90
10	17:00	31.8	273.9	19.60	0.43	8.52	13.90

**Fig 8:** Variation of solar intensity and voltage of solar panel with time

Battery discharging behavior using solar panel

The battery discharging characteristics of solar powered insect trap was studied to determine the discharge time of battery. The variation of battery voltage and current with respect to time is shown in Table 6 and Fig 9.

It was observed that the battery is fully charged (13.9 V)

through solar panel and it was reduces gradually up to 10.89 V. The average operating time of solar powered insect trap was found to be 11 hours. It was revealed that the use of only battery as a power source reduced the efficiency of overall system due to gradual reduction operating voltage.

Table 6: Battery discharging behavior

Sr. No.	Time (h)	Cumulative power consumption of bulb (W)	Battery power (W) (12v, 7 Ah)	Performance of battery power under discharge mode (V)						Average Performance of battery power under discharge mode (V)
				Trail 1 (date 26/06/2019)	Trail 2 (date 29/06/2019)	Trail 3 (date 02/07/2019)	Trail 4 (date 05/07/2019)	Trail 5 (date 08/07/2019)	Trail 6 (date 11/07/2019)	
1	19:00	0	84	13.90	13.90	13.90	13.90	13.90	13.90	13.90
2	20:00	5	79	13.07	13.09	13.05	13.08	13.07	13.08	13.07
3	21:00	10	74	12.83	12.86	12.84	12.80	12.85	12.86	12.84
4	22:00	15	69	12.60	12.58	12.61	12.59	12.58	12.57	12.59
5	23:00	20	64	12.31	12.29	12.28	12.32	12.30	12.27	12.29
6	0:00	25	59	12.05	12.02	12.00	11.99	12.05	12.04	12.02
7	1:00	30	54	11.78	11.79	11.77	11.80	11.79	11.78	11.79
8	2:00	35	49	11.53	11.51	11.51	11.50	11.49	11.50	11.50
9	3:00	40	44	11.34	11.35	11.36	11.35	11.35	11.37	11.36
10	4:00	45	39	11.22	11.20	11.21	11.21	11.20	11.19	11.20
11	5:00	50	34	10.97	10.97	10.96	11.00	10.97	10.98	10.98
12	6:00	55	29	10.87	10.89	10.88	10.88	10.89	10.89	10.89

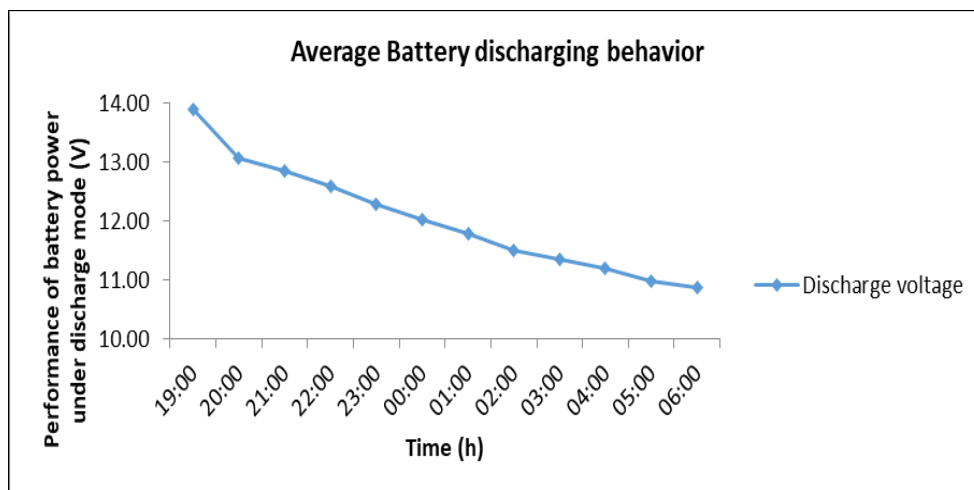


Fig 9: Battery discharging characteristics of solar powered insect trap

Order wise distribution of insects attracted towards different colour solar powered insect trap (white, yellow and blue)

The total number of insects caught in white, yellow and blue colour light was 3148, 2166 and 949, respectively during the period of study.

Table 7, 8 and 9 shows the order wise and daily distribution of insects in white, yellow and blue colour LED light respectively. The highest population of Coleopteran insects

was found in all three lights. The maximum number of Coleopteran insects was observed day 9th and day 1st with white LED light trap shown in Table 7. Similarly in yellow and blue LED light trap, the maximum number of Coleopteran insects was noted on 8th & 9th day and 4th & 7th day, respectively as shown in Table 8 and 9. The number of insects were increased in number on the day of rainfall during observations.

Table 7: Total number of insects representing each order in White light

Order	Coleoptera	Hemiptera	Lepidoptera	Hymenoptera	Diptera	Total insects
Day						
1st	192	52	21	12	5	282
2nd	174	47	19	11	4	255
3rd	167	41	17	7	0	232
4th	142	38	15	7	3	205
5th	139	39	14	10	3	205

6th	131	36	15	7	1	190
7th	128	31	16	7	0	182
8th	116	29	11	7	1	164
9th	198	48	21	14	7	288
10th	181	37	17	13	5	253
11th	169	32	14	10	3	228
12th	139	29	15	7	2	192
13th	128	30	15	8	0	181
14th	109	24	13	6	2	154
15 th	101	19	10	4	3	137
Total	2214	532	233	130	39	3148

Table 8: Total number of insects representing each order in Yellow light

Order Day	Coleoptera	Hemiptera	Lepidoptera	Hymenoptera	Diptera	Total insects
1st	141	29	16	5	6	197
2nd	135	30	11	3	5	184
3rd	122	21	12	3	2	160
4th	110	16	9	2	3	140
5th	101	11	5	5	4	126
6th	94	8	4	4	0	110
7th	86	6	5	3	1	101
8th	156	36	15	6	5	218
9th	143	29	10	2	2	186
10th	128	26	8	1	1	164
11th	119	17	6	3	4	149
12th	103	16	3	1	3	126
13th	97	13	2	2	0	114
14th	88	9	3	1	1	102
15 th	79	5	3	1	1	89
Total	1702	272	112	42	38	2166

Table 9: Total number of insects representing each order in Blue light

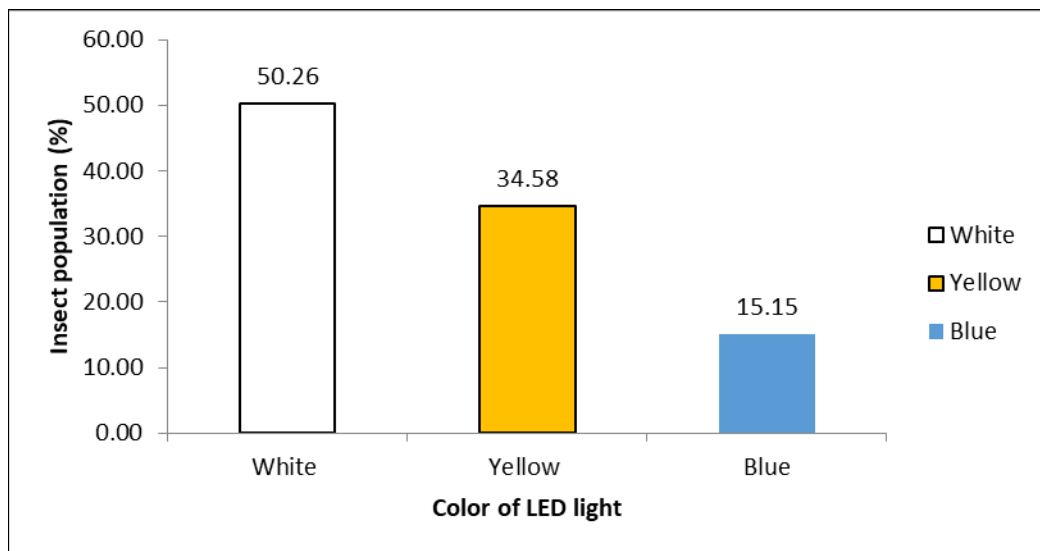
Order Day	Coleoptera	Hemiptera	Lepidoptera	Hymenoptera	Diptera	Total insects
1st	42	24	13	1	0	80
2nd	66	23	8	0	0	97
3rd	51	16	9	0	0	76
4th	76	9	6	0	0	91
5th	41	10	5	1	0	57
6th	43	8	4	1	0	56
7th	69	19	8	2	1	99
8th	53	15	5	0	0	73
9th	47	9	3	0	1	60
10th	42	9	5	0	1	57
11th	38	8	1	2	0	49
12th	29	7	2	1	0	39
13th	28	9	2	0	0	39
14th	30	12	2	1	0	45
15 th	22	8	0	0	1	31
Total	677	186	73	9	4	949

Table 10 and Fig 10 represents the percentage of the total number of insects caught in various coloured LED light traps. According to the percentage of insects collected, the lowest number of insects were attracted towards blue colour LED light *i.e.* 15.15%. This finding is in accordance with Ashfaq *et al.*, 2005 ^[5] and Pate and Curtis (2011) ^[7] who

also found that the lowest numbers of insects were trapped in blue colored light among the various coloured lights tested. White LED light attracted the highest number of 50.26 % insects. Yellow LED light was rated second in attracting the insects (34.58%).

Table 10: Percentage of insects attracted in different light trap

Sr.No.	Colour of light	Number of insects in trap	Percent (%)
1	White	3148	50.26
2	Yellow	2166	34.58
3	Blue	949	15.15
	Total	6263	

**Fig 10:** Insects attracted in different coloured LED light trap

Use of light trap for collecting harmful insect is one of the tool in IPM. Among all three light traps, the performance of white LED light insect trap was found better in terms of insect collected. Most of the harmful insects were attracted towards white LED light and hence it was observed that the use of white LED light in solar insect trap is beneficial in integrated pest management practices.

Economic feasibility of solar powered insect trap

The economic feasibility of the solar powered insect trap was evaluated using discount cash flow (DCF) method. The economic parameters are present worth of cost, present worth of benefit, net present value and payback period were determined.

Table 11: Parameters used to analyses the economic feasibility of solar powered insect trap

Sr. No	Costs	SPV trap	Electrical trap
1.	Capital cost	7100	5200
2.	Maintenance Cost	710	710
3.	Electricity charge	Nil	3713

Table 10 shows the information used to analyze the economic feasibility of the solar power insect trap. The net saving in cost per annum was worked out and found to be Rs.3713/-. The cost of the two solar powered insect traps were found to be Rs.7100. The annual operation cost kept to be Rs.710/-.

The economic performance has been worked out by considering the cost and benefit. Table 12 showed the discount cash flow analysis over the period. The present worth cost after the 12 years were found to be Rs. 11937.72. The present worth of benefit after 12 years were

worked out to be Rs. 25299.24. The net present value of the project is positive and hence the developed solar powered insect trap has offered the financial benefits to the end user. The net present value for the 12 years of cash flow analysis was found to be Rs. 13361.06. The benefit cost ratio of the financial system has been worked out for the cost and benefit involved over the period. The benefit cost ratio of the solar powered insect trap was observed to be 2.11 and payback period of the investment was found 3 years (36 months).

Table 12: Cash flow for of solar powered insect trap

Year	Cash Outflow	Present value factor at 10 %	PW cash Outflow	Cash Inflow	PW of Cash Inflow	NPV
0	7100	1	7100	0	0.00	-7100
1	710	0.909	645.45	3713	3375.45	2730.00
2	710	0.826	586.78	3713	3068.60	2481.82
3	710	0.751	533.43	3713	2789.63	2256.20
4	710	0.683	484.94	3713	2536.03	2051.09

5	710	0.621	440.85	3713	2305.48	1864.63
6	710	0.564	400.78	3713	2095.89	1695.12
7	710	0.513	364.34	3713	1905.36	1541.01
8	710	0.467	331.22	3713	1732.14	1400.92
9	710	0.424	301.11	3713	1574.67	1273.57
10	710	0.386	273.74	3713	1431.52	1157.79
11	710	0.350	248.85	3713	1301.38	1052.53
12	710	0.319	226.23	3713	1183.08	956.85
Total			11937.72		25299.24	13361.06

Conclusions

- A cable less solar power insect trap is more effective with white LED light for physical control of harmful nocturnal insects.
- The estimated cost of the system was Rs, 3550 /- with payback period of 3 years and benefit cost ratio was found as 2.11. It could be inferred that the solar powered insect trap was technically as well as economically feasible.

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