DEVELOPMENT AND EVALUATION OF SOLAR PHOTOVOLATIC INSECT LIGHT TRAP

THESIS

Submitted to
Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola
in partial fulfilment of the requirements
for the Degree of

MASTER OF TECHNOLOGY
IN
AGRICULTURAL ENGINEERING
(RENEWABLE ENERGY SOURCES)

By
GAVHANDE AJAY MURLIDHAR

DEPARTMENT OF UNCONVENTIONAL ENERGY SOURCES AND ELECTRICAL ENGINEERING,
POST GRADUATE INSTITUTE, AKOLA

DR.PANJABRAO DESHMUKH KRISHI VIDYAPEETH
KRISHINAGAR PO, AKOLA (MS) 444104

Enrolment Number – JJ-1611 **2018**

DECLARATION OF STUDENT

I hereby declare that the experimental work and its interpretation of the thesis entitled **"DEVELOPMENT AND EVALUATION OF SOLAR PHOTOVOLATIC INSECT LIGHT TRAP"** or part thereof has neither been submitted for any other degree or diploma of any University, nor the data have been derived from any thesis/publication of any University or Scientific Organization. The sources of material used and all assistance received during the course of investigation have been duly acknowledged.

Place: Akola. (**GAVHANDE AJAY MURLIDHAR**)

Date: / /2018 Enrolment No. JJ-1611

CERTIFICATE

This is to certify that the thesis entitled **"DEVELOPMENT AND EVALUATION OF SOLAR PHOTOVOLATIC INSECT LIGHT TRAP"** submitted in partial fulfillment of the requirement for the degree of "**Master of Technology In Agricultural Engineering (Renewable Energy Sources)"** of Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola is a record of bonafide research work carried out by **Gavhande Ajay Murlidhar** under my guidance and supervision.

The subject of thesis has been approved by the Student's Advisory Committee.

Place: Akola
Date : / /2018

Dr. S. R. Kalbande
Chairman,
Advisory committee

Countersigned

Associate Dean,
Post Graduate Institute
Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola.

THESIS APPROVED BY THE STUDENT'S ADVISORY COMMITTEE INCLUDING EXTERNAL EXAMINER (AFTER VIVA–VOCE)

1. Chairman	Dr. S.R. Kalbande	_________________
2. Member	Dr. A. K. Kamble	_________________
3. Member	Shri. V. P. Khambalkar	_________________
4. Member	Dr. U. S. Kulkarni	_________________
5. External Member		_________________

ACKNOWLEDGEMENTS

Project is an art, which ensure the thinking, understanding and searching the new ideas and skills relating to scientific attitude and surrounding. Success is not possible lonely without involvement of many minds and hands to beautify it. Emotions cannot be adequately expressed in words because then emotions are transformed into mere formalities. Never the less, formalities have to be completed. My acknowledgement are many more than what expressing here. The showers of blessing of the almighty God, who blessed me in each and every step of my life, and always giving me strength and courage to counter to conquer the darkness and produce this thesis.

Frist and foremost, I feel immense pleasure in taking this golden opportunity to express my devoted indebtedness, sincere and heartiest sense of gratitude to the chairman of my advisory committee **Dr. S. R. Kalbande,** Professor and Head of the Department of UCES and EE., Dr. PDKV, Akola under whose guidance this research work was undertaken and for his sustained interest, constant inspiration and constructive criticism which has helped in the final shaping of this dissertation. His encouraging words always filled me with sense of courage in very trying situations during the course of this investigation.

Indeed the words at my command are not adequate either in form or spirit to convey the depth of gratitude to my advisory committee member. **Dr. A.K. Kamble,** Assistant Professor, Department of UCES and EE., Dr. PDKV, Akola, **Shri. V. P. Khambalkar,** Assistant Professor, Department of FPM, Dr. PDKV, Akola and **Dr. U. S. Kulkarni** Assistant Professor, Department of Entomology, Dr. PDKV, Akola their intellectual stimulation, valuable guidance, constant inspiration and providing me all the facilities required during the course of this investigation without which the work would not have been completed.

I wish to record my sincere thanks to **Dr. V. M. Bhale**, Hon'ble Vice Chancellor, Dr. PDKV, Akola and **Dr. P. K. Nagre,** Associate Dean, PGI, Dr. PDKV Akola for giving me opportunity to undergo this research work.

My heart is filled with sweet memories while conveying my heartiest thanks to my dear friends Milind, Nishigandha, Swati, Krishnadeep, Zaqi, Shailendra, Pallavi, Fasila, Manish and Vikram. My Sincere thanks to my seniors Amardeep Dere, Sagar Patil, Sneha Deshmukh, Gajanan Wasu, Amol Dhondge, Snehal Jadhav and all my colleagues for intimate cooperation in completing this research work.

I express my sincere thanks to my father Shri. Murlidhar T. Gavhande, my mother Sau. Vatsala M. Gavhande for their care and spontaneous help during final stages of this venture.

My biggest debt of gratitude is owned my elder sisters Mrs. Reshma Shirsat, Mrs. Vijaya Pargharmor, Mrs. Rupali Wankhade and my little sister Miss. Arti Gavhande for their love, moral support and understanding without his willing co-operation help and affection. I wouldn't able to complete the work with ease and relish.

Words are insufficient to place on record my deepest sense of fillings of love, affection and gratitude to my brother in law Mr. Ravi Shirsat, Mr. Jivan Pargharmor and Siddharth Wankhade for their encouragement and sacrifices in educating me at the cost of their comfort and consolation, without which this work could not have completed.

Last but not least, it is difficult to list all these to whom I express my gratitude for their good will and moral support during my academic attainments, through nobody is mentioned, none is mentioned, none is forgotten too. I would like to say that I remember all of you with love and regards and you were always in my heart .No words are sufficient to give full sense when the matter with the loving parents. How can one express complete thanks for the efforts they have taken right from spoon-feeding in the childhood to the last moment just passed.

Place: Akola **(Gavhande Ajay Murlidhar)**

Date: / /2018 Enrollment No. JJ-1611.

TABLE OF CONTENTS

(A) LIST OF TABLES

(B) LIST OF FIGURES

(C) LIST OF PLATES

(D) ABBREVIATIONS

%	:	Per cent
η_{pc}	:	Efficiency of the PV system.
η_{pv}	:	Efficiency of the PV array
$	:	Dollar
£	:	Pounds
A	:	Surface area
AC	:	Alternating current
A_c	:	Effective module cell area
AICRP	:	All India Coordinate Research Project
a.m.	:	Anti-meridian
amp	:	Ampere
BIS	:	Bureau of Indian Standard
Bt	:	Benefit in each year
Ct	:	Cost in each year
CIS	:	Copper indium diselenide
C-Si	:	Crystalline silicon
DCF	:	Discount Cash Flow
DC	:	Direct current
Deptt.	:	Department
E	:	Annual net cash revenue in rupees.
Ea	:	Array efficiency
et al.,	:	And other
etc.	:	Etcetera
FAO	:	Food and Agriculture organization
Fig	:	Figure

GI	: Galvanized Iron
GW	: Giga Watt
h	: Hour
Is	: Solar radiation
i	: Discount rate
I_{SC}	: Short circuit currant
IPM	: Integrated pest management
JNNSM	: Jawaharlal Nehru National Solar Project
Kwh	: Kilo Watt hour
LED	: Light emitting diode
LCB	: Linear Current Booster
LDR	: Light Difference Resistance
m^2	: Meter square
MNRE	: Ministry of new and renewable energy
M.P.	: Madhyapradesh
NCIPM	: National centre of integrated pest management
NPW	: Net Present Worth
P	: Payback period
Pi	: Input power
Po	: Panel output power
PDKV	: Panjabrao Deshmukh Krishi Vidyapeeth
PGI	: Post graduate institute
RES	: Renewable Energy Sources
SN	: Serial number
SPV	: Solar Photovoltaic
S_t	: Solar radiation

STC : Standard test condition

T : Temperature

t : Time

UCES & EE : Unconventional Energy Sources and Electrical Engineering

UV : Ultra-violet

viz. : Namely

V_{oc} : Short –circuit voltage

V : Voltage

Vmp : Maximum peek voltage

(E) THESIS ABSTRACT

a)	**Title of thesis**	**:**	**"DEVELOPMENT AND EVALUATION OF SOLAR PHOTOVOLTAIC INSECT LIGHT TRAP"**
b)	**Name of Student**	**:**	**Gavhande Ajay Murlidhar**
c)	**Name and address of Major Advisor**	**:**	**Dr. S. R. Kalbande** Professor Deptt.of UCES & EE, Dr.Panjabrao Deshmuke Krishi Vidyapeeth, Akola (M.S)-444104
d)	**Degree to be awarded**	**:**	M.Tech. (Renewable Energy Sources)
e)	**Year for award of degree**	**:**	2018
f)	**Major subject**	**:**	Renewable Energy Sources
g)	**Total number of pages in the thesis**	**:**	58
h)	**Number of words in the abstract**	**:**	567
i)	**Signature of student**	**:**	
j)	**Signature, name and address of forwarding authority**	**:**	

Head,
Department of Unconventional Energy
Sources & Electrical Engineering,
Post Graduate Institute,
Dr. PDKV, Akola.

ABSTRACT

The research work was undertaken on "Development and evaluation of solar photovoltaic insect light trap." A solar insect light trap was developed consisted of 10 W SPV panel, 12 V; 7 Ah lead acid battery, charge controller, dusk to down electrical circuit and adjustable stand. As per design calculations the trap was fabricated in the workshop. The performance of solar photovoltaic insect light trap installed in the farmer's field at Vazegaon village in Akola Dist. (Maharashtra), was evaluated for insect trapping during night hours. The performance of the solar

photovoltaic insect light trap was evaluated during March 2018 in the cotton field for finding out the efficiency of the developed solar insect light trap. The average values of ambient temperature, wind velocity, panel temperature, solar intensity, panel output, panel efficiency, panel voltage, panel current, exergy efficiency of panel and battery voltage in different colour light trap viz., blue, yellow and UV-A blue were recorded. During the month maximum panel temperature of blue light trap, yellow light trap and ultra violet-A blue light trap were found to be 47.1, 47.4 and 47.5 °C, respectively during 11.00 to 17.00 h of the day and solar intensity corresponding to this panels temperature was observed in the range 154.6 W/m^2 to 811.3 W/m^2, 154.5 W/m^2 to 805.5 W/m^2 and 157.6 W/m^2 to 806.3 W/m^2. The ambient temperature range of 29.9℃ to 32.5℃, 29.1 ℃ to 32.6℃ and 29.8℃ to 32.4℃ during system working whereas the array output 2.0 Watt to 9.9 Watt, 2.04 Watt to 9.9 Watt and 2.04 Watt to 10.05 Watt was found during 11.00 to 15.00 h of the day, respectively. The panel efficiency of blue, yellow and UV-A blue light trap varies from 10.04 to 12.53 percent, 10.45 to 14.25 percent and 10.05 to 12.02 percent, respectively and found that panel efficiency of system increased during 11.00 to 14.00 h. The total number of insects caught in blue, yellow and UV-A blue colour light were 6820, 8199 and 19872, respectively during the experimentation. The order wise and daily distribution of insects in blue colour light, the highest population of Lepidopteran insects was observed in 6^{th}, 11^{th} and 12^{th} day, for Hemipteran insects it was in the 9^{th}, 10^{th} and 11^{th} day and for Dipteran it was during 9^{th}, 10^{th} and 11^{th} day. In yellow light, highest population of Lepidopteran insects was caught in the 11^{th}, 12^{th} and 13^{th} day, for Hemipteran insects it was in the 10^{th}, 11^{th} and 12^{th} day and for Diptera it was during 11^{th}, 12^{th} and 13^{th} day. In UV-A blue light highest population of Lepidopteran insect were caught during 11^{th}, 12^{th}, 13^{th} and 14^{th} day, while for Hemiptera it was during 10^{th}, 11^{th}, 12^{th} and 13^{th} day and for Dipterans it was in the 11^{th}, 12^{th}, 13^{th} and 14^{th} day. Regarding the order wise comparison of the insects caught in the ultra violet- A blue light trap, blue light trap and yellow light trap, the UV-A blue light trap was found more efficient than the blue light trap and yellow light trap. Hence, use of ultra violet-A blue light trap could be promoted. The estimated cost of the system

was Rs, 3000 /- with 12 year payback period 2 years 1 month, and benefit cost ratio was found as 1.93. It could be inferred that the solar insect light trap was technically as well as economically feasible.

Keywords: - Solar Photovoltaic Insect Light Trap, Ultra violet-A blue, Efficiency, Payback Period, Benefit Cost Ratio, Net Present Worth.

CHAPTER I

INTRODUCTION

1.1 Background Information

The demand for energy is growing day by day in the whole world. The Conventional energy sources like coal and petroleum are limited. Renewable energy resources will play an important role in the future. India is situated in sunny belt India is endowed with vast solar energy potential. Government of India had launched Jawaharlal Nehru National Solar Mission (JNNSM) in 2009. The target was to start grid connected solar projects of 20 GW by 2022. In May 2015 government increases the target to 100 GW by 2022 (Rachit 2016).

Solar power is the most ecofriendly resource mainly because it is free, unlimited and free from pollution. The solar energy is usually harvested through solar panels that are made up of photovoltaic cells. The photovoltaic (PV) or solar cells convert the sun’s energy into the electricity which is then used to meet out requirement of domestic, industrial, agricultural sector.

Agriculture is a principal occupation in India and more than 70 % peoples are involved in agriculture. Insect pests are the major problem to the farmers greatly reducing their income by destroying the field crops. There are many preventions and exterminations for pest problems, such as physical, biological, chemical and mechanical methods are controlling the insect pests. For example, pests are chemical resistant which leads farmers using more and more pesticides. This causes plant residue which is dangerous for consumers and when consuming the fruits and vegetables gives us major problems to the health (Brimapureeswaran 2016).

Maharashtra has 40 lakh hectares – which is 35% of the total cultivable area in state – under cotton crop. The main or major phototropic insect pests of cotton that cause economic loss to this crop are cotton jassid, cotton whitefly, Armyworm, Cotton Mealy Bug, American bollworm, Pink bollworm and other (Muhammad 2017).

Pink bollworm is a major chewing insect pest of cotton crop having scientific name Pectinophora gossypiella (Saunders). It belongs to family Gelechiidae and order Lepidoptera. Pink bollworm eggs take about three to four days to hatch after they are laid. They are white at first and progress to an orange color as development progresses. Freshly-hatched larvae are white with a brown head.

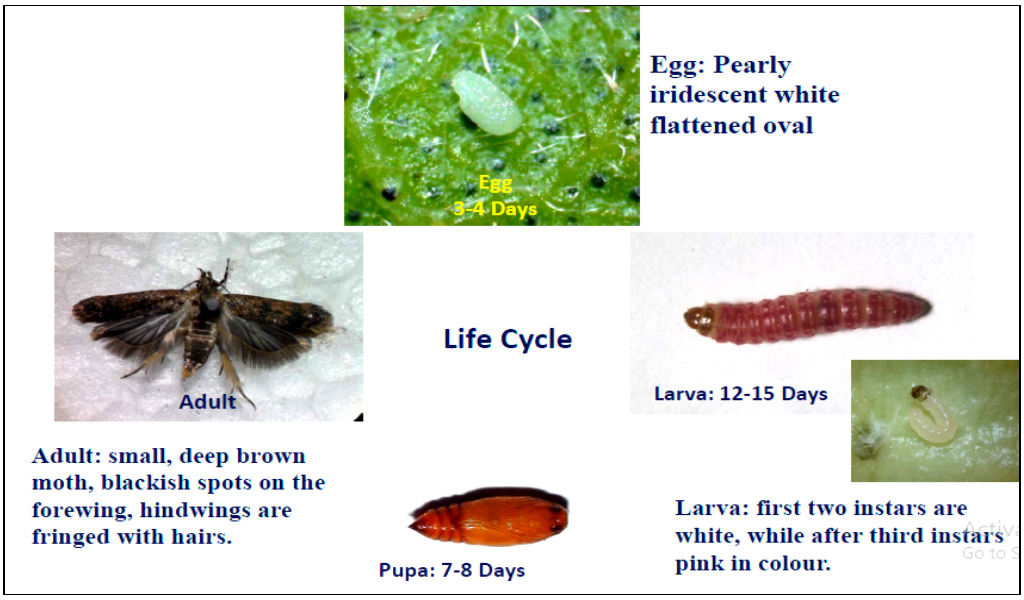


Fig.1.1 Life cycle of pink bollworm

The Pink Bollworm life cycle includes four stages. These are the egg, larva, pupa, and adult. The time required from egg to egg varies because of temperature and other conditions but generally is about one month during the summer months.

To understand fully the concept of background knowledge of light and insects is essential. There are seven colors in the light spectrum: violet, indigo, blue, green, yellow, orange and red. These seven colors lights are known as visible lights. Each light color has a different wavelength and frequency. Red has the longest wavelength and lowest frequency and violet has the shortest wavelength and highest frequency. The wavelengths of visible lights range from 400-700 nanometers. For temperature, red light is the coolest and blue is the warmest. White light is the combination of all visible light. It appears white because none of the light is absorbed; it is all reflected back to the human eye. The sun is an example of white light. The reason why the sun may sometimes appear yellow is because yellow wavelengths of light are very abundant in sunlight. Black light consists of long wavelengths of ultraviolet light and is visible to insects, but not to humans. Light becomes visible to insects around the yellow part of the spectrum and ends at ultraviolet light. (Ashfaq *et al.,* 2005)

Reducing and controlling the pest population using light traps is an age old practice. Though several models and designs of insect light trap are available but according to Reddy *et al.,* 2010 solar powered trap with collecting net developed which has not dependent on any other source like wind power, mechanical power, fuel and electricity. This device operates automatically, turning on the light during night hours and turned off before sunrises. Most of the damage causing insects was active only during night time. Installing one light trap in an acre attracted at least more than 1000 adult pests for a day. The insects attract solar light trap model had been tested in the field crops like vegetables, paddy, and sugarcane, fruit crops like mango, pomegranate, guava, coconut and tea, coffee and jasmine crops across India.

1.2 Importance and need of study

Agriculture is a principal occupation for farmer. Every year farmers are facing problems due to pest attack which seriously destroy their crops and thus reduce their income. In Vidarbha and other region of Maharashtra, cotton crop has been grown predominantly as a cash crop. Vidarbha and Marathwada regions of Maharashtra are staring at huge losses owing to a pest (pink bollworm) attack on the cotton crop, across at least eight lakh hectares of land in 20 districts. More than 96% farmers use BT cotton seeds, which were supposed to be averse to the attack of pink bollworm and thus cotton production was reduced drastically. The farmers are using costly pesticides but the bollworm was found resistant to the chemicals available in the market. Hence the integrated pest management techniques for pest control use of pheromone trap, yellow sticky trap, electrically operated light trap etc. was suggested. One of the limitations of electrically operated light trap use on the farmer's field in the unavailability of electricity/grid on each and every field.

In Indian villages, availability of electricity is a major constrain and almost absent in remote villages (Bhamre *et al.,* 2005) along with higher cost of electricity or electrically based light traps. Keeping these points in view, the present investigation was carried under the following objectives:

1. To develop solar photovoltaic insect light trap.
2. To evaluate the comparative performance of solar photovoltaic based insect light traps using blue, yellow and UV-A blue light.
3. To study economics of solar photovoltaic insect light trap.

CHAPTER II

REVIEW OF LITERATURE

A comprehensive review of concepts and past relevant literature of Solar Photovoltaic Insect Light Traps are presented in this chapter. The work of various researches related to the present study has been reviewed and their findings are reported briefly as under in following three sections.

1. Insect light traps.

2. Solar photovoltaic based insect light trap.

3. Performance of SPV based insect light traps.

4. Economic feasibility of the SPV based insect light traps.

5. Exergy analysis of photovoltaic system.

2.1 Insect light traps

Watson (1979) conducted a research by using a 2.3 m diameter portable swimming pool placed beneath a conventional Robinson light trap to compare the efficiency of catch during studies of the flight behavior of black beetle, Heteronychusarator (Fabricius). Use of the pool increased the catchment area of the trap by 103 times, resulting in a 4.6 times increased in the number of black beetle and a 58 times increased in the number of black field cricket, Teleogrylluscommodus (Walker), caught. There was increased sensitivity in detection of flight at the lower activity extremes, so that the total number of evenings on which flight activity was recorded during individual flight seasons was increased by a factor of 1.4 for black beetle and 2.7 for black field cricket. The modified trap could also be useful in insect surveys and flight monitoring or recapture studies of a variety of other insect species.

According to Truxa and Fiedler (2012) moths were frequently used as indicators of biodiversity or habitat quality. Light traps were the most effective and widely used method for gathering data on moth communities. Knowing the distance from which moths were drawn to a light trap was therefore essential for the ecological interpretation of such data. Two community-wide mark-release-recapture experiments were carried out in forest habitats in central Europe in order to investigate whether the percentage of marked moths recaptured at weak artificial light sources (2 × 15 W UV-light tubes) was dependent on the distance they were released from the light source. Altogether 2,331 moths belonging to 167 species were caught at light traps and released at distances of 2–100 m. of these moths 313 returned to the light trap within 5 min of release. Percentage recapture was generally low (gross rate 13.4%) and strongly decreased with increase in the distance at which they were released.

Sharma and Bisen (2013) studied the scope of light trap as IPM technology in vegetable ecosystem, on insect pest fauna collected in Balaghat region of M.P. The data of trap catch during the year 2006 (Kharif season) was classified on taxonomic basis and economic aspect (crop pest). A total of 56 species were recorded in Kharif cropping season of vegetable cropping area. These insect pests belonged to 8 orders and 34 families Lepidoptera was the largest order with 23 species. Other orders were Hemipterra (14species), Coleoptera (11 species) and Orthoptera (4 species).

Thangalakshmi and Ramanujan (2015) reported that the Insects were easily attracted to bluish-purple (UV) radiations because these rays are visible to insects. Yellow pan traps with yellow sticky plates were used to catch daylight insects. Lamps with yellow illumination were also used to control pest during night. Thus, the extent of damage to flowers, vegetables and fruits could be controlled. The population of hovering bugs could be limited by covering the cultivated land using reflective materials. A real time checking system with insect counters and field servers was employed to monitor insects. Convectional fluorescent lights were replaced with bar coated aromatic substance to attract a particular insect.

2.2 Solar photovoltaic based insect light trap.

Bombale *et al.,* (2010) reported that the present light traps were working on conventional A.C. electricity which was not economical with respect to depleting conventional energy sources and it was also difficult to operate in agriculture fields as supply of electricity was not available everywhere. Also lanterns were used everywhere in rural sectors as well as during the load shading time in the urban sector. In present era of energy crisis, solar energy was abundantly available. Considering the demands, a light trapper cum lantern, working on the SPV technology was developed and tested for its performance. The developed light trapper cum lantern consisted of a solar array panel of 1058 cm^2 to recharge the battery in the day time from 8.00 am to 6.00 pm and its performance was tested by using a 9 watt lamp. A battery of 6 volt; 4.5 amp-h was used. The SPV panel had 18V; 1.5A voltage and current. An average working hours was 5. It collected maximum insects in the range of 40-60 at temperature range of 27-30°C. Also as wind speed increased above 5 kmph the number insects collected were observed to be decreased.

Bera (2015) developed a new model of solar light trap which would be the most effective IPM tool for the monitoring of insect pests and their mechanical control in the field of agriculture, provide no harm to the nature and also have low cost involvement so that it could be utilized by most of the farmers. Keeping in view above purpose a model of light trap box with iron structure was developed, which consisted of solar panel, charging unit, battery and LED bulb installed with the light trap box so that this solar light trap can monitor and control the insect pests of different crops effectively. The operation of the solar light trap was very easy. The switch above the LED bulb was provided. A farmer was to switch on the bulb every evening time and switch-off in the morning and the solar light trap would be charged during day time and provide light at night. The solar light attracted the insect pests and the same would be collected in the light trap box through funnel and would be stored in a plastic jar placed within the box. A little amount of water with a few drops of kerosene oil or even a few drops of liquid soap might be placed in the jar so that the insect pests caught by the trap could not fly away through the same hole.

Sermsri and Torasa (2015) developed solar energy-based insect pests trap by using ultraviolet light emitting diode tube to lure the insect pests and 12 Volt battery as power supply to light emitting diode tube. The battery charging system derived electrical energy from 20 Watts of solar cell for use at night. This proposed solar energy-based insect pests trap had an automatic control system to lure insect pests when there was no sunlight and the system would be stop working when the sun shines. The results of the system installation test showed that this proposed solar energy-based insect pest's trap could lure several types of insect pests in vegetable and coconut plantations including Brotispa, Elephus beetles, and Aphis, etc.

Brimapureeswaran *et al.,* (2016) developed a new model of solar light cum glue trap which was an effective tool for the monitoring of insect pests in the field of agriculture. It was safe to the nature and also cost effective at farmer's level. Solar light glue trap box with iron structure was developed. It had components such as solar panel, charging unit, battery, LDR Control unit and UV LED bulb installed with the solar light glue trap box. Demonstrations were taken in different field crops for their effectiveness. Nowadays, the consumers emphasized more in food resistance to insect pests for better health and environment on safe and non-chemical food. Moreover, researchers and farmers had still trying to find the suitable alternate method for controlling the insect's pests to the farmers instead of chemical methods had been used so far. However, due to lack of electrical energy problems in rural and villages usage of renewable energy resources of solar energy would help the expense of farmers. Hence a model of low cost solar light was developed and effective for various field crop pests to save the electrical energy.

2.3 Performance of SPV based insect light traps

Ashfaq *et al.,* (2005) evaluated the response of insects to varying wavelengths of light in Faisalabad, Pakistan. Six different colors (blue, green, yellow, red, black and white) were tested, arranged in a line on agriculture land, close to Faisalabad Airport. Tree rows/blocks, forest nursery, fruit garden, wheat, maize and fodder crops were the main vegetative covers in the vicinity. Each selected color light was properly projected on 1m^2 vertical screens (made of white cotton fabric) placed one meter high above the ground. All lights were kept on simultaneously for half an hour and the insects attracted on both sides of the screens were collected in tubs containing soapy water. The highest numbers of insects were observed in container placed under black light (ultraviolet light), while the lowest in that of red light. Similarly, the common insect orders frequented among all color lights were Diptera, Coleoptera and Lepidoptera respectively. The experimental results indicated that insects were attracted in more number on lights with short wavelengths and high frequencies and vice a versa.

Fayle et al. (2007) was compared three Robinson-type trap designs, each of which employs a 125W mercury vapour bulb. The first used a standard bulb; the second used the same bulb with the addition of a Pyrex beaker, often deployed to prevent bulbs from cracking in the rain, and the third used a bulb coated with a substance that absorbs visible wavelengths of light (also known as a black light). The black light trap caught few moths than either of the other traps, and had lower macro moth species richness and diversity than the standard beaker trap. This lower species richness could be accounted for the smaller number of moths caught by the black light trap. Furthermore the black light caught a different composition of both species and families to the other two trap types. Electromagnetic spectra of the three trap types showed that the black light trap lacked peaks in the visible spectrum present in both of the other traps. It was concluded that the addition of a beaker to a Robinson type trap does not make catches incomparable, but use of a black light does.

Hogsette (2008) noticed traps that use ultraviolet light as an attractant for flies were widely used in urban situations. To determine the differences in trap efficiency from design and lighting, pairs of traps were compared under laboratory conditions. Comparisons were made between traps with open fronts and with traps with restricted open fronts, black light bulbs, blue bulbs and glue boards with and without *z*-9-tricosene pheromone. In a windowless laboratory, pairs of traps were placed approximately 90 cm above the floor and 3 m apart. Fifty mixed-sex, 3 to 5 day-old house flies (*Musca domestica*) were released and counts of captured flies were made after 1, 4, 24 hrs. Traps with black light bulbs attracted and captured significantly more flies than blue bulbs. Black light bulbs increased the catch significantly in traps with open fronts but blue bulbs did not.

According to Steiner and Hauser (2009) light-trapping was a general term which covered all methods of attracting and capturing nocturnal insects with lamps that usually had a strong emission in the ultraviolet range of the spectrum, *e.g.* mercury vapour lamps, black light lamps or fluorescent tubes. Nocturnal Lepidoptera (moths), Trichoptera and Ephemeroptera were the insect grouped which could be collected most efficiently by light-trapping but many nocturnal species in several other orders were rarely recorded with other methods, *e.g.* some Coleoptera.

Ramamurthy *et al.,*(2010) conducted field observations at weekly interval (standard week), in 2007-08 at the Indian Agricultural Research Institute, New Delhi for studying the effect of three light sources in light traps (*viz.,* mercury, black and ultra violet) on insect catch and relationship with weather parameters. Results when analyzed revealed that coleopterans dominated the catches, followed by hemipterans, hymenopterans and lepidopterans. The mercury light was more efficient for Lepidoptera, Hemiptera, Hymenoptera, Odonata, and Diptera and black light was more efficient for Coleoptera, Orthoptera, Isoptera, and Dictyoptera. Similar attractiveness to the mercury and black light sources were found for coleopterans. Average temperature showed significant relationship with coleopterans, lepidopterans and hemipterans when all insect traps were considered together.

Dadmal and Khadakkar (2014) investigated the species composition of insect fauna attracted towards the light trap. Observations revealed that order Coleoptera showed a rich population i.e. 41.81% and 35.10% of the total collection for 2011-12 and 2012-13, respectively followed by Hemiptera 16.86% and 21.77% and Lepidoptera 12.96% and 12.89%, respectively. A 19 species of scarab beetles belonging to 10 genera were found to be the prominent visitors for both the years. Subfamily, Melolonthinae had rich species diversity with five species of genus *Holotrichia* and *Schizonycharuficollis.* Amongst Rutelines, *Rhinyptiaindica*, *R.nigrifrons*, *Anomalavaricolor, A. dimidiata, A. ruficapilla*and*Adoretus* *bicolor* prevailed. *Onthophagous gazelle* ruled the scarabaeinae fauna. *Protaetiaaurichalcea, P. teracea, Oxycetoniajucunda, O. versicolor, Clinteriaklugi, Heterorrhinamicans* of Cetoninae were also found predominant in this vicinity.

2.4 Economic feasibility of solar photovoltaic insect light trap

Kame Khouzam and RonelleTibaldi (1997) studied electric utilities throughout Australia and issued technical guidelines for interconnection of renewable energy sources to the grid. He suggested that the small-scale roof-top grid-connected photovoltaic systems were found technically feasible with and without battery storage. Economic analysis had shown that the electricity tariff structure for PV and other renewable needed a major change to allow a reasonable and acceptable pay-back period if PV was to become an attractive investment to home owners.

Stampolidis *et al*. (2006) presented a model for the economic evaluation of electrical energy production from photovoltaic systems. The economic evaluation model took into account all the operational income as well as all the expenses for the implementation, operation and maintenance of the photovoltaic system. The model used five financial criteria and was applied for the economic evaluation of an on-grid photovoltaic station at the prefecture of Chania.

Odeh *et al.,* (2006) investigated economic viability of photovoltaic water pumping systems. The net present value (NPV), annuity and cost annuity per equivalent hydraulic energy unit was calculated. It was found that PV water pumping systems were more economical than diesel pumping system for equivalent hydraulic energy below 2100000 m^4/year (5750 $m^{4/}$day and around 11kWp system size at 21.6 MJ/m^2 day average insolation), where diesel pumping system become more economical than PV water pumping system for larger application.

Qoaider and Steinbrecht (2016) investigated a cost competitive option to supply energy to off grid agriculture communities in arid regions. Economic viability of PV technology to supply the whole energy generation demands to off-grid irrigated-agriculture based communities in the arid region in southern Egypt. The PV generator was sized to daily pump 111 000 m^3 of lake water to irrigate 1260 ha acreage plot. Calculated cost of diesel generators-based electricity, they real market value of the diesel fuel of 86.55 c£/L was considered. Diesel generator –based electricity unit cost 39 c£/kWh, while a unit of PV electricity costs only 13 c£/kWh for the equivalent system size and project lifetime.

2.5 Exergy analysis of photovoltaic system

Steffen *et al*. (2013) presented the results of an analysis of hourly data obtained from forty-three photovoltaic (PV) systems installed in North America. Energy data collected from these systems were organized according to monthly output in an effort to identify factors which were effective in predicting energy generation. Independent variables such as system capacity, shading, longitude, latitude, seasonal variation, and orientation were considered. Multiple regression analysis was used to quantify the kilowatt-hours that could be expected from a change in the independent variables. Results showed that all six independent variables were significant predictors which could be used in a regression model to estimate system output with a high level of confidence. The analysis showed that approximately 83% of the variation in the amount of energy generated monthly by the forty-three solar panels was explained by the independent variables and the derived equation.

Srinivas and Jayaraj (2013) designed and fabricated a double pass hybrid solar air (PV/T) heater with slats to study elaborately its thermal and electrical performance corresponding to the warm and humid environment. Thermal and electrical performances of the whole system at different cooling rates were presented. The exergy analysis of double pass hybrid solar air (PV/T) heater with slats had been carried out. The instantaneous overall energy and overall exergy efficiency of the double pass hybrid (PV/T) solar air heater varied between 29 – 37%and 14-17% respectively.

Sudhakar and Srivastava (2013) evaluated thermal, electrical and exergy output of solar PV panel installed at Energy Centre, NIT Bhopal. Using the first law of thermodynamics, energy analysis was performed and exergy analysis was carried out to determine exergy losses during the PV conversion process by applying the second law of thermodynamics. The operating and electrical parameters of a PV array include PV module temperature, overall heat loss coefficient, open-circuit voltage, short-circuit current, fill factor, etc. were experimentally determined for a typical hazy day of March (10 March 2012) at Bhopal. The experimental data were used for the calculation of the energy and exergy efficiencies of the PV systems. Energy efficiency was seen to vary between 6% and 9% during the day. In contrast, exergy efficiency was lower for electricity generation using the considered PV module, ranging from 8% to 10%. It was observed that the PV module temperature had a great effect on the exergy efficiency, and the exergy efficiency could be improved if the heat could be removed from the PV module surface. It was concluded that the exergy losses increased with increasing module temperature.

Pandey *et al*. (2013) carried out performance evaluation and parametric study of multi-crystalline solar photovoltaic module using energy and exergy analysis for different months of the year at a typical climatic zone in north India. Three different efficiencies viz. energy, power conversion and exergy had been calculated and plotted against time based on hourly solar radiation. All the three efficiencies for the month of February had been found to be the highest among all the months analyzed and presented in the study. The energy efficiency for the month of December was found to be the least; however, the exergy efficiency for the month of July was found to be the least. All the efficiencies had been found to be much higher during the morning and evening hours as compared to the noon hours for all the operating months. The energy efficiency was found to be higher than those of the power conversion and exergy efficiencies throughout the year.

CHAPTER III

MATERIAL AND METHODS

This chapter deals with the materials and methods used for development of "Solar photovoltaic insect light trap" and methodology adopted for evaluation of it performance in field. The materials and methodology used for research work was discussed in following sections.

3.1 Location of study

Akola is located at latitude 20.7° North and longitude 77.07° East. It is situated at an altitude of 287 m to 316 m above mean sea level. The experiment was conducted at the field of Vazegaon, Taluka Balapur Dist. Akola.

3.2 Development of solar photovoltaic insect light trap

This system is mainly consisted of solar panel, sealed lead acid battery, charge controller, relay circuit, LED light, bulb holding funnel, insect collecting chamber, battery box and adjustable three leg support base frame.

3.2.1 Solar photovoltaic insect light trap component

A solar insect light trap system used for the experimentation has the following components.

i. Photovoltaic panel
ii. Sealed lead acid battery
iii. Charge controller
iv. Relay circuit
v. LED light
vi. ON/OFF switch
vii. Bulb holding funnel
viii. Insect collecting chamber
ix. Battery box
x. Adjustable three leg support based frame

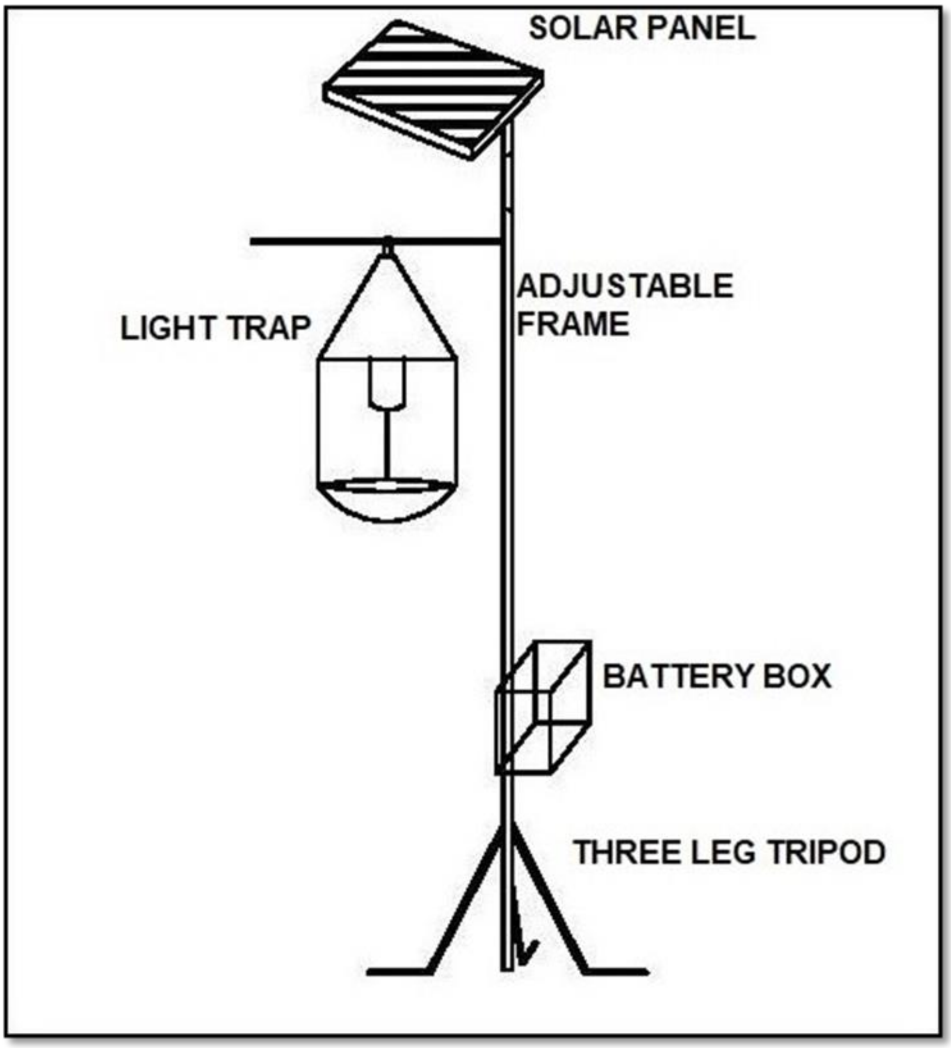


Fig.3.1: Schematic view of solar photovoltaic insect light trap

3.2.1.1 Photovoltaic Panel

A solar PV panel of 10 watt peak, measured under standard test condition (STC) were used for solar insect light trap. Photovoltaic panels containing Multi crystalline Silicon Solar cells with outlined below feature could be used in the photovoltaic panel for the solar insect light trap. The solar panel could produce rated voltage even under low light exposure. For getting full performance solar panel were oriented towards the south direction. The technical specifications of SPV panel are shown in Table 3.1.

Table No.3.1 Technical specifications of SPV Panel

S.N.	Particular	Specification
1	Model No	JJ-M 672
2	Cell Type	Multi Crystalline Silicon
3	Maximum Power (Pmax)	10 W
4	Rated Current	0.588 A
5	Rated Voltage	17 V
6	Short circuit current	0.659 A
7	Open circuit Voltage	21.6 V
8	Size of panel	0.1156 m^2
9	Weight of panel	1.45 Kg

3.2.1.2 Sealed lead acid battery

Battery is a source of stored electrical energy or it is called as storage cell battery, means it can store electrical energy and give whenever requires. There are two types of storage batteries available in market. 1. Lead acid and 2. SMF (Sealed maintenance free lead acid battery) having charging capacity 12 V 6Ah, 7Ah. According to available power source 12V, 7Ah sealed Lead acid battery was selected having no maintenance.

3.2.1.3 Charge controller

A charge control unit prevents the reverse flow of current from battery to panel. It prevents battery from overcharging. As per specification of the selected solar panel of 10 W, 0.588 A, charge control unit having capacity 10 A was suitable for 1 Watt to 40 Watt power of Solar panel.

Therefore charge controller of 5 A was selected to control the battery charging.

3.2.1.4 Relay circuit

A relay is an electrically operated switch where in current flowing through the coil of the relay created a magnetic field which attracted a lever and changes the switch contacts. The coil current can be on or off so relays have two switch positions and they are double throw (changeover) switches. The working of relay is to turn on by sunset and turn off after sunrise and it is a continuous operation. As per specification of charge controller 12 V, 10 A relay was selected.

3.2.1.5 LED light

Most of the insects are phototropic and hence light is the most important component of the solar insect light trap which attracts the insects. The most suitable bulbs which attract the insect were UV-A blue L.E.D. bulb, blue L.E.D. bulb and yellow L.E.D. bulb as in order. Hence, we were selected three bulbs for making comparison among them to evaluate its effectiveness in light attracting insects. A 5-watt blue and yellow L.E.D. strip bulb having 3 bulbs on each strip and total of 30 bulbs were used. One 5-watt ultra violet light having 16 number bulbs on each line and total 48 numbers of bulbs were joined to make a single bulb. In order to protect the bulb from dust, insects, water, a transparent plastic cover of 6 cm diameter was used.

3.2.1.6 ON/OFF switch

It used to ON or OFF the complete system.

3.2.1.7 Bulb holding funnel

It was hanged over the stand with the help of iron angle and holds the bulb assembly.

3.2.1.8 Insect collecting chamber

It acts as a collection unit for insect which was hanged to the bulb holding funnel with the help of chains.

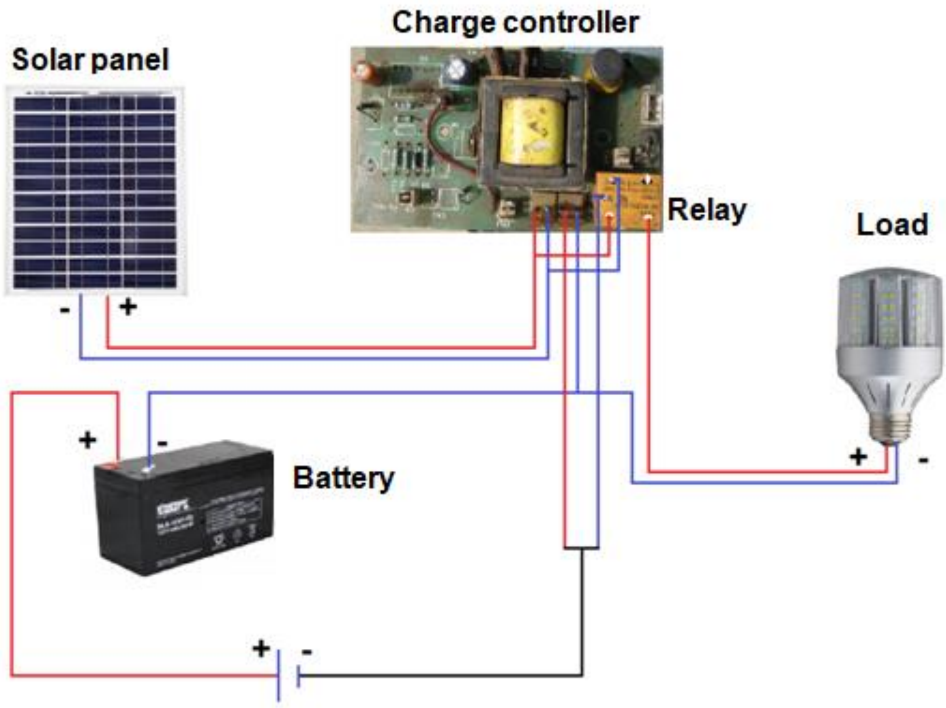


Fig.3.2: Circuitry arrangement of solar photovoltaic insect light trap

3.2.1.9 Battery box

The battery box was placed over the battery box stand above 40 cm height by the main stand which holds the battery, solar charge controller, relay, ON/OFF switch, power outlets and input in the same box.

3.2.1.10 Adjustable three leg support frame

A stand was a portable frame, used as a platform for supporting the weight and maintaining the stability of insect trap. A stand provides stability against downward forces and horizontal forces and movements about horizontal axes. It was provided with adjustable screw to maintain the height of bulb according to crop height.

3.2.2 Fabrication procedure with dimension of various parts of solar photovoltaic insect light trap

3.2.2.1 Fabrication of main stand frame with tripod

A hollow G.I pipe of outer diameter of 2.4 cm and inner diameter of 2.1cm with the length of 150 cm was selected. The pipe was cut to a suitable height of 130 cm considering average crop height. The screw hole was made at the distance of 3 cm from top portion of main stand. Bolt with diameter of 1.1 cm was provided for adjusting the height of adjustable stand according to crop height.

Another G.I. pipe of same dimension (Outer diameter of 2.4 cm and Inner diameter of 2.1cm) and of different length 150 cm was chosen. The pipe was cut into three equal parts of length 50 cm by using iron cutter. The pipe was welded to the main stand at the height of 30 cm from bottom surface of main pipe and angle between these three pipes was taken as 120° for better stability.

An iron bar of length 100 cm was chosen to make battery box stand frame. Then with the help of cutter it was cut into four parts of dimensions 25 cm, 25 cm, 20 cm and 20 cm. These four parts were joined in a rectangular pattern of dimension 23 cm × 19 cm by electric welding these four iron bars at its end. This battery box stand frame was welded to the main stand at lower height of 20 cm from the top of tripod stand to provide stability.

3.2.2.2 Fabrication of adjustable stand

A hollow pipe of outer diameter of 1.8 cm and inner diameter of 1.4 cm was chosen, which was smaller in diameter than the main stand pipe so that they are easily move inside the main pipe and adjusted according the crop height i.e. adjusted two feet above the crop height. Hollow pipe of length 210 cm was selected and the pipe was cut into two parts of length 153 cm and 53 cm. The longer pipe was selected as adjustable stand and smaller pipe was selected for the extension purpose. Extension pipe was welded at the right angle to the adjustable stand at the distance of 18 cm from the top of adjustable pipe. Extension pipe was used to hold the bulb holding funnel and insect collecting chamber.

3.2.2.3 Fabrication of solar panel frame

A rectangular iron bar of thickness of 0.6 cm was selected and the bar was cut into three parts of dimension 34 cm with the help of iron cutter. Two iron bars are kept parallel and made a hole in the bar at same point like as in solar panel, third one is welded perpendicularly bisector to these two bars. The another pipe of same diameter as main stand pipe (2.4 m outer diameter and 2.1 cm inner diameter) was welded to panel stand frame at an angle of 55° (which suited the solar panel tilt angle according to Akola (latitude 20.706°E). The length of pipe was selected as 13 cm.

The bigger diameter of pipe was provided the free movement of panel in the direction of sun. In this pipe, a screw hole of diameter 9 mm was provided to tight the panel frame outside the adjustable stand.

3.2.2.4 Fabrication of funnel and insect collecting chamber

Inverted conical funnel was made of high quality plastic of upper diameter 30 cm and lower diameter 5 cm was selected in which a thin M.S sheet of length (36 cm) was fitted with the help of screw. The LED bulbs and glass cover was fixed to M.S sheet with the help of mixture of aerolite and flex-kwik.

Insect collecting tub of circular diameter 38 cm was selected in which three holes were made at equal distance of 40 cm by using drilling machine. Then it was connected to the inverted conical funnel by using chains at three equal hole distance of 27 cm. the length of chain was chosen 22.5 cm which was adjustable.

3.2.2.5 Fabrication of battery box

Firstly, battery was taken and space covered by solar charge controller and wiring was measured. According to that point of we made the M.S box of suitable dimension. Then arranged all the parts of solar circuit in battery box. Two ports were made to provide holes for solar input wire and battery output at the back of the box. Two holes at the right face of the box are made for ON/OFF switch and for indicator (provided to indicate charging of battery by solar panel).

Table No. 3.2 Technical specification of solar insect light trap

S. N.	Component	Specification	Material used
1	Photovoltaic panels	10 W, 17 V Size: 34 cm × 34 cm	-
2	Battery	Voltage: 12 V Capacity: 7 Ah	Sealed lead acid battery
3	Charge controller	5 A	-
4	Relay circuit	12 V, 10 A	-
5	LED light Blue, Yellow and Ultra violet	3 No. 5 W of each light	-
6	ON/OFF switch	1 No. ON/OFF	-
7	Bulb holding funnel	Upper dia.: 30 cm Lower dia.: 5 cm	Plastic
8	Insect collecting chamber	Diameter: 38 cm	Plastic
9	Battery box	22 cm × 18 cm	Mild steel
10	Adjustable frame	Length: 153 cm	G.I. pipe
11	Tripod stand	Height: 98 cm	G.I. pipe
12	Solar panel stand	34 cm × 34 cm	G.I. pipe

Blue light trap **Yellow light trap**

Ultra violet light trap

Plate 3.1: Solar photovoltaic insect light trap

Table 3.3 Cost of solar photovoltaic inset light trap

S. N.	Item Name	Cost (Rs.)
1.	Solar panel	500
2.	Battery	650
3.	Charge controller with relay circuit	350
4.	LED light with glass cover	300
5.	Battery box	50
6.	Main frame	550
7.	Bulb holding funnel	100
8.	Insect collecting chamber with chain	100
9.	Labour charge	400
	Total	3000

3.3 Methodology

The components of solar photovoltaic insect light trap included solar panel, solar charge controller and Lead acid battery. The appropriate sizing and configuration of these components was necessary for getting efficient performance of the system. Average power consumption was determined by using following formula.

Average Power Consumption

$$P_{rated} = \frac{Ep}{T/60} \qquad \text{.....(3.1)}$$

Where,

P_{rated} = Average power

Ep = Energy consumption in wh.

T = Time period in minutes

60 = Conversion factor from minutes to hours

3.4 Sizing of photovoltaic system

The photovoltaic panel was used to operate the insect light trap. The size of a photovoltaic system was depended on the power of the light, duty hours and the solar insolation. The size of photovoltaic system was calculated by using following equations.

a) Load estimation

Total wattage, $P_{ratedtotal} = q \times P_{rated}$ …..(3.2)

Where,

P_{rated} = Wattage of light

q = Quantity of light

Energy Demand, $E_{d(Wh)} = P_{ratedtotal} \times H$ …..(3.3)

Where,

H = Operating hours

$$\text{Load demand, } E_{d(Ah)} = \frac{E_{d(wh)}}{V_{nsv}} \quad \text{…..(3.4)}$$

Where,

V_{nsv} = Nominal system voltage

$$\text{Corrected load, } E_{c(Ah)} = \frac{E_{d(Ah)}}{n_b} \quad \text{…..(3.5)}$$

Where,

n_b = Battery efficiency

b) Battery sizing

The size of battery required for solar insect light trap was determined by using following formula.

$$\text{Battery capacity, } B_{rc} = \frac{E_{c(Ah)} \times D_s}{DOD_{max} \times n_T} \quad \text{…..(3.6)}$$

Where,

D_5 = Battery autonomous day

DOD_{max} = Max. depth of discharge of battery

n_T = Temp. correction factor

$E_{c(Ak)}$ = Corrected load

$$\text{No. of battery in parallel, } B_p = \frac{B_{rc}}{B_{sc}} \qquad \text{.....(3.7)}$$

Where,

B_{sc} = Capacity of selected battery

$$\text{No. of battery in series, } Bs = \frac{V_{nsv}}{V_{nbv}} \qquad \text{.....(3.8)}$$

Where,

V_{nsv} = Nominal system voltage

V_{nbv} = Nominal battery voltage

$$\text{Total battery, } B_t = B_p \times B_s \qquad \text{.....(3.9)}$$

c) PV array sizing

The PV array required for solar insect light trap was determined by using following formula.

$$\text{Corrected current load, ID} = \frac{E_{c(Ah)}}{G} \qquad \text{.....(3.10)}$$

Where,

G = Lowest daily sunshine hours

$$\text{Rated design current, } I_{DE} = \frac{I_d}{n_m} \qquad \text{.....(3.11)}$$

Where,

n_m = Module derate factor

$$\text{No. of solar panel in parallel, } N_p = \frac{I_{DE}}{I_p} \quad \text{.....(3.12)}$$

Where,

I_p = Peak current of selected solar panel.

$$\text{No. of solar panel in series, Ns} = \frac{V_{nbv} \times B_s \times 1.2}{V_p} \quad \text{..... (3.13)}$$

Where,

V_{nbv} = Nominal battery voltage

B_s = No. of battery in series

V_p = Peak voltage of selected solar panel

$$\text{Total solar panel, } N_T = N_p \times N_s \quad \text{.....(3.14)}$$

d) Charge controller sizing

$$\text{Maximum current, } I_T = N_p \times I_p \quad \text{.....(3.15)}$$

Where,

N_p = No. of solar panel in parallel

Ip = Peak current of selected solar panel.

Thus, a charge controller with current >I_T and system voltage of V_{nsv} was chosen.

3.5 Performance evaluation of solar photovoltaic insect light trap

The experiment was conducted by using solar insect light trap with three different colored light viz. blue, yellow and ultra violet having 5 W rating. All Three light traps were installed as per crop height from the ground level and solar insect light trap was installed in the field for specific intervals from each other to let the insect towards the trap. The solar panel of 17 V; 0.588 A 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 hrs. The battery was charge using the solar panel from 8.00 am. A wind speed was recorded to know the velocity of wind, which would affect during performance of the solar panel. Solar

Plate 3.2: Field performance of solar photovoltaic insect light trap

insect light trap was operated from 19.00 hrs to 22.00 hrs and 4 hrs to 6 hrs daily in the cotton field number of insects caught was recorded. The performance of three light traps viz., blue, yellow and UV-A blue was evaluate in the cotton field.

3.6 Performance evaluation of solar photovoltaic system

The performance of the SPV system was evaluated in terms of V-I characteristics, power output, photovoltaic and its exergy efficiency determination. The effect of insolation on the solar photovoltaic panel performance was ascertained by positioning of the solar panel at 23° angle and it was placed in the direction of sun in sunshine hours from 8.00 hrs to 17.00 hrs. When solar radiation incident on module, electric current was generated. Charge controller was used to control the charging and multimeter to measure the current and voltage in the circuit. Solar intensity was measured by pyranometer, wind velocity by anemometer, panel temperature by IR thermometer and ambient temperature by mercury thermometer.

The observation of V_m, I_m of solar panel was recorded at different conditions and the power was determined by using the equation.

$$P_m = I_m \times V_m \qquad \text{….(3.16)}$$

Where,

P_m = Power at maximum point, Watt

I_m = Current at maximum power point, A

V_m = Voltage at maximum power point, V

3.7 Energy analysis

The performance of a PV module was expressed in terms of their current, voltage and power-voltage characteristic which is a function of solar radiation and module temperature.

3.7.1 Photovoltaic efficiency

The efficiency of the solar panels defined as the ratio of the electrical power produced to the incident radiation and varies in between 10 to 15%

at maximum power conditions for the PV panel. If the PV system is to operate at high efficiency, it is essential that the voltage imposed on the PV panel be close to the voltage that provides maximum power. Photovoltaic efficiency of solar panel was determined at no load and full load condition by using following formula.

$$n_{pv} = \frac{P_{max}}{S \times A_{pv}} \qquad .....(3.17)$$

Where,

n_{pv} = Efficiency of photovoltaic system

P_{max} = Maximum power from photovoltaic system (W)

S = Solar irradiance (W/m^2)

A_{pv} = Area of the photovoltaic system (m^2)

3.8 Exergy analysis

Exergy is defined as the maximum amount of work that can be done by a system. Unlike energy, exergy is not subject to a conservation law; exergy is consumed or destroyed, due to the irreversibility present in every real process.

3.8.1 Photovoltaic exergy

The energy of a PV module depends on two major components electrical and thermal. In SPV system electricity is generated by the PV effect, the PV cells are heated due to the thermal energy present in the solar radiation. The electricity (electrical energy), generated by a photovoltaic system, is also termed as electrical exergy since it is the available energy that can completely be utilized in useful purpose (K. Sudhakar and Tulika Srivastava, 2013). Since the thermal energy available on the photovoltaic surface was not utilized for a useful purpose it was considered to be a heat loss to the ambient. Therefore, due to heat loss, it becomes exergy destruction. The exergy output of the photovoltaic system can be calculated as:

$$Ex_{out} = V_m I_m - \left(1 - \frac{T_0}{T_{cell}}\right) [h_c \times A_{pv} (T_{cell} - T_0)] \qquad …..(3.18)$$

Where,

V_m, I_m, h_c, A_{pv}, T_{cell} and T_o are the maximum voltage and current of the photovoltaic system, convective heat transfer coefficient from the photovoltaic cell to ambient, area of the photovoltaic surface, cell temperature and ambient temperature (dead state temperature), respectively.

The convective heat transfer coefficient from the photovoltaic cell to ambient can be calculated by using correlation

$$h_c = 5.7 + 3.8 \times V \qquad …..(3.19)$$

Where,

V = Wind velocity (m)

The module or cell temperature was used to predict the energy production of the photovoltaic module. Cell temperature is a function of ambient temperature, wind speed and total irradiance. The cell temperature can be determined by the following relationship:

$$T_{cell} = 0.943T_a + 0.028 \text{ Irradiance} - 1.528 \text{ Wind speed} + 4.3 \qquad …..(3.20)$$

Exergy input of the photovoltaic system, which is the energy of solar energy, can be calculated approximately as below

$$Ex_{in} = Ex_{solar} = A_{pv} \times S \times \left[1 - \frac{4}{3}\left(\frac{T_o}{T_{SUN}}\right) + \frac{1}{3}\left(\frac{T_o}{T_{SUN}}\right)\right] \qquad …..(3.21)$$

Where,

T_{SUN} = Temperature of the Sun taken as 5760 °K

Exergy efficiency of the photovoltaic system is defined as the ratio of total output energy (recovered) to total input energy (supplied). It could be expressed as

$$\Psi_{pv} = \frac{Ex_{out}}{Ex_{1n}} \quad \text{.....(3.22)}$$

3.9 Evaluation of light trap using different colour LED bulbs for trapping phototrophic insects

The experiment was conducted by using solar photovoltaic operated light trap with three coloured LED having 5 Watt power rating bulb viz., blue, yellow, and UV-A blue. All three light traps were installed at 2 feet above the crop height and 30 meter apart from each other to let the insect to orient toward their most favorite colour. Light traps were operated from 19.00 hrs to 22.00 hrs and 4.00 hrs to 6.00 hrs daily numbers of insects caught were recorded and the insects were separated order wise.

3.10 Order wise comparison of the insects caught in the above mentioned light traps

The insects collected by the above mentioned light traps were sorted out order wise and tabulated to know the effect of light on the attraction of insect.

3.11 Instrument used for experimentation

The technical specification of instruments used during the experimentation is given in Table 3.4.

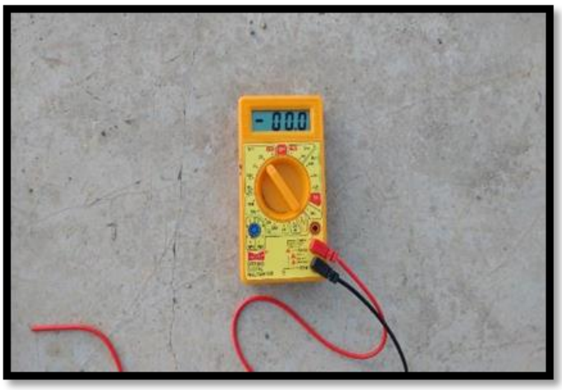
Table 3.4 Technical specification of instruments

S.N.	Instruments used	Specifications	Measurement
1.	Digital anemometer	Make: LUTRON Measurement =m/s km/h. ft./min Operating temp:0°C 50°C	Air flow rate
2.	Multimeter	Make: Beemet Range :300 V Make :Meco Max : 20 A COM-max 750 VAC,1000 VDC	Voltage(DC) and Current (DC)
3.	Infrared thermometer	Make : Mextech Range: -50 to 200°C	Temperature
4.	Thermometer	Measuring range 0 to 100 °C Display accuracy ±3%	Ambient Temperature
5.	Lux meter	Measurement (lx)	Light intensity
6.	Pyranometer	Make: CEL	Solar Radiation

Plate 3.3: Insect collected from solar photovoltaic insect light trap

Annemometer

Pyranometer



Multimeter

Infrared thermometer

Thermometer

Lux meter

Plate 3.4: Instrument used for experimentation

3.12 Economic feasibility of solar photovoltaic insect light trap

The economic feasibility of solar insect trap was calculated by using discount rate method.

Following assumptions/consideration were made for carrying out economic analysis of solar photovoltaic insect light trap.

1) Operating hours of solar insect light trap was 12 h per day.
2) Total operating hours of solar insect light trap in year were 2400 h.
3) Total electricity saved by using solar insect light trap instead of 170 watt light trap was 408 KW-h/ year (units).
4) Cost of 1 unit of electricity was Rs. 7. Thus Rs. 2856 was saved throughout the year by using solar insect light trap.
5) The repair and maintenance cost of light trap was Rs.600 per year.
6) Initial investment on solar trap was Rs. 3000 per trap.
7) Useful life of solar insect trap is 12 year.
8) It was assumed that 2 solar insect light trap were required to match the area covered by 170 watt electrical light trap.
9) The discount was considered to be 10 percent.

Following different economic indicators were used for economic analysis of solar system under this study:

1) Net present worth (NPW)
2) Benefit cost ratio (B/C ratio)
3) Payback period

3.12.1 Net present worth

The difference between the present value of all future returns and the present money required to make an investment is the net present worth or net present principles for the investment. The present value of the future returns can be calculated through the use of discounting. Discounting essentially a technique by which future benefits and cost streams can be converted to their present worth. The interest rate was assumed as the discount rate for discounting purpose. A project returns the same benefit in each of several years and we need to know the present worth of that future income stream to know how much it was justified in investing today to receive that income stream. The most straight forward discounted cash flow measure of project worth is the net present worth (NPW). The net present worth may be computed by subtracting the total discounted present worth of the cost streams from that of the benefit stream. To obtain the incremental net benefit gross cost is subtracted from gross benefit or the investment cost from the net benefit.

The mathematical statement for net present worth can be written as:

$$\text{NPW} = \sum_{t=1}^{t=n} \frac{B_t - C_t}{(1+i)^t} \quad \text{---} \quad (3.23)$$

Where,

C_t = Cost in each year

B_t = Benefit in each year

t = 1, 2, 3................n

i = discount rate

3.12.2 Benefit cost ratio

This is the ratio obtained when the present worth of the benefit stream is divided by the present worth of the cost stream. The formal selection criterion for the benefit cost ratio for measure of project worth is to accept projects for a benefit cost ratio of one or greater. In practice, it was probably more common not to compute the benefit cost ratio using gross cost and gross benefit, than rather to compare the present worth of the net benefit with the present worth of the investment cost plus the operation and maintenance cost. The ratio is computed by taking the present worth of the gross benefit less associated cost and then comparing it with the present worth of the project cost. The associated cost is the value of the goods and service over and above those included in project costs needed to make the immediate products or services of the project available for use or sale. Project economic cost is the sum of installation costs, operation and maintenance and replacement costs. The mathematically benefit-cost ratio can be expressed as:

$$\text{Benefit-cost ratio} = \frac{\sum_{t=1}^{t=n} \frac{B_t}{(1+i)^t}}{\sum_{t=1}^{t=n} \frac{C_t}{(1+i)^t}} \quad \text{---} \quad (3.24)$$

Where,

C_t = Cost in each year

B_t = Benefit in each year

t = 1, 2, 3................n (year)

i = discount rate

3.12.3 Payback period

The payback period is the length of time from the beginning of the project until the net value of the incremental production stream reaches the total amount of the capital investment. It shows the length of time between cumulative net cash outflow recovered in the form of yearly net cash inflow. The matimatically payback period can be expressed as:

$$P = \frac{I}{E} \quad \text{--} \quad (3.25)$$

Where,

P= Payback period of the project in years,

I = Investment of the project in rupees and

E = Annual net cash revenue in rupees.

CHAPTER IV

RESULTS AND DISCUSSION

This chapter deals with the results obtained from study of the development and techno economics evaluation of solar photovoltaic insect light trap. The solar photovoltaic insect light traps were installed in the village Vazegaon, Taluka Balapur, District Akola. The data was generated on the parameters of solar intensity, solar radiation, ambient temp, current, and voltage developed by panel, panel temp, panel efficiency, exergy efficiency of panel, light intensity, 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.

4.1. Performance evaluation of SPV insect light trap

The comparative performance of solar photovoltaic insect light trap of the three colour LED light viz., blue, yellow and ultra violet-A blue were evaluated and the results obtained are discussed.

4.1.1 Performance of solar photovoltaic system

The variation of solar intensity and corresponding power from solar panel was recorded for the consecutive days in March when solar insect light trap was kept in cotton field. The average values were reported in Appendix C.

The variation of solar intensity and power developed with respect to time in blue, yellow and UV-A blue light trap solar panel are shown in Fig.4.1, Fig.4.2 and Fig 4.3, respectively. It was observed that, the solar intensity was varied in blue, yellow and UV-A light trap from 154.6 W/m^2 to 811.3 W/m^2, 154.5 W/m^2 to 805.5 W/m^2 and 157.6 W/m^2 to 806.3 W/m^2, respectively. The peak value of solar intensity was achieved at 13:00 h (811.3 W/m^2, 805.5 W/m^2 and 806.3 W/m^2, respectively).

The power developed by selected 10 W solar panel of blue, yellow and UV-A light trap panel varies from 2.0 W to 9.9 W, 2.04 W to 9.9 W and 2.04 W to 10.05 W, respectively. The peak value of power was achieved at 13:00 h (9.9 W, 9.9 W and 10.05 W, respectively).

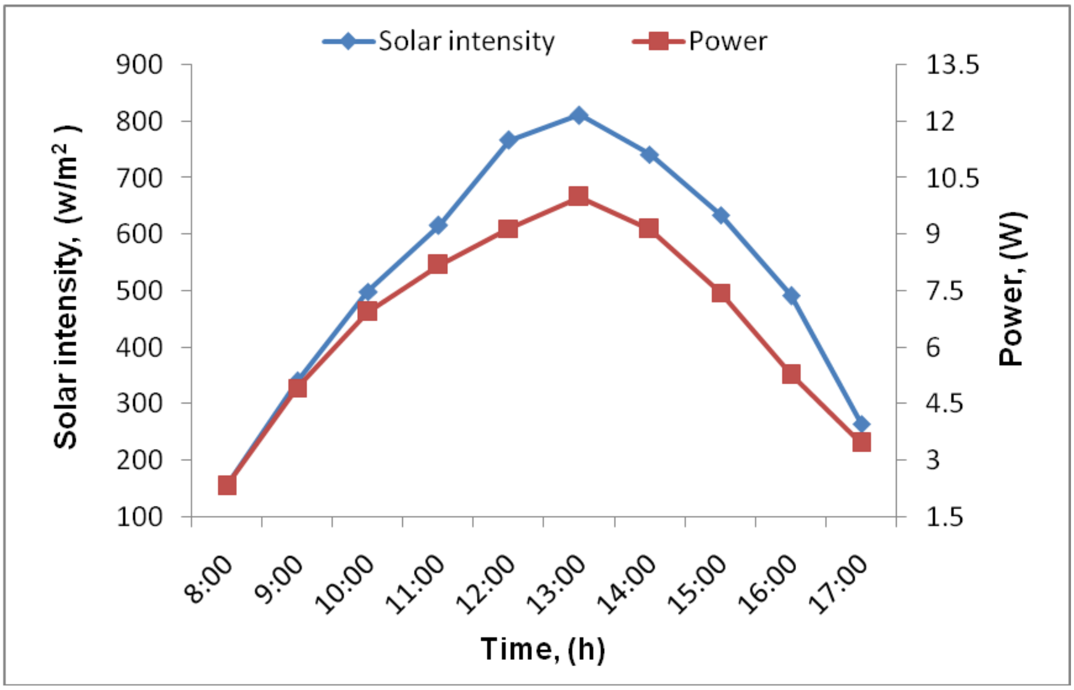


Fig 4.1 Variation in solar intensity and power of blue trap solar panel with time

The variation of solar intensity and power developed with respect to time in yellow trap solar panel is shown in Fig.4.2.

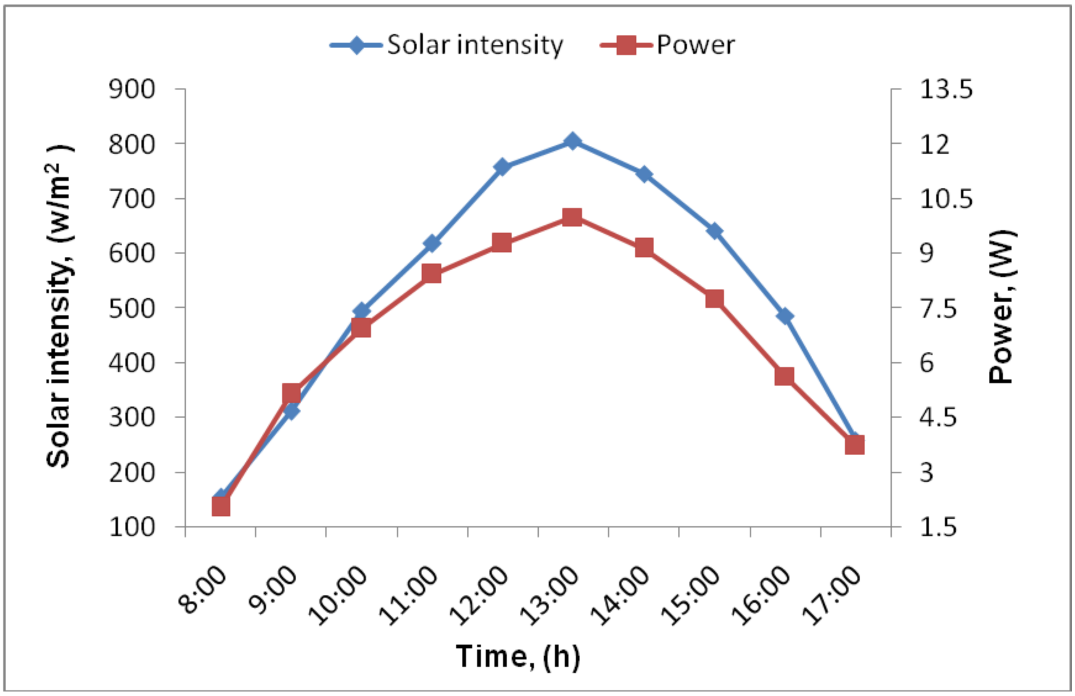


Fig 4.2 Variation in solar intensity and power of yellow trap solar panel with time

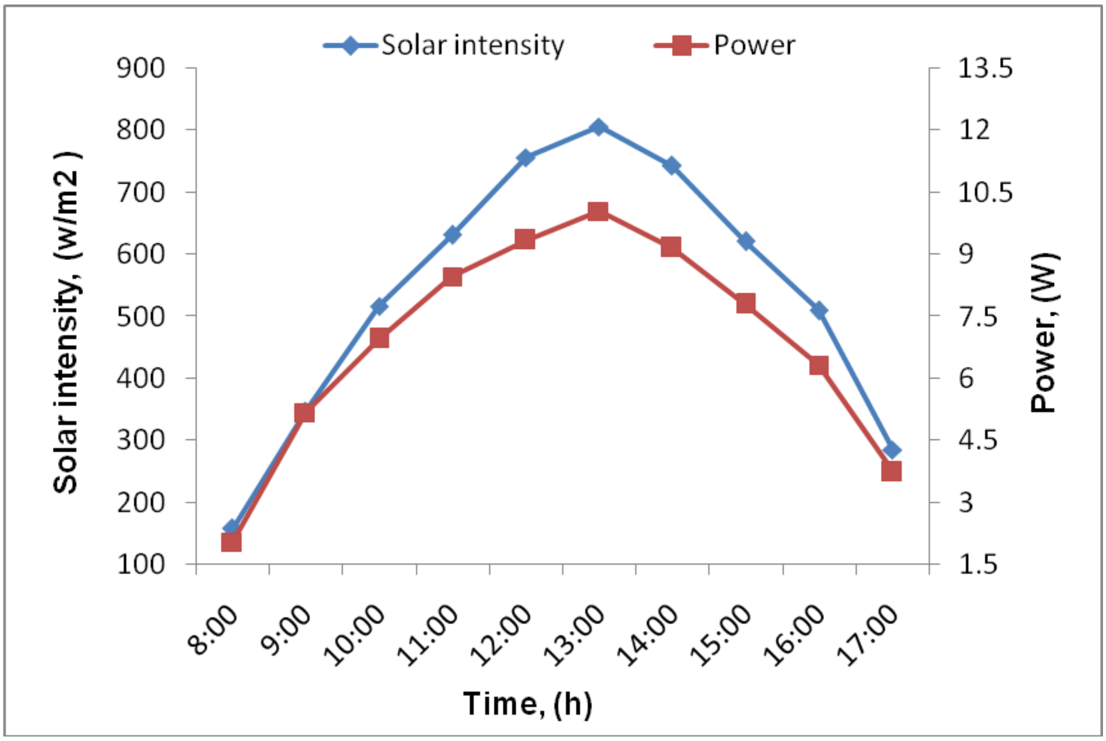


Fig 4.3 Variation in solar intensity and power of UV trap solar panel with time

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 photovoltaic insect light trap.

The V-I and power characteristics of the 10 W solar panel were carried out at normal condition on clear sunny day to determine the maximum current and maximum voltage with respect to time. The typical V-I characteristic's curve of solar panel of blue, yellow and ultra violet light trap is shown in Fig.4.4, Fig.4.5 and Fig.4.6 respectively.

It was observed that, 10 W solar panel developed 0.659 amp short circuit current (I_{sc}) and 21.6 volt open circuit voltage (Voc). The current at maximum power point (I_m) was observed to be 0.588 amp and voltage at maximum power point (V_m) was observed to be 17 volt. The maximum power point of selected 10 W panel was found to be 9.9 W. It was revealed that, the selected panel is suitable in terms of current, voltage and power supply to the solar photovoltaic insect light trap.

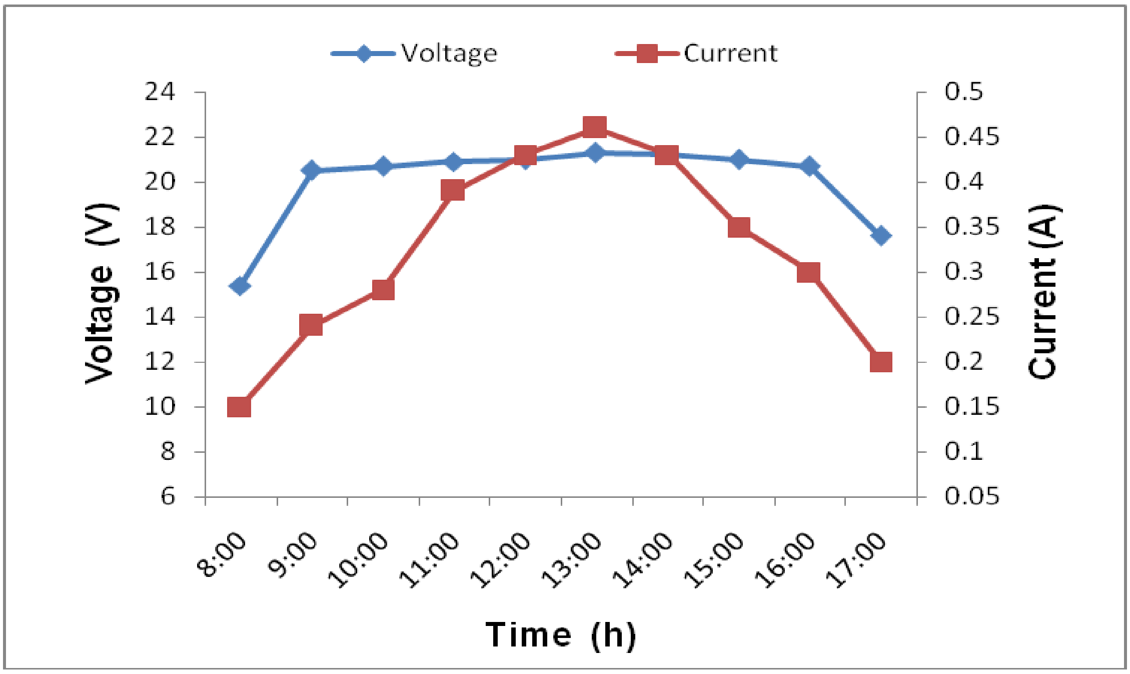


Fig 4.4 Variation in current and voltage of blue trap solar panel with time

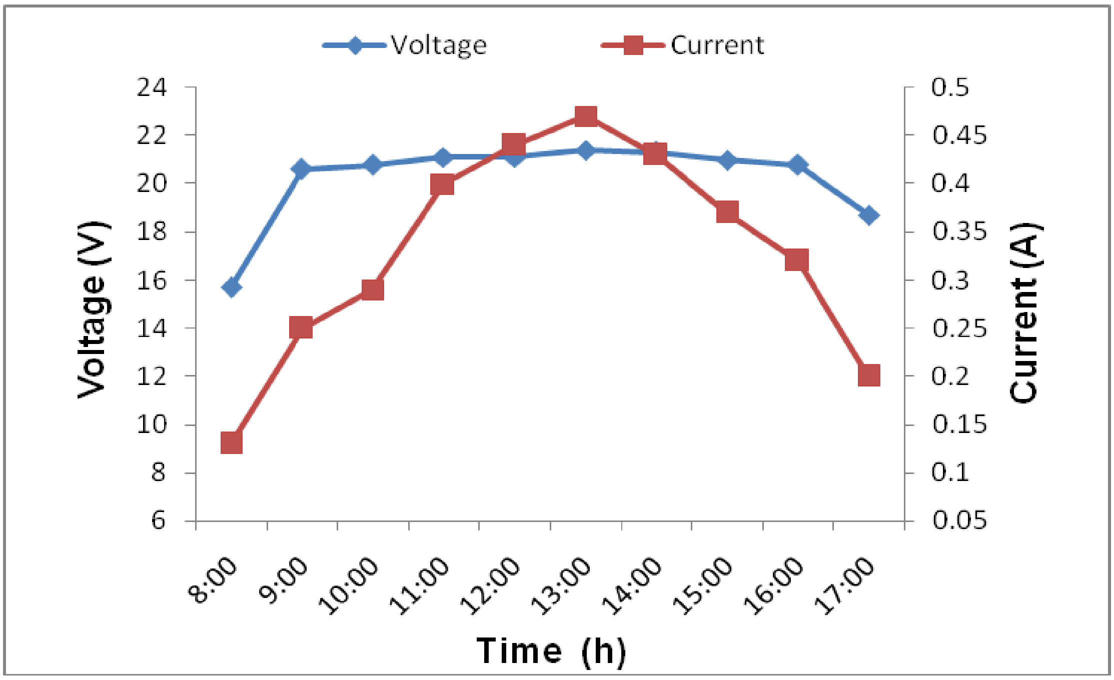


Fig 4.5 Variation in current and voltage of yellow trap solar panel with time

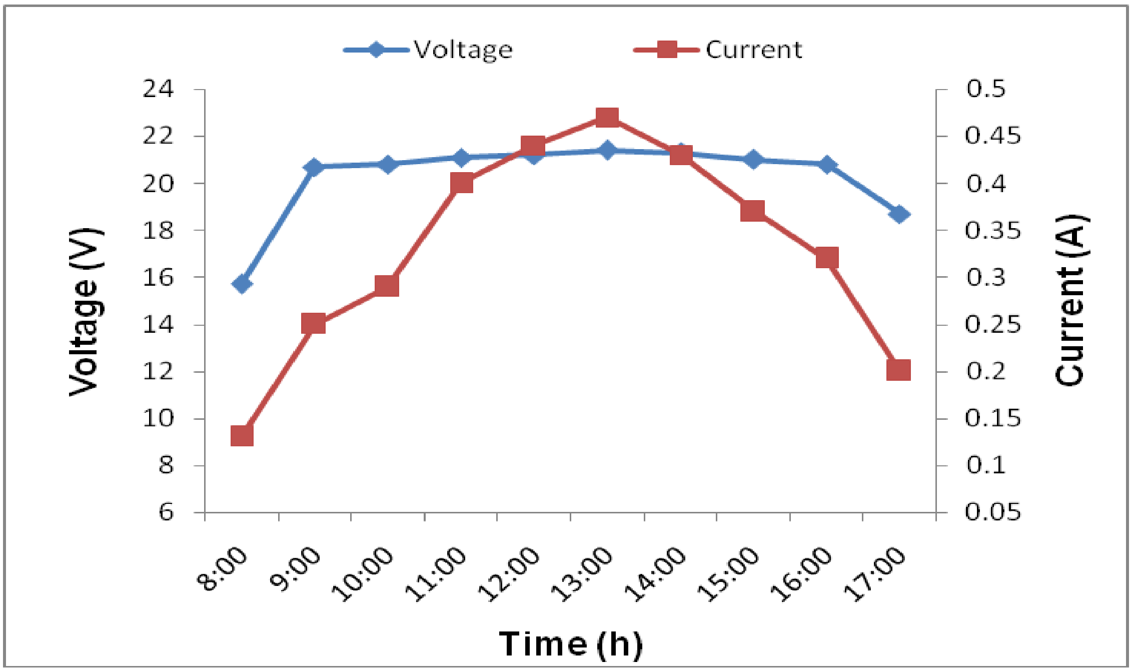


Fig 4.6 Variation in current and voltage of UV light trap solar panel with time

The variation of solar intensity, ambient temperature and panel temperature developed with respect to time in blue, yellow and UV-A blue trap solar panel is shown in Fig.4.7, Fig.4.8 and Fig.4.9, respectively. The average values were reported in Appendix C.

It was observed that, the solar intensity was varied in blue, yellow and UV-A blue trap panel from 154.6 W/m^2 to 811.3 W/m^2, 154.5 W/m^2 to 805.5 W/m^2 and 157.6 W/m^2 to 806.3 W/m^2, respectively. The peak value of solar intensity was achieved at 13:00 h (811.3 W/m^2, 805.5 W/m^2 and 806.3 W/m^2, respectively).

The ambient temperature developed by selected 10 Watt solar panel varie from 29.9℃ to 32.5℃, 29.1℃ to 32.6℃ and 29.8℃ to 32.4℃, respectively.

Also the panel temperature of selected 10 Watt solar panel of blue, yellow and UV-A blue light trap varies from 32.1℃ to 47.1℃, 32.0℃ to 47.4℃ and 32.2℃ to 47.5℃, respectively.

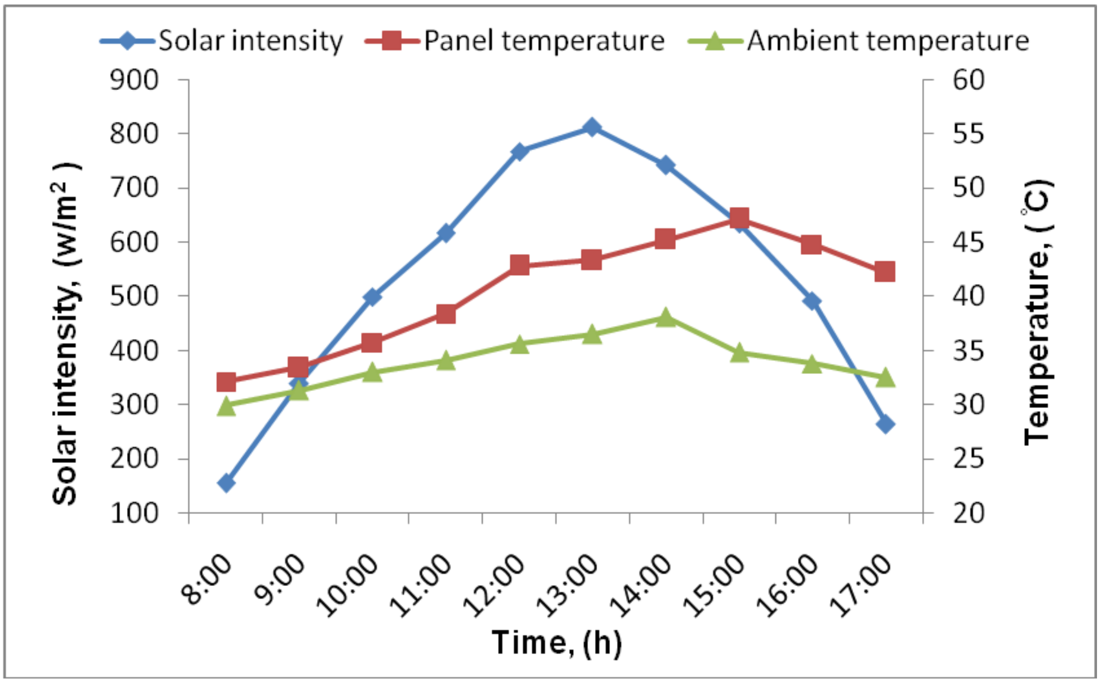


Fig.4.7 Variation in ambient temperature, panel temperature and solar intensity with time of blue light trap

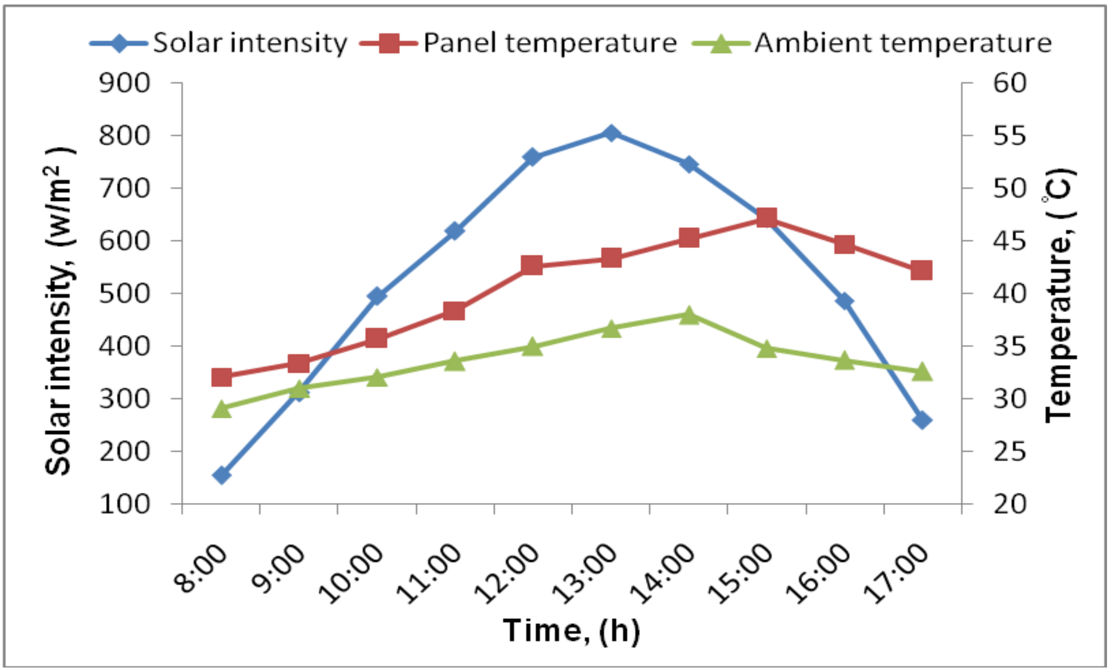


Fig.4.8 Variation in ambient temperature, panel temperature and solar intensity with time of yellow light trap

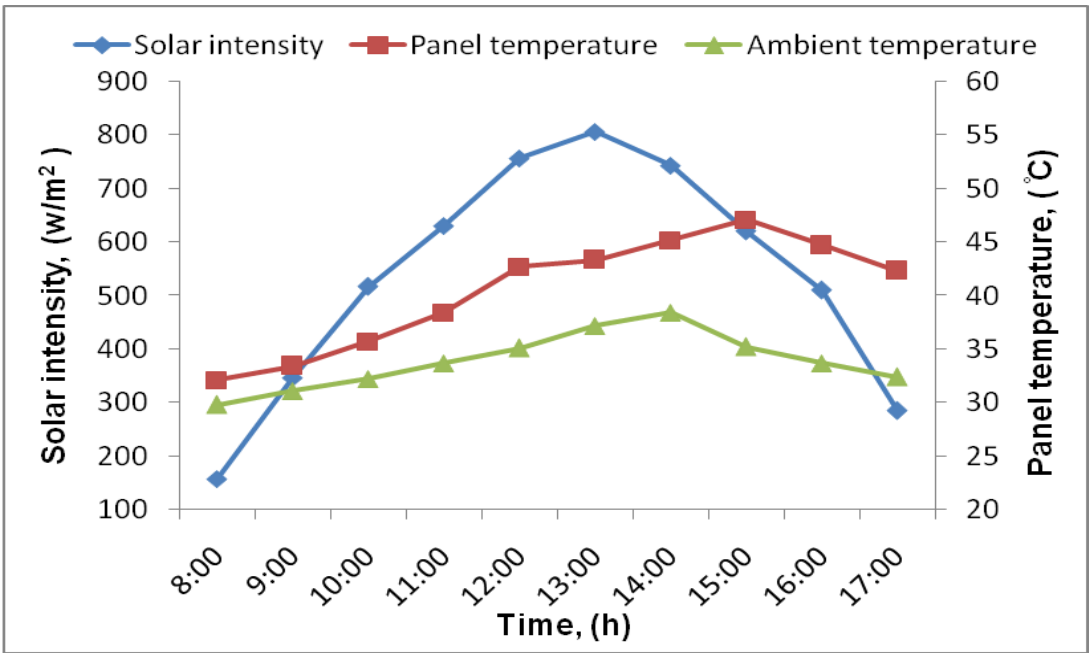


Fig.4.9 Variation in ambient temperature, panel temperature and solar intensity with time of UV light trap

The variation of solar intensity, panel efficiency and exergy efficiency of panel developed with respect to time in blue, yellow and UV-A trap solar panel is shown in Fig.4.10, Fig.4.11 and Fig.4.12, respectively. The average values were reported in Appendix C.

It was observed that, the solar intensity was varied in blue, yellow and UV-A blue light trap panel from 154.6 W/m^2 to 811.3 W/m^2, 154.5 W/m^2 to 805.5 W/m^2 and 157.6 W/m^2 to 806.3 W/m^2, respectively. The peak value of solar intensity was achieved at 13:00 h (811.3 W/m^2, 805.5 W/m^2 and 806.3 W/m^2, respectively).

The panel efficiency of selected 10 Watt solar panel of blue, yellow and UV-A blue light trap varies from 10.04 % to 12.53 %, 10.45 % to 14.25 % and 10.05 % to 12.02 %, respectively. The peak value of panel efficiency was achieved at 9.00 h (12.53 %, 14.25 % and 12.02 %, respectively).

The exergy efficiency of selected 10 W solar panel of blue, yellow and UV-A blue light trap varies from 9.81 % to 12.70 %, 8.65 % to 14.42 5 and 8.46 % to 13.19 %, respectively. The peak value of exergy efficiency of panel was achieved at 9.00 h (12.70 %, 14.42 % and 13.19 %, respectively). Similar result was found by Kalbande and Deshmukh, 2015.

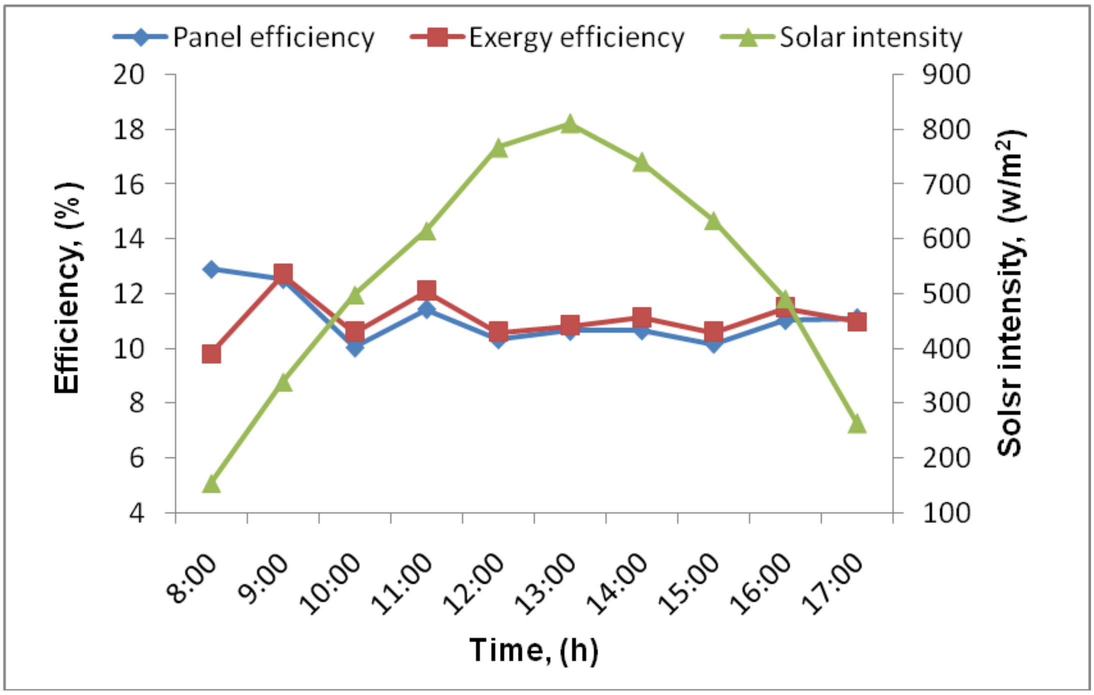


Fig.4.10 Variation in panel efficiency, exergy efficiency and solar intensity with time of blue light trap

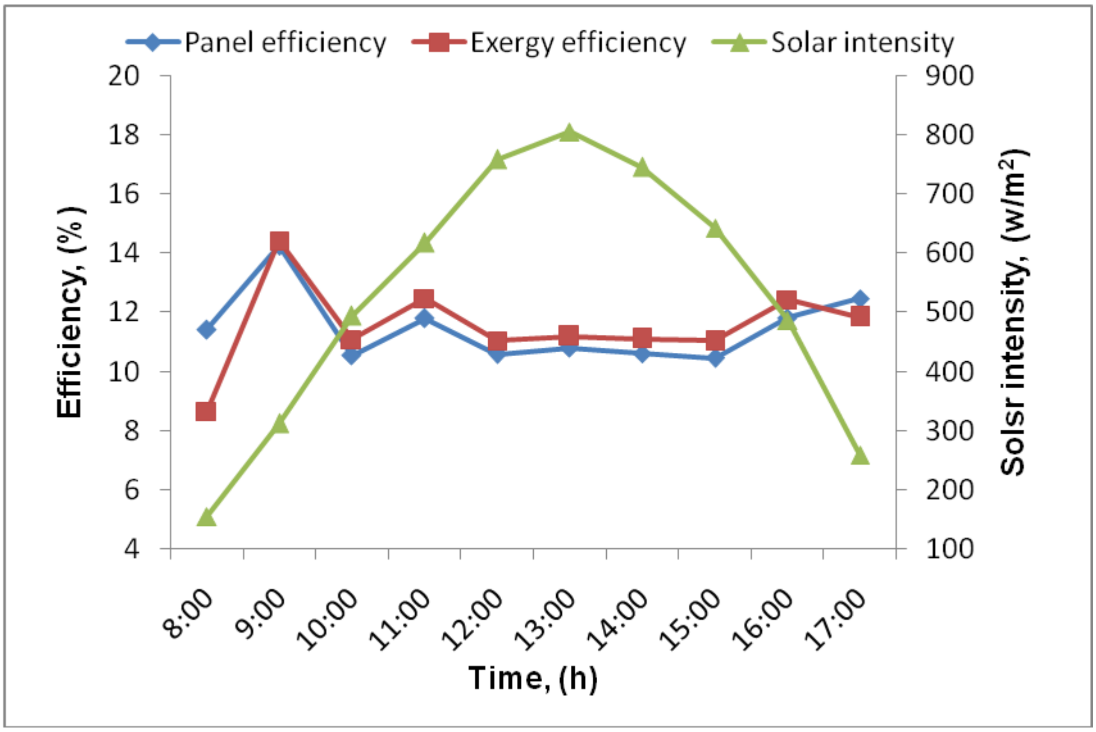


Fig.4.11 Variation in panel efficiency, exergy efficiency and solar intensity with time of yellow light trap

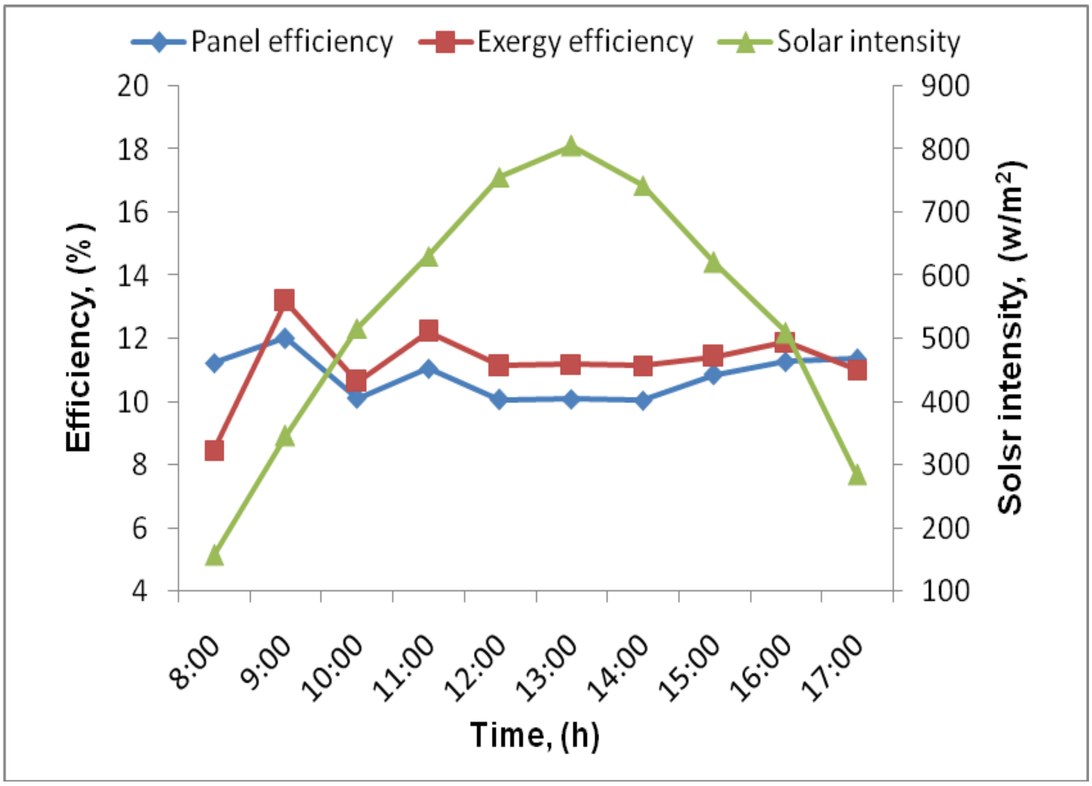


Fig.4.12 Variation in panel efficiency, exergy efficiency and solar intensity with time of UV light trap

4.2 Battery charging and discharging behavior using solar photovoltaic panel.

4.2.1 Battery discharging behavior using solar photovoltaic panel.

The battery discharging characteristics of solar insect light trap was studied to determine the discharge time of battery. The various parameter recorded during the testing are summarized in Appendix C. The variation of battery voltage and current with respect to time and corresponding power of solar insect light trap is shown in Table 4.1 and Fig 4.13

Table: 4.1 Average battery discharging behavior using solar photovoltaic panel

Sr. No.	Time (h)	Voltage (V)	Current (A)	Power (W)
1.	07:00	13.9	0.57	7.9
2.	08:00	13.29	0.57	7.5
3.	09:00	12.90	0.57	7.3
4.	10:00	12.77	0.56	7.1
5.	11:00	12.67	0.56	7.0
6.	12:00	12.61	0.56	7.06
7.	13:00	12.49	0.55	6.8
8.	14:00	12.37	0.54	6.6
9.	15:00	12.29	0.52	6.3
10.	16:00	12.24	0.48	5.8
11.	17:00	12.16	0.47	5.7
12.	18:00	12.11	0.47	5.6
13.	19:00	10.30	0.21	2.1
14.	20.00	9.90	0.12	1.1
15	21.00	9.90	0.12	1.1

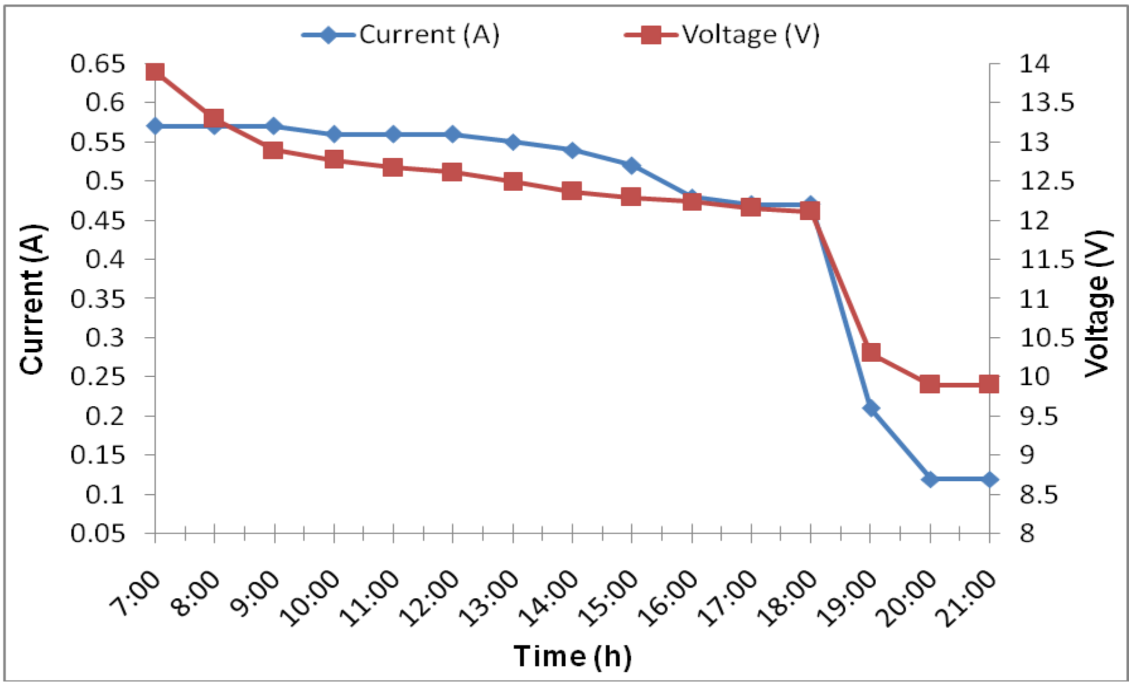


Fig.4.13 Battery discharging characteristics of solar insect light trap

It was observed that the charged battery (13.9 V) of solar photovoltaic insect light trap, the battery voltage reduces gradually up to 9.9 V. The average operating time of solar photovoltaic insect light trap was found to be 12 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.

4.2.2 Battery charging behavior using solar photovoltaic panel

The battery charging characteristics of solar photovoltaic insect light trap was studied to determine the charging time and battery voltage. The SPV panel was fully exposed to sunlight for battery charging. The various parameters like panel voltage, panel current, battery voltage, solar intensity and ambient temperature were measured (Appendix-C).

The variation of battery voltage, panel voltage corresponding solar intensity with time is shown in Table 4.2 and Fig. 4.14.

Table: 4.2 Average battery charging behavior using solar photovoltaic panel

S. N.	Time (h)	Amb Temp, (^{0}C)	Wind speed, (m/s)	Solar intensity, (W/m^2)	Solar panel		Battery voltage, (V)
					Voltage (V)	Current (A)	
1.	08:00	29.8	1.66	155.6	17.6	0.19	9.9
2.	09:00	31.3	1.70	332.9	20.7	0.25	10.6
3.	10:00	32.6	1.86	503.2	20.7	0.29	11.2
4.	11:00	34.0	2.28	621.7	21.0	0.40	11.9
5.	12:00	35.4	2.20	760.7	21.1	0.44	12.7
6.	13:00	36.9	2.01	807.7	21.3	0.47	13.1
7.	14:00	38.3	1.95	743.7	21.3	0.43	13.9
8.	15:00	34.9	1.83	632.5	21.1	0.37	13.9
9.	16:00	33.8	1.90	496.4	20.8	0.31	13.9
10.	17:00	32.4	1.84	269.0	18.0	0.22	13.9

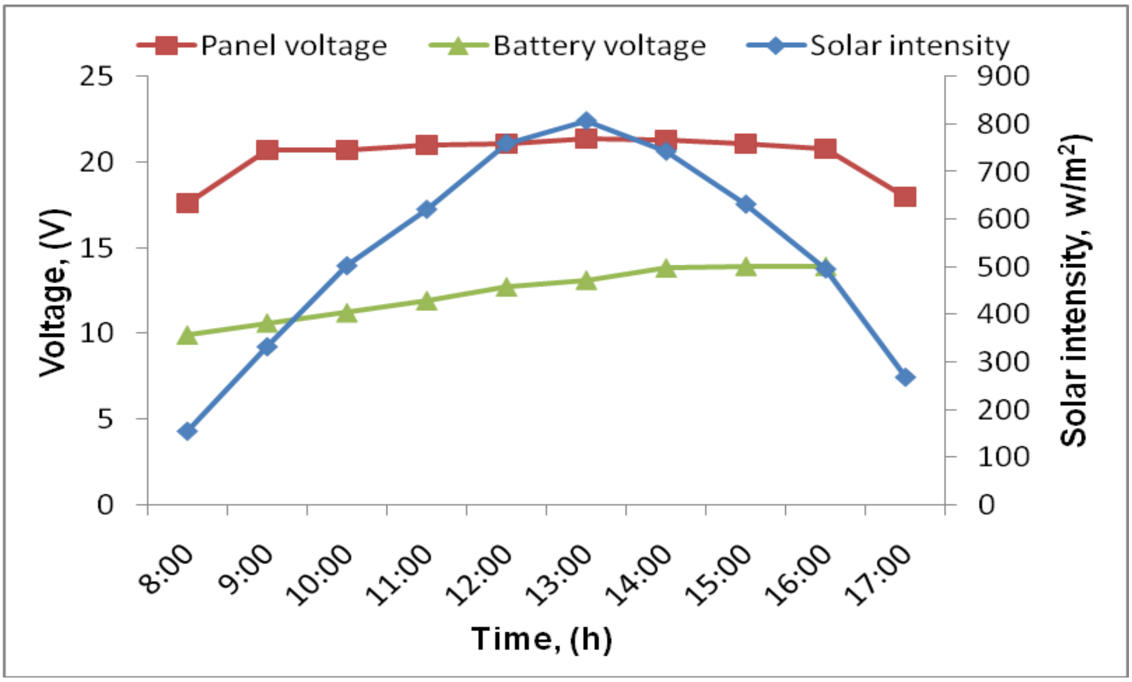


Fig.4.14 Battery charging characteristics of solar insect light trap

It was observed that, the time required for charging of battery starting at 8.00 a.m. (9.9 V) was found to be 6 hours to achieve full voltage of 13.9 V. The solar isolation was ranges from 155.6 W/m^2 to 807.7 W/m^2 during the test. The panel output voltages were varied from 17.6 V to 21.3 V during the test.

4.3 Evaluations of light trap using different colour LED light for trapping phototrophic insects

Table 4.3 represents the percentage of the total number of insects caught in various coloured light traps. According to the percentage of insects collected, the lowest number of insects were attracted towards blue colour light i.e. 19.54%. This finding is in accordance with Ashfaq *et al.,* 2005 and Pate and Curtis (2011) who also found that the lowest numbers of insects were trapped in blue colored light among the various coloured lights tested. Ultra violet light attracted the highest number of 56.95% insects. Yellow light was rated second in attracting the insects (23.49%).

Percentage of insects attracted towards different coloured light was computed separately and tabulated in Table 4.4, 4.5 and 4.6. Blue colour light attracted maximum of Hemiptera (50.52%) followed by Lepidoptera (44.36%), Diptera (4.85%) and Coleoptera (0.24%) insects (Table 4.4).

Yellow colour light also trapped maximum percent of Hemiptera (50.28%) followed by Lepidoptera (44.77%), Diptera (4.72%) and Coleoptera (0.21%) insecets (Table 4.5). The same trend was observed in ultra violet light which also attracted maximum Hemiptera (51.92%) followed by Lepidoptera (41.00%), Diptera (6.96%) and Coleoptera (0.10%) insects (Table 4.6).

These findings are partially not in agreement with the findings of Sharma *et al.,* (2013) and Dadmal and Khaddekar, (2014), who mentioned that Lepidoptera and Coleoptera were the dominant orders respectively in the light trap catches; however hemiptera was the second largest order in findings of both the authors.

4.4 Order wise distribution of insects attracted towards different colour

The total number of insects caught in blue, yellow and ultra-violet-A blue colour light was 6820, 8199 and 19872 respectively during the period of study.

Table 4.7 shows the order wise and daily distribution of insects in blue colour light. The highest population of Lepidopteran insects was observed in 6^{th}, 11^{th} and 12^{th} day, for Hemipteran insects it was in the 9^{th}, 10^{th} and 11^{th} day and for Dipteran it was during 9^{th}, 10^{th} and 11^{th} day respectively. Table 4.8 represents order wise and daily distribution of insects in yellow light. Highest population of Lepidopteran insects was caught in the 11^{th}, 12^{th} and 13^{th} day, for Hemipteran insects it was in the 10^{th}, 11^{th} and 12^{th} day and for Diptera it was during 11^{th}, 12^{th} and 13^{th} day. Table 4.9 further shows order wise and daily distribution of insects in ultra-violet light where highest population of Lepidopteran insects were caught during 11^{th}, 12^{th}, 13^{th} and 14^{th} day, while for Hemiptera it was during 10^{th}, 11^{th}, 12^{th} and 13^{th} day and for Dipterans it was in the 11^{th}, 12^{th}, 13^{th} and 14^{th} day. Other order insects i.e. Coleoptera was caught in the ultra-violet-A blue light but their population was very scanty and highest population observed in 8^{th}, 9^{th} and 10^{th} day. The similar evaluation was carried out by Nimal, (2015).

The above discussion concluded that maximum activity of the insects belonging to order Hemiptera, Lepidoptera, Diptera was noticed during the 11th, 12th and 13th day i.e. during the period of 7th march 2018 to 30th March 2018.

Table: 4.3 Percentage of insects attracted in different light trap

S.N.	Colour of light	Insect population percent (%)
1.	Ultra violet	56.95
2.	Yellow	23.49
3.	Blue	19.54

Table: 4.4 Percentage of insects attracted in blue light

S.N.	Order	Insect population percent (%)
1.	Hemiptera	50.52
2.	Lepidoptera	44.36
3.	Diptera	4.85
4.	Coleoptera	0.24

Table: 4.5 Percentage of insects attracted in yellow light

S.N.	Order	Insect population percent (%)
1.	Hemiptera	50.28
2.	Lepidoptera	44.77
3.	Diptera	4.72
4.	Coleoptera	0.21

Table: 4.6 Percentage of insects attracted in ultra violet light

S.N.	Order	Insect population percent (%)
1.	Hemiptera	51.92
2.	Lepidoptera	41.00
3.	Diptera	6.96
4.	Coleoptera	0.10

Table: 4.7 Total numbers of insects representing each order in blue light

Order / Day	Lepidoptera	Hemiptera	Diptera	Coleoptera	Population mean
1st	150	162	16	0	82.00
2nd	156	160	20	0	84.00
3rd	171	164	21	0	89.00
4th	170	170	23	0	92.75
5th	172	178	23	1	95.75
6th	182	181	24	3	97.50
7th	179	169	27	5	95.00
8th	171	187	28	0	96.50
9th	169	191	31	7	99.50
10th	168	192	33	0	98.25
11th	184	195	31	1	101.25
12th	183	191	23	0	96.50
13th	136	187	12	0	83.75
14th	112	171	9	0	73.00
15th	109	156	7	0	68.00
16th	107	142	0	0	62.25
17th	108	131	0	0	59.75
18th	102	112	0	0	53.50
19th	96	101	2	0	49.75
20th	73	96	0	0	42.25
21st	54	74	0	0	32.00
22nd	37	56	0	0	23.25
23rd	24	42	0	0	16.50
24th	13	38	1	0	13.00
Total	3026	3446	331	17	

Table: 4.8 Total number of insects representing each order in yellow light

Order / Date	Lepidoptera	Hemiptera	Diptera	Coleoptera	Population mean
1st	172	181	17	0	92.50
2nd	169	178	21	0	92.00
3rd	178	180	18	0	94.00
4th	174	179	23	0	94.00
5th	179	183	21	1	95.75
6th	181	191	20	2	98.75
7th	184	196	24	2	101.50
8th	191	201	27	0	104.75
9th	195	213	35	3	111.50
10th	201	241	38	4	121.00
11th	221	244	42	5	128.00
12th	212	238	39	0	122.25
13th	203	210	40	0	113.25
14th	189	196	12	0	99.25
15th	173	184	3	1	90.25
16th	154	174	0	0	82.00
17th	144	167	0	0	77.75
18th	132	148	6	0	71.50
19th	112	139	1	0	63.00
20th	97	122	0	0	54.75
21st	84	109	0	0	48.25
22nd	56	91	0	0	36.75
23rd	41	87	0	0	32.00
24th	29	71	0	0	25.00
Total	3671	4123	387	18	

Table: 4.9 Total number of insects representing each order in ultra violet light

Order / Date	Lepidoptera	Hemiptera	Diptera	Coleoptera	Population mean
1st	370	421	41	0	208.00
2nd	375	420	40	0	208.75
3rd	378	424	39	0	210.25
4th	382	431	42	0	213.75
5th	397	442	46	0	221.25
6th	386	448	48	2	221.00
7th	387	451	52	0	222.50
8th	371	459	59	3	223.00
9th	389	461	67	4	230.25
10th	395	486	72	7	240.00
11th	402	510	92	0	251.00
12th	412	503	91	1	251.75
13th	403	496	87	2	247.00
14th	397	472	89	1	239.75
15th	381	451	82	0	228.50
16th	373	423	81	1	219.50
17th	323	410	79	0	203.00
18th	284	402	72	0	189.50
19th	270	396	63	0	182.25
20th	254	384	57	0	173.75
21st	239	372	39	0	162.50
22nd	218	361	23	0	150.50
23rd	191	354	14	0	139.75
24th	172	341	09	0	130.50
Total	8149	10318	1384	21	

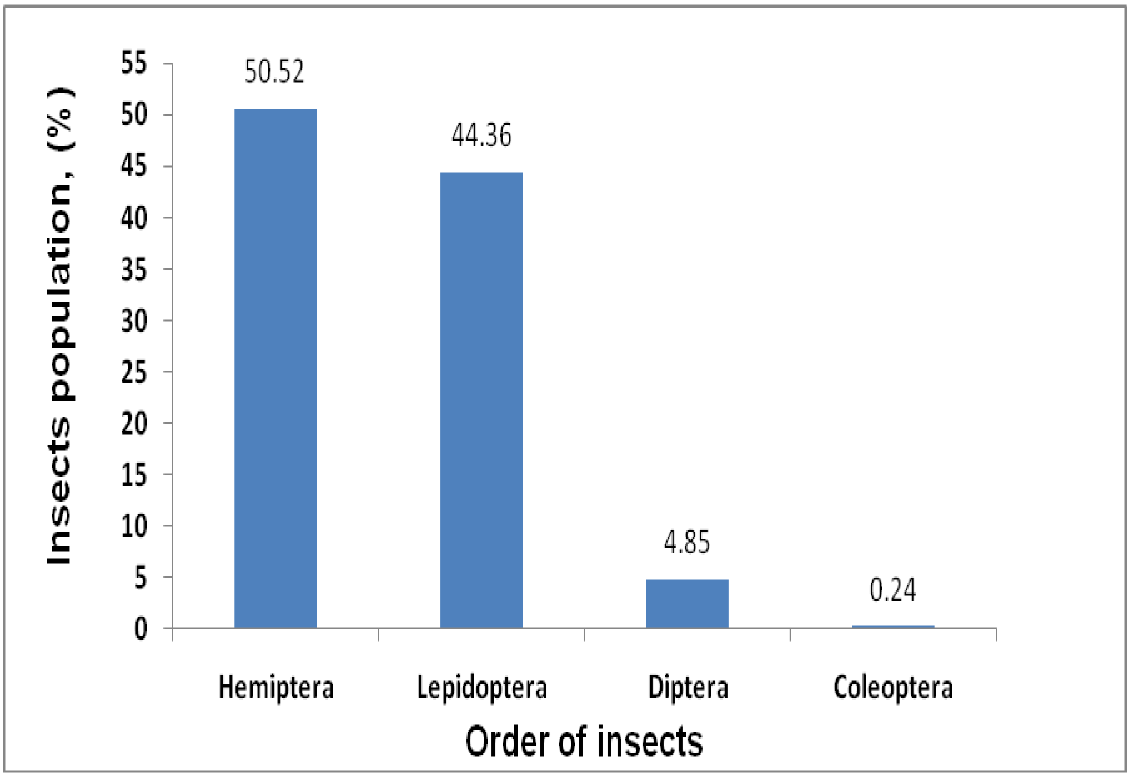


Fig.15 Insects attracted in blue coloured light trap

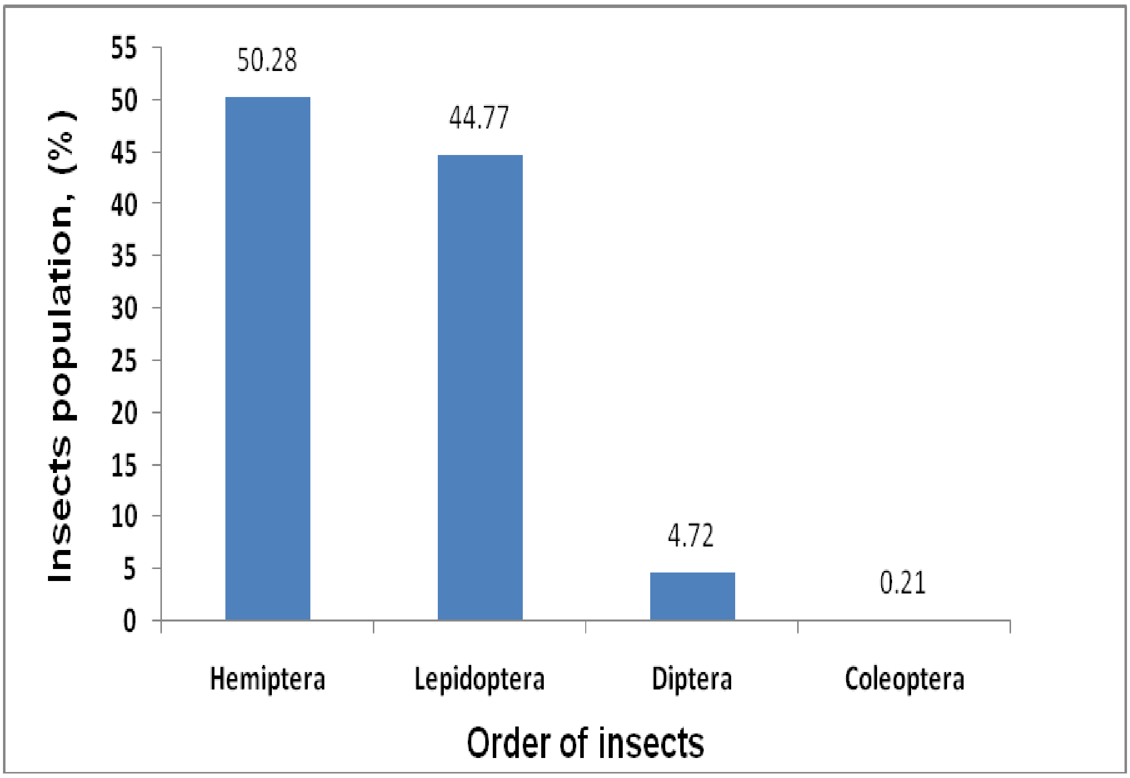


Fig.16 Insects attracted in yellow coloured light trap

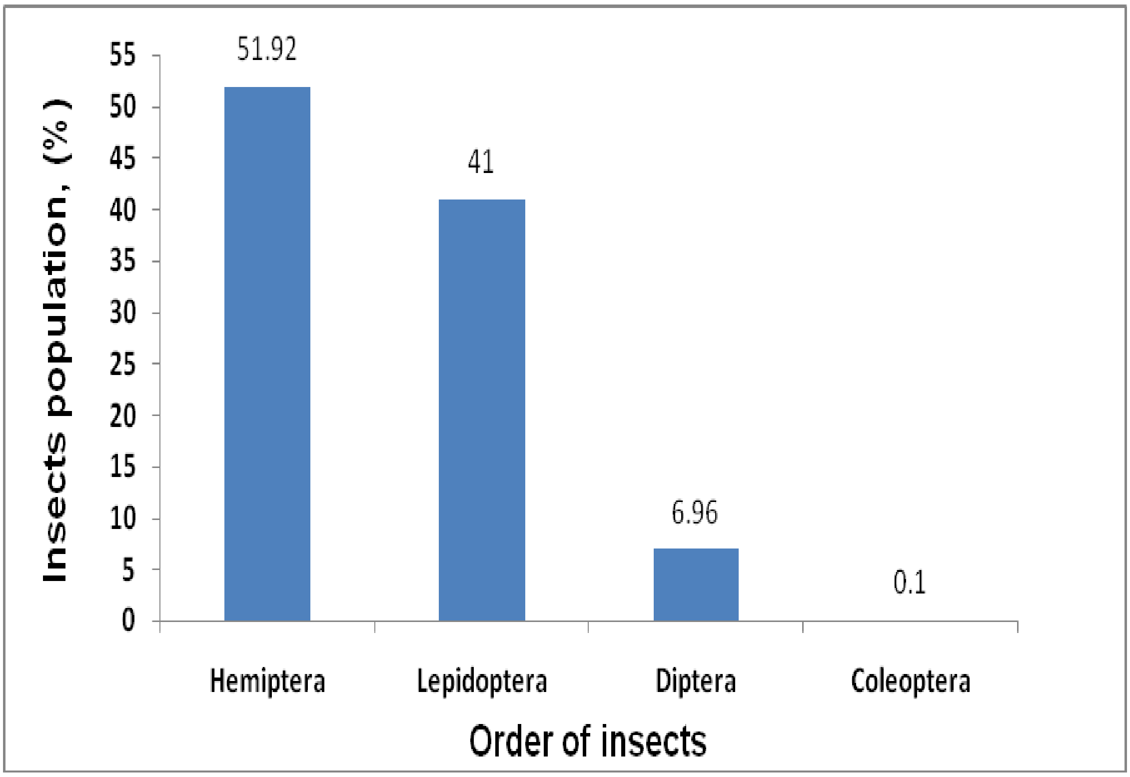


Fig.17 Insects attracted in ultra violet coloured light trap

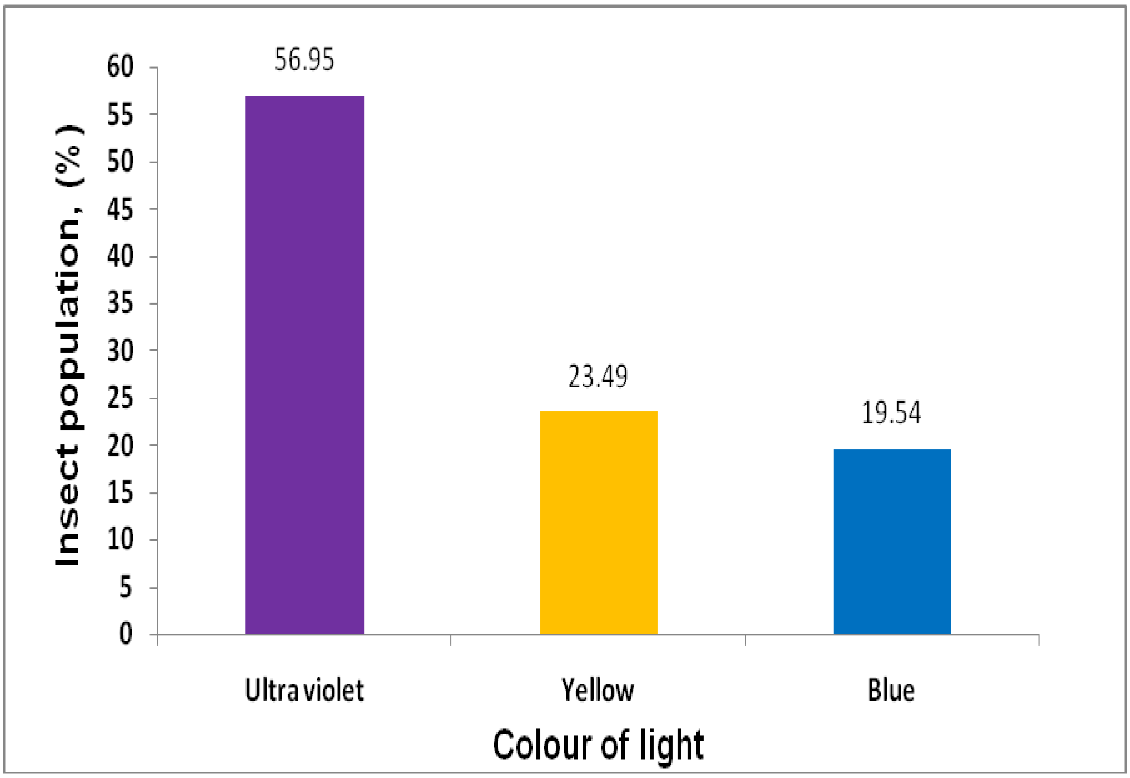


Fig.18 Insects attracted in different coloured light trap

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

4.4 Economic feasibility of Solar Photovoltaic insect light trap

The economic feasibility of the solar photovoltaic insect light 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 was determined.

Table 4.10 Parameters used to analyses the economic feasibility of solar photovoltaic insect light trap

Sr.No	Costs	SPV trap	Electrical trap
1.	Capital cost	6000	3800
2.	Maintainance Cost	600	600
3.	Electricity charge	Nil	2856

Table 4.10 shows the information used to analyze the economic feasibility of the solar photovoltaic insect light trap. The net saving in cost per annum was worked out and found to be Rs.2856. (Appendix-E). The cost of the solar photovoltaic insect light trap was found to be Rs.6000. The annual operation cost was determined and found to be Rs.600.

4.7.1 Discount cash flow method

The economic performance has been worked out by considering the cost and benefit. Table 4.11 showed the discount cash flow analysis over the period. The present worth cost after the 12 year was found to be Rs.10088.22 The present worth of benefit after 12 year was worked out to be Rs.19459.90. The net present value of the project is positive and hence the developed solar water pump has offered the financial benefits to the end user. The net present value for the 12 year of cash flow analysis was found to be Rs.9371.69. 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 phovoltaic insect light trap was observed to be 1.93 as depicted in table 4.11. (Appendix E).

Table 4.11 Cash flow for solar photovoltaic insect light trap.

Year	Cash Outflow	PW cash Outflow	Cash Inflow	PW of Cash Inflow	NPV
1	2	3	4	5	6
0	6000	6000.00	0	0	-6000.00
1	600	545.45	2856	2596.36	2050.91
2	600	495.87	2856	2360.33	1864.46
3	600	450.79	2856	2145.76	1694.97
4	600	409.81	2856	1950.69	1540.88
5	600	372.55	2856	1773.35	1400.80
6	600	338.68	2856	1612.14	1273.45
7	600	307.89	2856	1465.58	1157.68
8	600	279.90	2856	1332.35	1052.44
9	600	254.46	2856	1211.22	956.76
10	600	231.33	2856	1101.11	869.79
11	600	210.30	2856	1001.01	790.71
12	600	191.18	2856	910.01	718.83
Total		**10088.22**		**19459.90**	**9371.69**

Table 4.12 Payback Periods for solar photovoltaic insect light trap

Year	PW of Total cash outflow in 12 years Rs,	Cash Inflow	Present Worth of Cash Inflow	Cumulative Cash Inflow
0	6000	-	-	-
1	600	2856	2596.36	2050.91
2	600	2856	2360.33	1864.46
3	600	2856	2145.76	1694.97
4	600	2856	1950.69	1540.88
5	600	2856	1773.35	1400.80
6	600	2856	1612.14	1273.45
7	600	2856	1465.58	1157.68
8	600	2856	1332.35	1052.44
9	600	2856	1211.22	956.76
10	600	2856	1101.11	869.79
11	600	2856	1001.01	790.71
12	600	2856	910.01	718.83
			NPW	**9371.69**
			BC Ratio	**1.93**

Payback Period =2 Yr. 1 month.

The payback period of the investment involved has been workout. The total cost of solar photovoltaic insect light trap was Rs.6000. (Table 4.12 and APPENDIX E). The payback period of the investment was found 2 years and 1 month. Similar evaluation was carried out by Narale *et al.,* (2014) and Roy *et.al,* (2015).

CHAPTER V

SUMMARY AND CONCLUSIONS

The study on "Development and evaluation of solar photovoltaic insect light trap" was undertaken to harness the solar energy to operate insect light trap particularly for reducing and controlling the insect population in the cotton fields. The solar photovoltaic insect light trap was evaluated during March 2018 in the field of Vazegaon Village in Akola District.

A Solar insect light trap was developed on the basis of agronomical parameters, functional requirement, physical and economic considerations of operators. Agronomical requirement included the type of crop, variety and height of crop. Functional requirement included types of panels, capacity of the battery, types of the bulb and its power consumption. Physical and economical consideration taken into account as the simplicity of development, durability, low cost, use of the locally available material. The traditional source of electric power is not available adequately to the farmer's fields to operate light trap. Keeping these points in view, the present investigation was carried out under the following objectives:

1. To develop solar photovoltaic insect light trap.
2. To evaluate the comparative performance of solar photovoltaic-based insect light traps using blue, yellow and UV-A blue light.
3. To study economics of solar photovoltaic insect light trap.

The average values of ambient temperature, wind velocity, panel temperature, solar intensity, panel output, panel efficiency, panel voltage, panel current and battery voltage in different colour light trap viz., blue, yellow and ultra-violet were recorded. During the month maximum panel temperature of blue light trap, yellow light trap and ultra violet light trap were 47.1, 47.4 and 47.5 °C respectively was observed during 11.00 to 17.00 h of the day and solar intensity corresponding to this panels temperature were observed in the range 154.6 W/m^2 to 811.3 W/m^2, 154.5 W/m^2 to 805.5 W/m^2 and 157.6 W/m^2 to 806.3 W/m^2 during 11.00 to 17.00

h of the day. The ambient temperature range of 29.9℃ to 32.5℃, 29.1℃ to 32.6℃ and 29.8℃ to 32.4℃ during system working whereas the array output 2.0 W to 9.9 W, 2.04 W to 9.9 W and 2.04 W to 10.05 W was found during 11.00 to 15.00 h. of the day, respectively.

The panel efficiency of blue, yellow and UV light trap varie from 10.04 % to 12.53 %, 10.45 % to 14.25 % and 10.05 % to 12.02 %, respectively and it was found that panel efficiency of system increased during 11.00 to 14.00 h.

The total number of insects caught in blue, yellow and ultra-violet colour light was 6820, 8199 and 19872, respectively during the experimentation.

The order wise and daily distribution of insects in blue colour light, the highest population of Lepidopteran insects was observed in 6th, 11th and 12th day, for Hemipteran insects it was on the 9th, 10th and 11th day and for Dipteran during 9th, 10th and 11th day.

In yellow light, highest population of Lepidopteran insects was caught in the 11th, 12th and 13th day, for Hemipteran insects it was in the 10th, 11th and 12th day and for Diptera it was during 11th, 12th and 13th day.

In ultra-violet light where highest population of Lepidopteran insects were caught during 11th, 12th, 13th and 14th day, while for Hemiptera it was during 10th, 11th, 12th and 13th day and for Dipterans it was on the 11th, 12th, 13th and 14th day.

The order wise comparison of the insects caught in the ultra violet light trap, blue light trap and yellow light trap, the ultra violet light trap was more efficient than the blue light trap and yellow light trap. Hence, use of ultra violet light trap could be promoted for trapping harmful insects.

The estimated cost of the system was Rs, 3000 /- with 12 year payback period 2 years 1 month, and benefit cost ratio was found as 1.93. It could be inferred that the solar insect light trap was technically as well as economically feasible.

Based on the results obtained during the experimental following conclusion could be drawn:

1) The maximum efficiency of 10 W solar panel was found to be 14.25 %.
2) The maximum working hours of SPV light trap was 10-13 hours.
3) The battery was full charged in 6 hour with the help of SPV panel.
4) The more insects were attracted by ultra violet coloured light trap rather than blue and yellow colored light trap.
5) The area of coverage of UV-A blue light trap was found 2.5 acre per two traps.
6) The solar insect light trap was found more effective for the control of different insect pests of all crops without any use of chemical pesticides in the agricultural fields in near future.
7) Net present worth and benefit cost ratio was found to be Rs. 9371.69 and 1.93, respectively. Thus, it is concluded that investment is justified and suitable to use in the area where electricity is not available.
8) Payback period of the system was 2 year 1 month.
9) The economic analysis suggested that the solar photovoltaic insect light trap was economically viable and could be used for controlling the insect and pest population in IPM technique.

CHAPTER VI

BIBLIOGRAPHY

Ashfaq, M., Khan, Rashid A., Khan, M. A., Rasheed, F. and Hafeez, S. 2005. Insect orientation to various colour light in the Agricultural biomass of Faisalabad. Pak. Entomol. 27(1): 49-52.

Bera P.K. 2015. Development of a New Solar Light Trap Model and It's Utilization as IPM Tool in Agriculture. Journal of Emerging Technologies and Innovative Research. 2(3): 549-554.

Bhamre, V., Sarkate, M.B., Wadnerkar, D.W. and Ramtake, R.T. 2005. A solar light Trap for monitoring and controlling of insect pests of cotton, *In*: National Conference on Applied Entomology, Udaipur, September 26-28, 2005. pp 20-21.

Bhubaneswari P., Iniyanb S. and Ranko G. 2011. A review of solar photovoltaic technologies. Renewable and Sustainable Energy Reviews 15: 1625–1636.

Bombale V.T., Magar A.P., Abuj M.D., Popale P.G. and P.R. Bhandari. 2010. In. J. of Agricultural Engineering. 3(1): 55-58.

Brimapureeswaran R., Nivas G., Meenatchi R., Sujeetha Alice R.P., Loganathan M. 2016. Development of a New Solar Light cum Glue Trap Model and its Utilization in Agriculture. In. J. of Emerging Technology and Innovative Engineering. 2(3): 37-41.

Dadmal, S.M. and Khadakkar, S. 2014. Insect found diversity collected through light Trap at akola vicinity of Maharashtra with reference to Scarabaeidae of Coleoptera. Journal of entomology and zoology. 2(3): 44-48.

Fayle, T. M., Sharp, E. R. and Majerus, M. E. N. 2007. The effects of moth trap type on catch size and composition in Britishian Lepidoptera. BR. J. ENT. NAT. HIST. 20(2): 221-232.

Hogsette, J.A. 2008. Ultra violet light traps: Design affects attraction and capture. Proceeding of the sixth International conference on urban pests. 193-196.

Johansen N.S., Vanninen I., Pinto D.M., Nissinen A.I. and Shipp L. 2011. In the light of new greenhouse technologies: direct effects of artificial lighting on arthropods and integrated pest management in greenhouse crops. Annals of Applied Biology. 127: 1-27.

Kalbande S. R. and Deshmukh S.D. (2014). Photovoltaic Based Vapour Compression Refrigeration System for Vaccine Preservation. Universal Journal of Engineering Science 3(2): 17-23.

Kame Khouzam and RonelleTibaldi. 1997. Economic Evaluation of Domestic Grid-Connected Photovoltaic Systems. Proceedings of Solar ’97 - Australian and New Zealand Solar Energy Society Paper 132.

Muhammad S. (2017). Biological Parameters of Pink Bollworm pectinophora gossypiella (Saunders) (Lepidoptera:Gelechiidae): A looming Threat for Cotton and its Eradication Opportunity. International Journal of Research in Agriculture and Forestry. Vol. 4(7): 25-36.

Narale PD, Rathore NS and LAD MM (2014). Techno economic assessment of solar photovoltaic water pumping system. International Journal of Agricultural Engineering. Vol. (7): 1-6.

Nirmal A. (2015). Evaluation of light traps using different coloured lamps for trapping insects in agro-forestry ecosystem. M.sc. Thesis. (Published). IGKV. Raipur.

Odeh I. Yohanis Y.G. Norton B. (2005). Economic viability of photovoltaic water pumping system. Solar Energy. 80. 850-860.

Pandey A. K., Tyagi V. V. and Tyagi S. K. 2013. ‘Exergetic analysis and parametric study of multi-crystalline solar photovoltaic system at a typical climatic zone’. Clean Technologies and Environmental Policy. 15(2) : 333-343.

Pate, J. and Curtis, A. 2001. Insects response to different wavelengths of light in New River state Park, Ash County, North Carolina. Field Biology and Ecology. 12(2): 4-8.

Qoaider L and Steinbrecht D (2016). Photovoltaic system: A cost competitive option to supply energy to off-grid agriculture communities in arid regions. Faculty for Mechanical and marine Engineering, University of Rostock Albert-Einstein-Str.2, 18059 Rostock, Germany Applied Energy. Vol. (87): 427-435.

Rachit S. and Vinod K.G. 2016. Solar power – Current Status, Challenges and Pollicies in India. ISSN. 5(2): 18-22.

Ramamurthy, V.V., Akhtar, M., Patankar, N.V., Menon, P., Kumar, R., Singh, S.K. Ayri, S., Parveen, S. and Mittal, V. 2010. Efficiency of different light Sources in light traps in monitoring insect diversity. Munis entomology and zoology. 5(1):109-114

Reddy H.L., Reddy A.V., Hemanth S. and Durga Prasad P.J. 2015. Modelling and Optimization of Solar Light Trap For “Reducing and Controlling” The Pest Population. In. J. of Engineering Technology, Management and Applied Sciences. 3(4): 224-234

Roy A, Wahedul I, Hassan SM and Najmul Hoque SM (2015). Prospect of solar pumping in the northern area of Bangladesh. Department of Mechanical Engineering Rajshahi University of Engineering and

Technology,Rajshahi, American Journal of Renewable and Sustainable Energy. Vol. (1): 172-179.

Sermsri and Torasa. 2015. Solar Energy-Based Insect Pests Trap. 7th World Conference on Educational Sciences. 197: 2548-2553.

Sharma, A. K. and Bisen, U. K. 2013. Taxonomic documentation of insect pests fauna of vegetable ecosystem collected in light trap. In. J. of Environmental Science: Development and Monitoring. 4(3): 4-11.

Srinivas M., S. Jayaraj. 2013. Energy and exergy analysis of a two pass photovoltaic – thermal (PV/T) air heater. International Journal of Energy and Environment. Volume 4, Issue 3, pp. 467-480.

Stampolidis Vassilis L., Yiannis A. Katsigiannis, Pavlos S. Georgilakis 2006. A methodology for the economic evaluation of photovoltaic systems. Operational Research. An International Journal. 6(1): 37-54.

Steffen Robert E., Sung Joon Suk, Yong Han Ahn and George Ford. 2013. Modeling energy generation by grid connected photovoltaic systems in the united states. Journal of Building Construction and Planning Research, 1, 39-44.

Steiner, A. and Hauser, C.L. 2009. Chapte-16, Recording insects by light trap. Berlin. 401-406.

Sudhakar K. and Tulika Srivastava. 2013. Energy and exergy analysis of 36 W solar photovoltaic module. International journal of ambient energy.

Thangalakshmi S. and RamanujanR. 2015. Electronic Trapping and Monitoring of Insect Pests troubling Agricultural Fields. In. J. of Emerging Engineering Research and Technology. 3(8): 206-213.

Truxa, C. and Fiedler, K. 2012. Attraction of light from how to for do moths (Lepidoptera) return to weak artificial sources of light. Eur. J. Entomology. 109: 77-84.

Watson, R. N. 1979. Use of modified light trap to improve catches of black beetle Heteronychusarator (Coleoptera: Scarabaedae) and black field cricket Teleogrylluscommodus (Orthoptera: Gryllidae). New Zealand Entomologist. 7 (1):92-97.

APPENDIX A

Sizing of photovoltaic system for solar insect light trap

a) Load estimation

Total wattage, $P_{ratedtotal} = q \times P_{rated}$
$= 1 \times 5$
$= 5$ W

Energy demand, $E_{d(Wh)} = P_{ratedtotal} \times H$
$= 5 \times 12$
$= 60$ W

Load demand, $E_{d(Ah)} = \frac{E_{d(wh)}}{V_{nsv}}$

$= \frac{60}{12}$
$= 5\ A$

Corrected load, $E_{c(Ah)} = \frac{E_{d(Ah)}}{n_b}$

$= \frac{5}{0.85}$

$= 5.88\ Ah$

b) Battery sizing

Battery capacity, $B_{rc} = \frac{E_{c(Ah)} \times D_s}{DOD_{max} \times n_T}$
$= \frac{5.88 \times 0.5}{0.80 \times 0.8}$
$= 4.6\ Ah$

No. of battery in parallel, $B_p = \frac{B_{rc}}{B_{sc}}$
$= \frac{4.6}{7}$
$= 0.66$

No. of battery in series, $B_s = \frac{V_{nsv}}{V_{nbv}}$
$= \frac{12}{12}$
$= 1$

Total battery, $B_t = B_p \times B_s$
$= 0.66 \times 1$
$= 0.66 \sim 1$

c) PV panel sizing

Corrected current load, $I_D = \frac{E_{c(Ah)}}{G}$

$$= \frac{5.88}{8}$$

$$= 0.73\ A$$

Rated design current, $I_{DE} = \frac{I_D}{n_m}$

$$= \frac{0.73}{0.9}$$

$$= 0.81\ A$$

No. of solar panel in parallel, $N_p = \frac{I_{DE}}{I_p}$

$$= \frac{0.81}{0.588}$$

$$= 1.37$$

No. of solar panel in series, $N_s = \frac{V_{nbv} \times B_s \times 1.2}{V_p}$

$$= \frac{12 \times 1 \times 1.2}{17}$$

$$= 0.84$$

Total solar panel, $N_T = N_p \times N_s$

$$= 1.37 \times 0.84$$

$$= 1.1 \sim 1$$

d) Charge controller sizing

Maximum current, $I_T = N_p \times I_p$

$$= 1.37 \times 0.588$$

$$= 0.80\ A$$

Thus, a charge controller with current > I_T and system voltage of V_{nsv} is chosen.

APPENDIX (B)

Efficiency of the PV system

$$(\eta_{pc}) = \frac{I_{sc}\ X\ V_{oc}}{S_c\ X\ A} \text{ x } 100$$

Where,

A = Surface area of the PV (m^2).

I_{sc} = Short circuit current value (A).

S_t = Total solar radiation (w/m^2).

V_{oc} = Short –circuit voltage value (V).

η_{pc} = The efficiency of the PV system.

Thus,

The result obtained from efficiency of the solar photovoltaic insect light trap

$$\eta_{pc} = \frac{0.25 \times 20.6}{312.5 \times 0.1156}$$

$$(\eta_{pc}) = 14.25\ \%.$$

APPENDIX (C)

Table C1: System performance with respect to climatic parameter for SPV blue light trap (07th March 2018)

S. N.	Time, h	Ambient temp, (^OC)	Solar Intensity, I (W/m^2)	Wind Speed, m/sec	SPV panel						Battery Voltage, (V)
					Voltage, (V)	Current, (A)	Temp (^OC)	Power, (W)	Effi, (%)	Exergy effi, (%)	
1	8:00	28.5	150.8	1.7	17.0	0.14	32.2	2.38	13.11	10.72	9.97
2	9:00	29.2	304.2	1.8	20.4	0.23	33.4	4.69	13.34	13.36	10.34
3	10:00	30.9	520.2	2.1	20.6	0.27	35.8	8.34	9.24	9.77	11.15
4	11:00	32.8	653.7	1.9	20.8	0.38	38.4	7.90	10.45	11.04	11.80
5	12:00	34.2	809.3	1.3	21.0	0.43	42.8	9.03	9.65	9.98	12.46
6	13:00	35.9	840.5	1.7	21.3	0.46	43.3	9.79	10.08	10.40	12.92
7	14:00	36.1	807.5	1.5	21.2	0.43	45.2	9.11	9.76	10.12	13.81
8	15:00	34.6	653.7	2.1	21.0	0.32	47.1	6.72	8.89	9.40	13.9
9	16:00	33.8	437.6	2.3	20.7	0.28	44.8	5.79	11.45	11.91	13.9
10	17:00	32.1	249.2	2.2	19.5	0.20	42.1	3.90	13.07	12.52	13.9

Table C2: System performance with respect to climatic parameter for SPV blue light trap (10th March 2018)

S. N.	Time, h	Ambient temp, (^OC)	Solar Intensity, I (W/m^2)	Wind Speed, m/sec	SPV panel						Battery Voltage, (V)
					Voltage, (V)	Current, (A)	Temp (^OC)	Power, (W)	Effi, (%)	Exergy effi, (%)	
1	8:00	28.7	152.5	2.3	17.2	0.14	31.8	2.408	13.47	9.33	09.95
2	9:00	30	360.5	1.9	20.5	0.23	33.6	4.715	11.31	11.52	10.52
3	10:00	31.2	518.6	1.5	20.7	0.27	35.7	5.589	9.30	9.84	11.23
4	11:00	33.2	667.8	1.8	20.9	0.38	38.4	7.942	10.87	10.82	11.92
5	12:00	35.6	779.8	2.6	21.1	0.43	42.8	9.073	10.06	10.49	12.70
6	13:00	36.1	812.4	2.3	21.4	0.47	43.3	10.05	10.70	11.11	12.98
7	14:00	36.7	658.7	1.6	21.3	0.43	45.7	9.159	12.02	12.67	13.72
8	15:00	34.3	587.9	2.9	21.0	0.36	47.4	7.56	11.12	11.74	13.9
9	16:00	33.2	445.6	1.7	20.7	0.29	44.8	6.003	11.65	12.21	13.9
10	17:00	31.2	223.4	1.2	19.6	0.19	42.3	3.724	14.73	14.01	13.9

Table C3: System performance with respect to climatic parameter for SPV blue light trap (13th March 2018)

S. N.	Time, h	Ambient temp, (℃)	Solar Intensity, I (W/m²)	Wind Speed, m/sec	SPV panel						Battery Voltage, (V)
					Voltage, (V)	Current, (A)	Temp (℃)	Power, (W)	Effi, (%)	Exergy effi, (%)	
1	8:00	28.9	159.7	2.1	17.1	0.13	32.1	2.223	12.12	8.48	9.97
2	9:00	30.1	342.5	1.7	20.4	0.23	33.4	4.692	11.85	12.06	10.34
3	10:00	31.6	568.2	1.9	20.6	0.27	35.8	5.562	8.46	8.94	11.15
4	11:00	32.8	614.5	2.2	20.8	0.38	38.4	7.904	11.11	11.75	11.80
5	12:00	34.6	735.6	2	21.0	0.43	42.8	9.03	10.61	11.10	12.46
6	13:00	35.2	812.5	1.8	21.3	0.46	43.3	9.798	10.43	10.79	12.92
7	14:00	36.1	725.6	1.2	21.2	0.43	45.2	9.116	10.86	11.36	13.81
8	15:00	34.4	568.7	2.4	21.0	0.32	47.1	6.72	10.22	10.79	13.9
9	16:00	33.1	472.4	2.5	20.7	0.28	44.8	5.796	10.61	11.05	13.9
10	17:00	32.5	302.4	1.8	20.5	0.24	42.5	4.92	14.07	14.06	13.9

Table C4: System performance with respect to climatic parameter for SPV blue light trap (16th March 2018)

S. N.	Time, h	Ambient temp, (°C)	Solar Intensity, I (W/m²)	Wind Speed, m/sec	SPV panel						Battery Voltage, (V)
					Voltage, (V)	Current, (A)	Temp (°C)	Power, (W)	Effi, (%)	Exergy effi, (%)	
1	8:00	29.2	159.8	1.9	17.2	0.13	32.2	2.23	12.04	8.99	9.95
2	9:00	30	345.7	1.8	20.5	0.23	33.4	4.71	11.79	11.98	10.52
3	10:00	31.5	507.2	2.1	20.7	0.27	35.8	5.58	9.85	10.02	11.23
4	11:00	32.9	602.4	1.8	20.9	0.38	38.4	7.94	11.40	12.04	11.92
5	12:00	34.3	785.5	1.6	21.1	0.43	42.8	9.07	9.93	10.35	12.70
6	13:00	35.1	807.5	2.2	21.4	0.47	43.3	10.05	10.77	11.17	12.98
7	14:00	39.4	734.3	1.8	21.3	0.43	45.2	9.15	10.78	11.30	13.72
8	15:00	34.5	667.5	1.4	21.0	0.36	47.1	7.56	9.774	10.29	13.9
9	16:00	33.2	494.8	2	20.7	0.29	44.8	6.00	10.49	11.03	13.9
10	17:00	32.3	321.2	2.1	20.6	0.26	42.1	5.35	14.42	14.42	13.9

Table C5: System performance with respect to climatic parameter for SPV blue light trap (19th March 2018)

S. N.	Time, h	Ambient temp (°C)	Solar Intensity I (W/m²)	Wind Speed m/sec	SPV panel Voltage, (V)	Current, (A)	Temp (°C)	Power, (W)	Effi, (%)	Exergy effi, (%)	Battery Voltage, (V)
1	8:00	30.2	153.6	1.3	17.6	0.12	32.2	2.112	11.83	9.71	9.90
2	9:00	32.6	336.5	1.7	20.6	0.25	33.4	5.15	13.23	13.48	10.72
3	10:00	34.6	450.4	1.8	20.8	0.29	35.8	6.032	11.58	12.13	11.24
4	11:00	33.6	562.1	1.5	21.1	0.40	38.4	8.44	12.98	13.72	11.93
5	12:00	35.7	708.6	1.4	21.1	0.44	42.8	9.284	11.33	11.87	12.77
6	13:00	36.5	824.1	1.3	21.4	0.47	43.3	10.058	10.55	10.90	13.15
7	14:00	38.7	758.1	1.8	21.3	0.43	45.2	9.159	10.45	10.91	13.72
8	15:00	35.1	629.9	2.1	21.0	0.37	47.1	7.77	10.67	11.26	13.9
9	16:00	34.4	474.2	2.3	20.8	0.32	44.8	6.656	12.14	12.70	13.9
10	17:00	33.2	235.6	1.8	19.7	0.20	42.1	3.94	14.28	13.64	13.9

Table C6: System performance with respect to climatic parameter for SPV blue light trap (22nd March 2018)

S. N.	Time, h	Ambient temp, (°C)	Solar Intensity, I (W/m²)	Wind Speed, m/sec	SPV panel Voltage, (V)	Current, (A)	Temp (°C)	Power, (W)	Effi, (%)	Exergy effi, (%)	Battery Voltage, (V)
1	8:00	31.1	151.3	2.1	17.7	0.13	32.3	2.30	13.15	9.18	9.95
2	9:00	32.6	345.6	2.4	20.6	0.25	33.4	5.15	12.89	12.85	10.71
3	10:00	35.4	452.3	2.6	20.8	0.29	35.8	6.03	11.53	11.94	11.24
4	11:00	36.5	564.1	1.3	21.1	0.40	38.7	8.44	12.94	13.68	11.93
5	12:00	36.8	753.4	1.7	21.1	0.44	42.9	9.28	10.65	11.12	12.77
6	13:00	37.5	789.2	1.8	21.4	0.47	43.3	10.00	11.02	11.47	13.22
7	14:00	39.4	736.8	1.3	21.3	0.43	45.2	9.15	10.75	11.24	13.82
8	15:00	35.1	642.7	2.1	21.0	0.37	47.1	7.77	10.45	11.03	13.9
9	16:00	34.7	543.8	1.6	20.8	0.32	44.8	6.65	10.58	11.18	13.9
10	17:00	33.1	247.2	1.8	20.7	0.28	42.5	3.94	13.28	13.11	13.9

Table C7: System performance with respect to climatic parameter for SPV blue light trap (25th March 2018)

Sr. No	Time, h	Ambient temp (°C)	Solar Intensity I (W/m²)	Wind Speed m/sec	SPV panel Voltage, (V)	Current, (A)	Temp (°C)	Power, (W)	Effi, (%)	Exergy effi, (%)	Battery Voltage, (V)
1	8:00	32.1	150.4	1.7	17.6	0.12	32.2	2.11	12.14	9.00	9.90
2	9:00	33.8	326.8	1.5	20.6	0.25	33.4	5.15	13.63	13.91	10.72
3	10:00	34.6	450.2	1.3	20.8	0.29	35.8	6.03	11.59	12.19	11.24
4	11:00	36.4	562.4	2.1	21.1	0.40	38.4	8.44	12.98	13.71	11.93
5	12:00	37.2	756.4	1.8	21.1	0.44	42.8	9.28	10.61	11.08	12.77
6	13:00	38.6	790.3	1.7	21.4	0.47	43.3	10.05	11.00	11.45	13.15
7	14:00	39.4	732.4	1.6	21.3	0.43	45.2	9.15	10.81	11.33	13.72
8	15:00	35.3	642.7	1.2	21.0	0.37	47.1	7.77	10.45	11.00	13.9
9	16:00	33.5	546.7	1.4	20.8	0.32	44.8	6.65	10.53	11.12	13.9
10	17:00	32.6	251.2	1.7	19.7	0.19	42.1	3.95	13.05	12.31	13.9

Table C8: System performance with respect to climatic parameter for SPV blue light trap (28th March 2018)

S. N.	Time, h	Ambient temp, (°C)	Solar Intensity I (W/m²)	Wind Speed, m/sec	SPV panel Voltage, (V)	Current, (A)	Temp (°C)	Power, (W)	Effi, (%)	Exergy effi, (%)	Battery Voltage, (V)
1	8:00	30.6	152.4	1.4	17.7	0.13	32.2	2.30	13.06	10.70	9.95
2	9:00	32.8	356.7	1.7	20.6	0.25	33.4	5.15	12.48	12.79	10.71
3	10:00	34.6	524.6	1.5	20.8	0.29	35.8	6.03	9.94	10.50	11.24
4	11:00	34.8	702.4	2.1	21.1	0.40	38.4	8.44	10.39	10.91	11.93
5	12:00	36.9	809.3	2.6	21.1	0.44	42.8	9.28	9.93	10.30	12.77
6	13:00	37.5	814.5	2.3	21.4	0.47	43.3	10.05	10.68	11.09	13.22
7	14:00	39.7	778.3	2.1	21.3	0.43	45.2	9.15	10.17	10.61	13.82
8	15:00	35.8	681.2	1.9	21.0	0.37	47.1	7.77	9.86	10.37	13.9
9	16:00	34.7	516.4	1.7	20.8	0.32	44.8	6.65	11.14	11.76	13.9
10	17:00	33.2	282.1	1.6	19.7	0.20	42.1	3.94	12.77	11.88	13.9

Table C9: System performance with respect to climatic parameter for SPV yellow light trap (8th March 2018)

S. N.	Time, h	Ambient temp (°C)	Solar Intensity I (W/m²)	Wind Speed m/sec	SPV panel						Battery Voltage, (V)
					Voltage, (V)	Current, (A)	Temp (°C)	Power, (W)	Effi, (%)	Exergy effi, (%)	
1	8:00	28.5	150.2	1.5	15.7	0.15	32.2	2.35	13.56	10.99	9.95
2	9:00	29.7	325.6	1.9	20.6	0.25	33.4	5.15	13.68	13.80	10.71
3	10:00	30.6	514.7	2.4	20.8	0.29	35.8	6.03	10.13	10.65	11.24
4	11:00	31.9	626.8	2.1	21.1	0.40	38.4	8.44	11.64	12.29	11.93
5	12:00	33.4	802.5	1.9	21.1	0.44	42.8	9.28	10.00	10.35	12.77
6	13:00	35.2	847.5	1.7	21.4	0.47	43.3	10.05	10.26	10.55	13.22
7	14:00	36.4	706.8	1.6	21.3	0.43	45.2	9.15	11.20	11.76	13.82
8	15:00	35.1	629.9	2.2	21.0	0.37	47.1	7.77	10.67	11.27	13.9
9	16:00	33.6	463.3	1.6	20.8	0.32	44.8	6.65	12.42	13.06	13.9
10	17:00	32.3	238.2	2.8	19.7	0.18	42.1	3.54	12.08	10.78	13.9

Table C10: System performance with respect to climatic parameter for SPV yellow light trap (11th March 2018)

S. N.	Time, h	Ambient temp, (°C)	Solar Intensity, I (W/m²)	Wind Speed, m/sec	SPV panel						Battery Voltage, (V)
					Voltage, (V)	Current, (A)	Temp (°C)	Power, (W)	Effi, (%)	Exergy effi, (%)	
1	8:00	28.9	152.5	1.3	15.7	0.15	31.8	2.35	13.35	11.24	9.95
2	9:00	29.9	358.9	1.7	20.6	0.25	33.6	5.15	12.41	12.74	10.71
3	10:00	30.2	520.6	2.1	20.8	0.29	35.7	6.03	10.02	10.56	11.24
4	11:00	31.6	678.5	2.6	21.1	0.40	38.4	8.44	10.76	11.33	11.93
5	12:00	33.5	778.4	2.2	21.1	0.44	42.8	9.28	10.31	10.73	12.77
6	13:00	35.2	801.4	2.1	21.4	0.47	43.3	10.05	10.85	11.27	13.22
7	14:00	36.1	658.7	2.6	21.3	0.43	45.7	9.15	12.02	12.70	13.82
8	15:00	34.3	586.4	2.3	21.0	0.37	47.4	7.77	11.46	12.11	13.9
9	16:00	33.1	452.4	2.7	20.8	0.32	44.8	6.65	12.72	13.18	13.9
10	17:00	32.1	225.6	2.1	19.7	0.18	42.3	3.54	12.22	12.20	13.9

Table C11: System performance with respect to climatic parameter for SPV yellow light trap (14th March 2018)

S. N.	Time, h	Ambient temp, (°C)	Solar Intensity, I (W/m²)	Wind Speed, m/sec	SPV panel						Battery Voltage, (V)
					Voltage, (V)	Current, (A)	Temp (°C)	Power, (W)	Effi, (%)	Exergy effi, (%)	
1	8:00	26.8	150.6	1.8	15.7	0.13	32.1	2.04	11.96	8.46	9.95
2	9:00	29.9	214.5	1.8	16.6	0.15	33.4	2.49	10.08	13.84	10.71
3	10:00	30.2	352.4	2.1	20.8	0.29	35.8	6.03	14.80	15.08	11.24
4	11:00	32	560.8	2.3	21.1	0.40	38.4	8.44	13.01	13.74	11.93
5	12:00	34.2	617.8	2.2	21.1	0.44	42.8	9.28	12.99	13.73	12.77
6	13:00	35.7	735.6	1.7	21.4	0.47	43.3	10.05	11.82	12.37	13.22
7	14:00	36.3	812.4	1.6	21.3	0.43	45.2	9.159	9.75	10.07	13.82
8	15:00	34.1	712.5	2.3	21.0	0.37	47.1	7.77	9.43	9.89	13.9
9	16:00	33.4	474.5	1.9	20.8	0.32	44.8	6.656	12.13	12.74	13.9
10	17:00	32.2	245.6	1.7	19.7	0.18	42.5	3.546	12.48	11.82	13.9

Table C12: System performance with respect to climatic parameter for SPV yellow light trap (17th March 2018)

S. N.	Time, h	Ambient temp, (°C)	Solar Intensity, I (W/m²)	Wind Speed, m/sec	SPV panel						Battery Voltage, (V)
					Voltage, (V)	Current, (A)	Temp (°C)	Power, (W)	Effii, (%)	Exergy effi, (%)	
1	8:00	28.6	152.3	2.3	15.7	0.16	32.2	2.51	14.90	9.96	9.95
2	9:00	29.8	322.3	1.8	20.6	0.25	33.5	5.15	13.82	13.97	10.71
3	10:00	30.7	578.6	1.6	20.8	0.29	35.7	6.03	9.018	9.52	11.24
4	11:00	31.8	688.7	2.4	21.1	0.40	38.4	8.44	10.60	11.15	11.93
5	12:00	33.6	807.4	1.7	21.1	0.44	42.6	9.28	9.946	10.27	12.77
6	13:00	35.4	882.4	1.6	21.4	0.47	43.5	10.05	9.860	10.06	13.22
7	14:00	37.6	780.4	2.3	21.3	0.43	45.2	9.15	10.15	10.58	13.82
8	15:00	34.5	673.8	2.1	21.0	0.37	47.1	7.77	9.975	10.50	13.9
9	16:00	33.9	489.8	2	20.8	0.32	44.7	6.65	11.75	12.36	13.9
10	17:00	32.3	289.8	1.8	18.7	0.24	42.1	4.48	13.30	13.23	13.9

Table C13: System performance with respect to climatic parameter for SPV yellow light trap (20th March 2018)

S. N.	Time, h	Ambient temp (ºC)	Solar Intensity I (W/m²)	Wind Speed m/sec	SPV panel						Battery Voltage, (V)
					Voltage, (V)	Current, (A)	Temp (ºC)	Power, (W)	Effi, (%)	Exergy effi, (%)	
1	8:00	30.2	150.2	1.5	15.8	0.14	32.3	2.21	12.02	10.09	9.97
2	9:00	32.5	346.8	1.7	20.6	0.25	33.5	5.15	12.84	13.12	10.71
3	10:00	33.6	475.6	2.1	20.8	0.29	35.7	6.03	10.97	11.49	11.24
4	11:00	35.4	624.4	2.6	21.1	0.40	38.4	8.44	11.69	12.35	11.93
5	12:00	35.9	763.5	1.6	21.1	0.44	42.6	9.28	10.51	10.95	12.77
6	13:00	36.5	800.2	1.5	21.4	0.47	43.3	10.05	10.87	11.27	13.22
7	14:00	38.9	781.6	1.9	21.3	0.43	45.2	9.15	10.13	10.55	13.82
8	15:00	35.1	640.9	2.1	21.0	0.37	47.1	7.77	10.48	11.06	13.9
9	16:00	33.6	481.6	2.3	20.8	0.32	44.7	6.65	11.95	12.52	13.9
10	17:00	32.7	254.5	1.5	19.7	0.20	42.0	3.94	13.70	13.05	13.9

Table C14: System performance with respect to climatic parameter for SPV yellow light trap (23rd March 2018)

S. N.	Time, h	Ambient temp, (ºC)	Solar Intensity, I (W/m²)	Wind Speed, m/sec	SPV panel						Battery Voltage, (V)
					Voltage, (V)	Current, (A)	Temp, (ºC)	Power, (W)	Effi, (%)	Exergy effi, (%)	
1	8:00	30.2	151.3	1.4	15.7	0.13	32.2	2.04	11.69	9.20	9.95
2	9:00	32.5	327.8	1.2	20.6	0.25	33.5	5.15	13.59	13.98	10.71
3	10:00	34.6	477.9	1.7	20.8	0.29	35.7	6.03	10.91	11.48	11.24
4	11:00	35.1	560.4	2.1	21.1	0.40	38.4	8.44	13.02	13.76	11.93
5	12:00	35.6	778.4	1.8	21.1	0.44	42.6	9.28	10.31	10.72	12.77
6	13:00	37.6	761.4	1.9	21.4	0.47	43.5	10.05	11.42	11.94	13.22
7	14:00	39.2	741.6	2.3	21.3	0.43	45.2	9.15	10.68	11.20	13.82
8	15:00	34.6	628.1	1.4	21.0	0.37	47.1	7.77	10.70	11.28	13.9
9	16:00	33.5	468.8	1.8	20.8	0.32	44.7	6.65	12.28	12.90	13.9
10	17:00	32.6	283.8	1.5	19.7	0.20	42.1	3.94	12.66	11.89	13.9

Table C15: System performance with respect to climatic parameter for SPV yellow light trap (26th March 2018)

S. N.	Time, h	Ambient temp, (ºC)	Solar Intensity, I (W/m^2)	Wind Speed, m/sec	SPV panel						Battery Voltage, (V)
					Voltage, (V)	Current, (A)	Temp, (ºC)	Power, (W)	Effi, (%)	Exergy effi, (%)	
1	8:00	30.1	153.6	1.5	17.7	0.13	32.3	2.30	12.83	10.45	9.95
2	9:00	31.9	347.8	1.7	20.6	0.25	33.5	5.15	12.80	13.09	10.71
3	10:00	32.6	455.6	1.9	20.8	0.29	35.7	6.03	11.45	11.99	11.24
4	11:00	34.5	568.3	2.1	21.1	0.40	38.4	8.44	12.84	13.57	11.93
5	12:00	36.3	755.8	2.4	21.1	0.44	42.6	9.28	10.62	11.11	12.77
6	13:00	38.7	790.2	1.7	21.4	0.47	43.3	10.05	11.01	11.45	13.22
7	14:00	39.7	745.3	1.9	21.3	0.43	45.2	9.15	10.63	11.13	13.82
8	15:00	35.2	645.8	2.3	21.0	0.37	47.1	7.77	10.40	10.98	13.9
9	16:00	33.7	546.4	1.5	20.8	0.32	44.7	6.65	10.53	11.13	13.9
10	17:00	33.2	248.6	1.6	18.7	0.20	42.0	3.74	13.16	12.49	13.9

Table C16: System performance with respect to climatic parameter for SPV yellow light trap (29th March 2018)

S. N.	Time, h	Ambient temp, (ºC)	Solar Intensity, I (W/m^2)	Wind Speed, m/sec	SPV panel						Battery Voltage, (V)
					Voltage, (V)	Current, (A)	Temp, (ºC)	Power, (W)	Effi, (%)	Exergy effi, (%)	
1	8:00	30.1	155.6	1.7	15.7	0.14	32.2	3.36	12.90	9.34	9.95
2	9:00	32.5	356.7	1.4	20.6	0.25	33.5	5.15	12.48	12.89	10.71
3	10:00	34.6	582.3	1.9	20.8	0.29	35.7	6.03	8.961	9.47	11.24
4	11:00	36.7	637.8	2.3	21.1	0.40	38.4	8.44	11.44	12.09	11.93
5	12:00	37.8	767.2	2.7	21.1	0.44	42.6	9.28	10.46	10.96	12.77
6	13:00	39.6	825.6	3.1	21.4	0.47	43.5	10.05	10.53	10.98	13.22
7	14:00	40.1	743.4	2.5	21.3	0.43	45.2	9.15	10.65	11.19	13.82
8	15:00	35.7	624.4	1.7	21.0	0.37	47.1	7.77	10.76	11.36	13.9
9	16:00	34.8	520.1	1.6	20.8	0.32	44.7	6.65	11.07	11.69	13.9
10	17:00	33.6	287.5	2.1	18.7	0.20	42.1	3.74	11.43	10.72	13.9

Table C17: System performance with respect to climatic parameter for SPV UV-A blue light trap (9th March 2018)

S. N.	Time, h	Ambient temp, (°C)	Solar Intensity, I (W/m²)	Wind Speed, m/sec	SPV panel						Battery Voltage, (V)
					Voltage, (V)	Current, (A)	Temp, (°C)	Power, (W)	Effi, (%)	Exergy effi, (%)	
1	8:00	28.6	152.5	1.7	15.8	0.14	32.2	2.63	12.10	9.59	9.92
2	9:00	29.2	356.4	2.1	20.8	0.25	33.4	5.20	12.62	12.80	10.72
3	10:00	30.6	516.7	2.2	20.9	0.29	35.8	6.06	10.14	10.68	11.24
4	11:00	32.4	703.1	1.9	21.2	0.40	38.4	8.48	10.43	10.93	11.93
5	12:00	34.2	813.1	2.4	21.3	0.44	42.8	9.37	9.970	10.32	12.77
6	13:00	35.6	802.4	1.7	21.4	0.47	43.3	10.05	10.84	11.24	13.22
7	14:00	36.1	763.8	2.3	21.3	0.43	45.2	9.15	10.37	10.83	13.82
8	15:00	34.7	655.5	1.9	21.1	0.37	47.1	7.80	10.30	10.85	13.9
9	16:00	33.3	509.1	2.6	20.8	0.32	44.8	6.65	11.30	11.86	13.9
10	17:00	32.5	223.4	2.1	17.7	0.21	42.1	3.71	14.44	12.98	13.9

Table C18: System performance with respect to climatic parameter for SPV UV-A blue light trap (12th March 2018)

S. N.	Time, h	Ambient temp, (°C)	Solar Intensity, I (W/m²)	Wind Speed, m/sec	SPV panel						Battery Voltage, (V)
					Voltage, (V)	Current, (A)	Temp, (°C)	Power, (W)	Effi, (%)	Exergy effi, (%)	
1	8:00	28.7	152.5	1.4	15.7	0.13	31.8	2.04	11.23	9.18	9.95
2	9:00	29.2	340.6	1.8	20.6	0.25	33.6	5.15	13.07	13.31	10.71
3	10:00	30	567.5	1.9	20.8	0.29	35.7	6.03	9.194	9.71	11.24
4	11:00	31.6	615.8	2.1	21.1	0.40	38.4	8.44	11.85	12.51	11.93
5	12:00	33.2	729.6	2.4	21.1	0.44	42.8	9.28	11.00	11.54	12.77
6	13:00	34.6	810.5	2.6	21.4	0.47	43.3	10.05	10.73	11.15	13.22
7	14:00	35.1	732.7	1.9	21.3	0.43	45.7	9.15	10.81	11.31	13.82
8	15:00	34.2	543.8	1.3	21.0	0.37	47.4	7.77	12.36	13.06	13.9
9	16:00	33.5	467.8	1.7	20.8	0.32	44.8	6.65	12.30	12.94	13.9
10	17:00	32.2	298.6	2.2	18.7	0.21	42.3	3.92	11.79	10.92	13.9

Table C19: System performance with respect to climatic parameter for SPV UV-A blue light trap (15th March 2018)

S. N.	Time, h	Ambient temp, (°C)	Solar Intensity, I (W/m²)	Wind Speed, m/sec	SPV panel						Battery Voltage, (V)
					Voltage, (V)	Current, (A)	Temp, (°C)	Power, (W)	Effi, (%)	Exergy effi, (%)	
1	8:00	28.6	151.5	1.9	15.8	0.14	32.1	2.21	12.86	9.19	9.92
2	9:00	29.8	345.6	1.7	20.8	0.25	33.4	5.2	13.01	13.31	10.72
3	10:00	30.2	565.8	2.1	20.9	0.29	35.8	6.06	9.266	9.78	11.24
4	11:00	31.9	613.4	2.6	21.2	0.40	38.4	8.48	11.95	12.63	11.93
5	12:00	33.4	732.4	2.2	21.3	0.44	42.8	9.37	11.06	11.59	12.77
6	13:00	35.7	814.8	1.6	21.4	0.47	43.3	10.05	10.67	11.04	13.22
7	14:00	37.8	736.1	1.8	21.3	0.43	45.2	9.15	10.76	11.26	13.82
8	15:00	33.5	589.9	2.1	21.1	0.37	47.1	7.80	11.44	12.09	13.9
9	16:00	32.4	474.2	1.9	20.8	0.32	44.8	6.65	12.14	12.75	13.9
10	17:00	31.9	316.8	2.3	18.7	0.25	42.5	5.79	12.82	12.51	13.9

Table C20: System performance with respect to climatic parameter for SPV UV-A blue light trap (18th March 2018)

S. N.	Time, h	Ambient temp, (°C)	Solar Intensity, I (W/m²)	Wind Speed, m/sec	SPV panel						Battery Voltage, (V)
					Voltage, (V)	Current, (A)	Temp, (°C)	Power, (W)	Effi, (%)	Exergy effi, (%)	
1	8:00	28.7	152.3	1.9	15.7	0.13	32.1	2.04	13.31	8.13	9.95
2	9:00	29.9	336.5	1.7	20.6	0.25	33.4	5.15	13.23	13.49	10.71
3	10:00	30.2	536.5	2.1	20.8	0.29	35.8	6.03	9.725	10.25	11.24
4	11:00	31.9	681.2	1.8	21.1	0.40	38.4	8.44	10.71	11.25	11.93
5	12:00	33.6	783.7	1.9	21.1	0.44	42.8	9.28	10.24	10.63	12.77
6	13:00	36.6	805.7	2.2	21.4	0.47	43.3	10.05	10.79	11.21	13.22
7	14:00	39.5	736.1	2.1	21.3	0.43	45.2	9.15	10.76	11.29	13.82
8	15:00	34.9	624.4	1.7	21.0	0.37	47.1	7.77	10.76	11.35	13.9
9	16:00	33.3	439.5	1.9	20.8	0.32	44.8	6.65	13.10	13.69	13.9
10	17:00	32.5	216.1	2.1	18.7	0.18	42.5	3.36	13.20	11.84	13.9

Table C21: System performance with respect to climatic parameter for SPV UV-A blue light trap (21st March 2018)

S. N.	Time, h	Ambient temp, (°C)	Solar Intensity, I (W/m²)	Wind Speed, m/sec	SPV panel						Battery Voltage, (V)
					Voltage, (V)	Current, (A)	Temp, (°C)	Power, (W)	Effi, (%)	Exergy effi, (%)	
1	8:00	30.1	154.5	1.3	15.9	0.13	32.1	2.06	11.57	9.40	9.94
2	9:00	32.6	345.7	1.6	20.8	0.25	33.4	5.20	13.01	13.33	10.72
3	10:00	34.7	468.9	1.8	20.9	0.29	35.8	6.06	11.18	11.74	11.24
4	11:00	35.4	585.9	2.2	21.2	0.40	38.4	8.48	12.52	13.23	11.93
5	12:00	36.4	732.4	2.6	21.3	0.44	42.8	9.37	11.06	11.62	12.77
6	13:00	39.5	816.4	2.3	21.4	0.47	43.3	10.05	10.65	11.07	13.22
7	14:00	38.5	739.7	1.7	21.3	0.43	45.2	9.15	10.71	11.20	13.82
8	15:00	34.8	650.1	1.5	21.1	0.37	47.1	7.80	10.38	10.93	13.9
9	16:00	33.6	545.6	1.4	20.8	0.32	44.8	6.65	10.55	11.15	13.9
10	17:00	32.5	311.3	1.3	17.7	0.21	42.5	3.71	10.10	10.42	13.9

Table C22: System performance with respect to climatic parameter for SPV UV-A blue light trap (24th March 2018)

S. N.	Time, h	Ambient temp, (°C)	Solar Intensity, I (W/m²)	Wind Speed, m/sec	SPV panel						Battery Voltage, (V)
					Voltage, (V)	Current, (A)	Temp, (°C)	Power, (W)	Effi, (%)	Exergy effi, (%)	
1	8:00	31.8	152.4	1.7	15.7	0.13	32.3	2.06	11.87	13.69	9.95
2	9:00	33.4	332.5	1.4	20.6	0.25	33.5	5.15	13.39	13.73	10.71
3	10:00	34.6	467.8	1.2	20.8	0.29	35.7	6.03	11.15	11.75	11.24
4	11:00	35.7	585.9	3.1	21.1	0.40	38.4	8.44	12.46	13.14	11.93
5	12:00	36.3	732.4	2.5	21.1	0.44	42.6	9.28	10.51	11.51	12.77
6	13:00	38.5	816.4	2.1	21.4	0.47	43.3	10.05	10.65	11.05	13.22
7	14:00	40.2	742.5	1.5	21.3	0.43	45.2	9.15	10.67	11.16	13.82
8	15:00	36.3	650.1	1.7	21.0	0.37	47.1	7.77	10.33	10.89	13.9
9	16:00	34.6	546.8	1.3	20.8	0.32	44.7	6.65	10.52	11.12	13.9
10	17:00	32.4	315.6	2.1	18.7	0.21	42.0	3.92	11.88	15.92	13.9

Table C23: System performance with respect to climatic parameter for SPV UV-A blue light trap (27th March 2018)

S. N.	Time, h	Ambient temp, (°C)	Solar Intensity, I (W/m²)	Wind Speed, m/sec	SPV panel						Battery Voltage, (V)
					Voltage, (V)	Current, (A)	Temp, (°C)	Power, (W)	Effi, (%)	Exergy effi, (%)	
1	8:00	31.8	151.5	1.2	15.8	0.14	32.1	2.21	12.86	13.32	9.92
2	9:00	32.9	356.7	1.3	20.8	0.25	33.4	5.2	12.61	13.04	10.72
3	10:00	33.8	442.9	1.4	20.9	0.29	35.8	6.06	11.83	12.43	11.24
4	11:00	35.7	565.4	2.6	21.2	0.40	38.4	8.48	12.97	13.69	11.93
5	12:00	37.5	752.5	2.3	21.3	0.44	42.8	9.37	10.77	11.28	12.77
6	13:00	38.9	778.9	3.1	21.4	0.47	43.3	10.05	11.17	11.71	13.22
7	14:00	40.2	743.5	2.4	21.3	0.43	45.2	9.15	10.65	11.18	13.82
8	15:00	36.5	645.7	1.9	21.1	0.37	47.1	7.80	10.45	11.03	13.9
9	16:00	34.2	542.6	2.6	20.8	0.32	44.8	6.65	10.61	11.17	13.9
10	17:00	32.6	248.7	1.3	18.7	0.20	42.5	3.74	12.16	10.28	13.9

Table C24: System performance with respect to climatic parameter for SPV UV-A blue light trap (30th March 2018)

S.N.	Time, h	Ambient temp, (°C)	Solar Intensity, I (W/m²)	Wind Speed, m/sec	SPV panel						Battery Voltage, (V)
					Voltage, (V)	Current, (A)	Temp, (°C)	Power, (W)	Effi, (%)	Exergy effi, (%)	
1	8:00	30.2	153.6	2.1	15.6	0.14	32.3	2.184	12.27	8.42	9.95
2	9:00	32.5	358.9	2.3	20.7	0.25	33.5	5.175	12.47	12.56	10.7
3	10:00	33.6	569.5	1.7	20.9	0.29	35.7	6.061	9.20	9.72	11.20
4	11:00	35.4	695.8	1.8	21.2	0.40	38.4	8.48	10.54	11.07	11.93
5	12:00	36.8	776.4	1.9	21.3	0.44	42.6	9.372	10.44	10.87	12.77
6	13:00	38.6	805.7	1.3	21.4	0.47	43.3	10.058	10.79	11.19	13.22
7	14:00	40.3	752.6	1.4	21.3	0.43	45.2	9.159	10.52	10.99	13.82
8	15:00	36.8	606.1	1.6	21.1	0.37	47.1	7.807	11.14	11.77	13.9
9	16:00	34.8	553.2	1.7	20.8	0.32	44.7	6.656	10.40	10.99	13.9
10	17:00	33.1	347.2	1.3	18.7	0.22	42.0	4.114	10.44	10.51	13.9

Table C25: Average system performance with respect to climatic parameter for SPV blue light trap

S.N.	Time, h	Ambient temp (°C)	Solar Intensity I (W/m²)	Wind Speed m/sec	SPV panel						Battery Voltage, (V)
					Voltage, (V)	Current, (A)	Temp, (°C)	Power, (W)	Effi, (%)	Exergy effi, (%)	
1	8:00	29.9	154.6	1.81	15.4	0.15	32.1	2.31	12.91	9.81	9.9
2	9:00	31.3	339.8	1.81	20.5	0.24	33.4	4.92	12.53	12.70	10.5
3	10:00	33.0	498.9	1.85	20.7	0.28	35.7	6.15	10.04	10.58	11.2
4	11:00	34.1	616.1	1.83	20.9	0.39	38.4	8.18	11.44	12.08	11.8
5	12:00	35.6	767.2	1.87	21.0	0.43	42.8	9.16	10.33	10.60	12.6
6	13:00	36.5	811.3	1.88	21.3	0.46	43.3	9.99	10.65	10.82	13.0
7	14:00	38.1	741.4	1.61	21.2	0.43	45.2	9.14	10.67	11.12	13.7
8	15:00	34.8	634.2	2.01	21.0	0.35	47.1	7.45	10.16	10.58	13.9
9	16:00	33.8	491.4	1.93	20.7	0.30	44.8	6.27	11.04	11.49	13.9
10	17:00	32.5	264.0	1.77	17.6	0.20	42.2	3.45	11.10	10.99	13.9

Table C26: Average system performance with respect to climatic parameter for SPV yellow blue light trap

S. N.	Time, h	Ambient temp, (°C)	Solar Intensity, I (W/m²)	Wind Speed m/sec	SPV panel						Battery Voltage, (V)
					Voltage, (V)	Current, (A)	Temp, (°C)	Power, (W)	Effi, (%)	Exergy effi, (%)	
1	8:00	29.1	154.5	1.62	15.7	0.13	32.0	2.04	11.42	8.65	9.9
2	9:00	31.0	312.5	1.65	20.6	0.25	33.4	5.15	14.25	14.42	10.7
3	10:00	32.1	494.7	1.97	20.8	0.29	35.7	6.03	10.54	11.09	11.2
4	11:00	33.6	618.2	2.31	21.1	0.40	38.4	8.44	11.80	12.47	11.9
5	12:00	35.0	758.8	2.06	21.1	0.44	42.6	9.28	10.58	11.04	12.7
6	13:00	36.7	805.5	1.91	21.4	0.47	43.3	10.0	10.80	11.20	13.2
7	14:00	38.0	746.2	2.08	21.3	0.43	45.2	9.15	10.61	11.11	13.8
8	15:00	34.8	642.7	2.05	21.0	0.37	47.4	7.77	10.45	11.03	13.9
9	16:00	33.7	487.1	1.92	20.8	0.32	44.7	6.65	11.82	12.43	13.9
10	17:00	32.6	259.2	1.88	18.7	0.20	42.1	3.74	12.48	11.84	13.9

Table C27: Average system performance with respect to climatic parameter for SPV UV-A blue light trap

S. N.	Time, h	Ambient temp, (°C)	Solar Intensity, I (W/m^2)	Wind Speed, m/sec	SPV panel						Battery Voltage, (V)
					Voltage, (V)	Current, (A)	Temp, (°C)	Power, (W)	Effi, (%)	Exergy effi, (%)	
1	8:00	29.8	157.6	1.65	15.7	0.13	32.2	2.047	11.23	8.46	9.9
2	9:00	31.1	346.6	1.73	20.7	0.25	33.4	5.178	12.02	13.19	10.7
3	10:00	32.2	516.9	1.80	20.8	0.29	35.7	6.050	10.12	10.64	11.2
4	11:00	33.7	630.8	2.26	21.1	0.40	38.4	8.465	11.06	12.22	11.9
5	12:00	35.1	756.5	2.27	21.2	0.44	42.7	9.339	10.07	11.14	12.7
6	13:00	37.2	806.3	2.11	21.4	0.47	43.3	10.05	10.09	11.20	13.2
7	14:00	38.4	743.3	1.88	21.3	0.43	45.2	9.159	10.05	11.15	13.8
8	15:00	35.2	620.7	1.71	21.0	0.37	47.5	7.793	10.87	11.43	13.9
9	16:00	33.7	509.8	1.88	20.8	0.32	44.7	6.656	11.29	11.90	13.9
10	17:00	32.4	284.7	1.83	18.7	0.20	42.3	3.740	11.36	11.01	13.9

Battery discharging behavior using solar photovoltaic panel

I) Trial 1 Date- 10 April 2018

Sr. No.	Time (h)	Voltage (V)	Current (A)
1.	07:00	13.9	0.57
2.	08:00	13.03	0.57
3.	09:00	12.80	0.57
4.	10:00	12.67	0.57
5.	11:00	12.60	0.56
6.	12:00	12.56	0.56
7.	13:00	12.47	0.55
8.	14:00	12.34	0.54
9.	15:00	12.25	0.52
10.	16:00	12.23	0.49
11.	17:00	12.16	0.48
12.	18:00	12.10	0.47
13.	19:00	10.30	0.21
14.	20.00	9.9	0.12
15	21.00	9.9	0.12

II) Trial 2 Date- 12 April 2018

Sr. No.	Time (h)	Voltage (V)	Current (A)
1.	07:00	13.90	0.57
2.	08:00	13.40	0.57
3.	09:00	12.80	0.57
4.	10:00	12.69	0.57
5.	11:00	12.62	0.56
6.	12:00	12.58	0.56
7.	13:00	12.43	0.55
8.	14:00	12.36	0.54
9.	15:00	12.28	0.51
10.	16:00	12.26	0.49
11.	17:00	12.18	0.46
12.	18:00	12.14	0.47
13.	19:00	10.32	0.21
14.	20.00	9.9	0.12
15	21.00	9.9	0.12

III) Trial 3 Date- 17 April 2018

Sr. No.	Time (h)	Voltage (V)	Current (A)
1.	07:00	13.90	0.57
2.	08:00	13.46	0.57
3.	09:00	13.11	0.57
4.	10:00	12.96	0.56
5.	11:00	12.80	0.56
6.	12:00	12.71	0.56
7.	13:00	12.59	0.55
8.	14:00	12.42	0.54
9.	15:00	12.34	0.54
10.	16:00	12.23	0.48
11.	17:00	12.16	0.48
12.	18:00	12.10	0.47
13.	19:00	10.29	0.21
14.	20.00	9.9	0.12
15	21.00	9.9	0.12

IV) Average battery discharging behavior using solar photovoltaic panel

Sr. No.	Time (h)	Voltage (V)	Current (A)	Power (W)
1.	07:00	13.9	0.57	7.9
2.	08:00	13.29	0.57	7.5
3.	09:00	12.90	0.57	7.3
4.	10:00	12.77	0.56	7.1
5.	11:00	12.67	0.56	7.0
6.	12:00	12.61	0.56	7.06
7.	13:00	12.49	0.55	6.8
8.	14:00	12.37	0.54	6.6
9.	15:00	12.29	0.52	6.3
10.	16:00	12.24	0.48	5.8
11.	17:00	12.16	0.47	5.7
12.	18:00	12.11	0.47	5.6
13.	19:00	10.30	0.21	2.1
14.	20.00	9.90	0.12	1.1
15	21.00	9.90	0.12	1.1

Battery charging behavior using solar photovoltaic panel

I) Trial 1 Date: 11 April 2018

S. N.	Time (h)	Amb Temp, (^{0}C)	Wind speed, (m/s)	Solar intensity, (W/m^2)	Solar panel		Battery voltage, (V)
					Voltage (V)	Current (A)	
1.	08:00	29.9	1.71	155.6	17.4	0.18	9.9
2.	09:00	31.4	1.73	339.8	20.6	0.24	10.5
3.	10:00	33.2	1.80	497.9	20.7	0.28	11.2
4.	11:00	34.3	2.26	616.1	20.9	0.39	11.8
5.	12:00	35.7	2.27	767.2	21.0	0.43	12.6
6.	13:00	36.7	2.0	811.3	21.3	0.46	13.0
7.	14:00	38.2	1.88	741.4	21.2	0.43	13.7
8.	15:00	34.7	1.71	634.2	21.0	0.36	13.9
9.	16:00	33.9	1.87	492.4	20.7	0.30	13.9
10.	17:00	32.5	1.82	264.1	17.5	0.21	13.9

II) Trail 2 Date: 14 April 2018

S. N.	Time (h)	Amb Temp, (^{0}C)	Wind speed, (m/s)	Solar intensity, (W/m^2)	Solar panel		Battery voltage, (V)
					Voltage (V)	Current (A)	
1.	08:00	29.7	1.64	154.6	17.7	0.19	9.9
2.	09:00	31.4	1.65	312.1	20.8	0.26	10.7
3.	10:00	32.3	1.98	494.7	20.7	0.29	11.2
4.	11:00	33.7	2.32	618.2	21.1	0.41	11.9
5.	12:00	35.1	2.06	758.4	21.2	0.44	12.7
6.	13:00	36.7	1.91	805.5	21.4	0.47	13.2
7.	14:00	38.3	2.09	746.5	21.3	0.43	13.8
8.	15:00	34.8	2.05	642.7	21.1	0.37	13.9
9.	16:00	33.7	1.93	487.1	20.8	0.32	13.9
10.	17:00	32.4	1.89	258.3	18.6	0.22	13.9

III) Trial 3 Date:16 April 2018

S. N.	Time (h)	Amb Temp, (^{0}C)	Wind speed, (m/s)	Solar intensity, (W/m^2)	Solar panel		Battery voltage, (V)
					Voltage (V)	Current (A)	
1.	08:00	29.8	1.64	156.6	17.8	0.19	9.9
2.	09:00	31.2	1.72	346.8	20.6	0.26	10.7
3.	10:00	32.2	1.81	516.9	20.8	0.29	11.2
4.	11:00	33.9	2.26	630.7	21.1	0.40	11.9
5.	12:00	35.3	2.26	756.5	21.2	0.44	12.7
6.	13:00	37.2	2.11	806.3	21.4	0.47	13.2
7.	14:00	38.4	1.88	743.3	21.3	0.43	13.8
8.	15:00	35.3	1.73	620.7	21.1	0.37	13.9
9.	16:00	33.7	1.89	509.7	20.8	0.32	13.9
10.	17:00	32.3	1.82	284.6	17.9	0.23	13.9

IV) Average battery charging behavior using solar photovoltaic panel

S. N.	Time (h)	Amb Temp, (^{0}C)	Wind speed, (m/s)	Solar intensity, (W/m^2)	Solar panel		Battery voltage, (V)
					Voltage (V)	Current (A)	
1.	08:00	29.8	1.66	155.6	17.6	0.19	9.9
2.	09:00	31.3	1.70	332.9	20.7	0.25	10.6
3.	10:00	32.6	1.86	503.2	20.7	0.29	11.2
4.	11:00	34.0	2.28	621.7	21.0	0.40	11.9
5.	12:00	35.4	2.20	760.7	21.1	0.44	12.7
6.	13:00	36.9	2.01	807.7	21.4	0.47	13.1
7.	14:00	38.3	1.95	743.7	21.3	0.43	13.8
8.	15:00	34.9	1.83	632.5	21.1	0.37	13.9
9.	16:00	33.8	1.90	496.4	20.8	0.31	13.9
10.	17:00	32.4	1.84	269.0	18.0	0.22	13.9

APPENDIX (D)

Table D1: Number of insects representing each order in blue light on 1st day

Insect order	Insect name	Time (h)				Population mean
		19-20	20-21	21-22	04-06	
Hemiptera	Red cotton bug	1	3	0	0	1
	Aphides	6	11	3	1	5.25
	Whitefly	20	46	12	18	24
	Leaf hopper	6	15	6	12	9.75
	Dusky cotton bug	0	2	0	0	0.5
Lepidoptera	Leaf miner	4	12	1	3	5
	Pink bollworm	21	32	8	24	21.25
	American bollworm	12	18	5	10	11.25
Diptera	Mosquitoes	0	0	6	10	4
Coleoptera	Lady bird beetle	0	0	0	0	0
Total		70	139	41	78	

Table D2: Number of insects representing each order in blue light on 2nd day

Insect order	Insect name	Time (h)				Population mean
		19-20	20-21	21-22	04-06	
Hemiptera	Red cotton bug	1	2	0	0	0.75
	Aphides	6	11	3	1	5.25
	Whitefly	20	45	12	18	23.75
	Leaf hopper	6	15	6	12	9.75
	Dusky cotton bug	0	2	0	0	0.5
Lepidoptera	Leaf miner	4	12	1	3	5
	Pink bollworm	21	32	8	24	21.25
	American bollworm	12	18	5	10	11.25
Diptera	Mosquitoes	0	0	8	12	5
Coleoptera	Lady bird beetle	0	0	0	0	0
Total		70	137	43	80	

Table D3: Number of insects representing each order in blue light on 3rd day

Insect order	Insect name	Time (h)				Population mean
		19-20	20-21	21-22	04-06	
Hemiptera	Red cotton bug	2	3	0	0	1.25
	Aphides	6	11	3	1	5.25
	Whitefly	21	46	12	18	24.25
	Leaf hopper	6	15	6	14	10.25
	Dusky cotton bug	0	2	0	0	0.5
Lepidoptera	Leaf miner	5	13	1	4	5.75
	Pink bollworm	22	35	8	25	22.5
	American bollworm	14	19	7	12	13
Diptera	Mosquitoes	0	0	10	11	5.25
Coleoptera	Lady bird beetle	0	0	0	0	0
Total		76	144	47	85	

Table D4: Number of insects representing each order in blue light on 4th day

Insect order	Insect name	Time (h)				Population mean
		19-20	20-21	21-22	04-06	
Hemiptera	Red cotton bug	2	3	0	0	1.25
	Aphides	6	12	3	2	5.75
	Whitefly	23	46	12	18	24.75
	Leaf hopper	6	15	7	14	10.5
	Dusky cotton bug	0	2	0	0	0.5
Lepidoptera	Leaf miner	7	13	1	4	6.25
	Pink bollworm	21	35	8	25	22.25
	American bollworm	14	19	7	12	13
Diptera	Mosquitoes	0	0	12	11	5.75
Coleoptera	Lady bird beetle	0	0	0	0	0
Total		79	145	50	86	

Table D5: Number of insects representing each order in blue light on 5th day

Insect order	Insect name	Time (h)				Population mean
		19-20	20-21	21-22	04-06	
Hemiptera	Red cotton bug	3	4	0	0	1.75
	Aphides	6	12	3	2	5.75
	Whitefly	25	46	12	18	25.25
	Leaf hopper	7	17	7	15	11.5
	Dusky cotton bug	0	2	0	0	0.5
Lepidoptera	Leaf miner	7	13	1	4	6.25
	Pink bollworm	21	35	8	25	22.25
	American bollworm	14	19	7	12	13
Diptera	Mosquitoes	0	0	12	11	5.75
Coleoptera	Lady bird beetle	0	0	1	0	0.25
Total		83	148	51	87	

Table D6: Number of insects representing each order in blue light on 6th day

Insect order	Insect name	Time (h)				Insect population
		19-20	20-21	21-22	04-06	
Hemiptera	Red cotton bug	4	5	0	0	2.25
	Aphides	6	13	3	2	6
	Whitefly	25	46	12	18	25.25
	Leaf hopper	7	17	7	15	11.5
	Dusky cotton bug	0	2	0	0	0.5
Lepidoptera	Leaf miner	7	13	1	4	6.25
	Pink bollworm	23	37	9	27	24
	American bollworm	14	21	7	13	13.75
Diptera	Mosquitoes	0	0	12	12	6
Coleoptera	Lady bird beetle	0	0	2	1	0.75
Total		86	154	53	92	

Table D7: Total number of insects representing each order on blue light in 7th day

Insect order	Insect name	Time (h)				Population mean
		19-20	20-21	21-22	04-06	
Hemiptera	Red cotton bug	4	5	0	0	2.25
	Aphides	5	13	3	2	5.75
	Whitefly	25	41	12	15	23.25
	Leaf hopper	7	16	7	13	10.75
	Dusky cotton bug	0	2	0	0	0.5
Lepidoptera	Leaf miner	6	13	1	4	6
	Pink bollworm	21	37	9	27	23.5
	American bollworm	14	21	7	13	13.75
Diptera	Mosquitoes	0	0	12	15	6.75
Coleoptera	Lady bird beetle	0	0	3	2	1.25
Total		82	148	54	91	

Table D8: Total number of insects representing each order in blue light on 8th day

Insect order	Insect name	Time (h)				Population mean
		19-20	20-21	21-22	04-06	
Hemiptera	Red cotton bug	5	7	0	2	3.5
	Aphides	8	13	3	2	6.5
	Whitefly	28	43	13	17	25.25
	Leaf hopper	7	18	7	13	11.25
	Dusky cotton bug	0	2	0	0	0.5
Lepidoptera	Leaf miner	5	11	1	4	5.25
	Pink bollworm	21	35	9	27	23
	American bollworm	13	19	5	13	12.5
Diptera	Mosquitoes	0	0	13	15	7
Coleoptera	Lady bird beetle	0	0	0	0	0
Total		87	148	51	93	

Table D9: Total number of insects representing each order in blue light on 9th day

Insect order	Insect name	Time (h)				Population mean
		19-20	20-21	21-22	04-06	
Hemiptera	Red cotton bug	5	7	0	2	3.5
	Aphides	9	13	3	2	6.75
	Whitefly	28	45	13	17	25.75
	Leaf hopper	7	19	7	13	11.5
	Dusky cotton bug	0	2	0	0	0.5
Lepidoptera	Leaf miner	5	11	1	4	5.25
	Pink bollworm	21	33	9	27	22.5
	American bollworm	13	19	5	13	12.5
Diptera	Mosquitoes	0	0	15	16	7.75
Coleoptera	Lady bird beetle	0	1	3	3	1.75
Total		88	150	56	97	

Table D10: Total number of insects representing each order in blue light on 10th day

Insect order	Insect name	Time (h)				Population mean
		19-20	20-21	21-22	04-06	
Hemiptera	Red cotton bug	6	7	0	2	3.75
	Aphides	9	13	3	2	6.75
	Whitefly	28	45	13	17	25.75
	Leaf hopper	7	19	7	13	11.5
	Dusky cotton bug	0	2	0	0	0.5
Lepidoptera	Leaf miner	4	11	1	4	5
	Pink bollworm	21	33	9	27	22.5
	American bollworm	13	19	5	13	12.5
Diptera	Mosquitoes	0	0	16	17	8.25
Coleoptera	Lady bird beetle	0	0	0	0	0
Total		88	149	54	95	

Table D11: Total number of insects representing each order in blue light on 11th day

Insect order	Insect name	Time (h)				Population mean
		19-20	20-21	21-22	04-06	
Hemiptera	Red cotton bug	6	9	0	2	4.25
	Aphides	9	13	3	2	6.75
	Whitefly	28	45	13	17	25.75
	Leaf hopper	7	19	7	13	11.5
	Dusky cotton bug	0	2	0	0	0.5
Lepidoptera	Leaf miner	5	11	1	5	5.5
	Pink bollworm	21	35	9	27	23
	American bollworm	13	20	7	16	14
Diptera	Mosquitoes	0	2	14	15	7.75
Coleoptera	Lady bird beetle	0	0	0	0	0
Total		89	156	54	97	

Table D12: Total number of insects representing each order in blue light on 12th day

Insect order	Insect name	Time (h)				Population mean
		19-20	20-21	21-22	04-06	
Hemiptera	Red cotton bug	7	9	0	1	4.25
	Aphides	9	13	3	2	6.75
	Whitefly	26	47	13	15	25.25
	Leaf hopper	7	19	7	11	11
	Dusky cotton bug	0	2	0	0	0.5
Lepidoptera	Leaf miner	5	11	1	5	5.5
	Pink bollworm	21	35	9	27	23
	American bollworm	13	19	7	16	13.75
Diptera	Mosquitoes	0	0	10	13	5.75
Coleoptera	Lady bird beetle	0	0	0	0	0
Total		88	155	50	90	

Table D13: Total number of insects representing each order in blue light on 13th day

Insect order	Insect name	Time (h)				Population mean
		19-20	20-21	21-22	04-06	
Hemiptera	Red cotton bug	5	7	0	1	3.25
	Aphides	9	13	3	2	6.75
	Whitefly	26	47	13	15	25.25
	Leaf hopper	7	19	7	11	11
	Dusky cotton bug	0	2	0	0	0.5
Lepidoptera	Leaf miner	5	11	1	5	5.5
	Pink bollworm	14	25	7	22	17
	American bollworm	17	9	7	13	11.5
Diptera	Mosquitoes	0	0	7	5	3
Coleoptera	Lady bird beetle	0	0	0	0	0
Total		83	133	45	74	

Table D14: Total number of insects representing each order in blue light on 14th day

Insect order	Insect name	Time (h)				Population mean
		19-20	20-21	21-22	04-06	
Hemiptera	Red cotton bug	5	7	0	1	3.25
	Aphides	6	13	3	2	6
	Whitefly	23	47	13	11	23.5
	Leaf hopper	7	17	7	9	10
	Dusky cotton bug	0	0	0	0	0
Lepidoptera	Leaf miner	3	9	1	3	4
	Pink bollworm	13	17	7	20	14.25
	American bollworm	12	9	7	11	9.75
Diptera	Mosquitoes	0	0	7	2	2.25
Coleoptera	Lady bird beetle	0	0	0	0	0
Total		69	119	45	59	

Table D15: Total number of insects representing each order in blue light on 15th day

Insect order	Insect name	Time (h)				Population mean
		19-20	20-21	21-22	04-06	
Hemiptera	Red cotton bug	3	5	0	0	2
	Aphides	5	13	3	2	5.75
	Whitefly	19	45	11	10	21.25
	Leaf hopper	7	17	7	9	10
	Dusky cotton bug	0	0	0	0	0
Lepidoptera	Leaf miner	3	9	1	3	4
	Pink bollworm	11	16	7	20	13.5
	American bollworm	12	9	7	11	9.75
Diptera	Mosquitoes	0	0	5	2	1.75
Coleoptera	Lady bird beetle	0	0	0	0	0
Total		60	114	41	57	

Table D16: Total number of insects representing each order in blue light on 16th day

Insect order	Insect name	Time (h)				Population mean
		19-20	20-21	21-22	04-06	
Hemiptera	Red cotton bug	3	5	0	0	2
	Aphides	5	13	3	2	5.75
	Whitefly	15	41	11	10	19.25
	Leaf hopper	5	15	5	9	8.5
	Dusky cotton bug	0	0	0	0	0
Lepidoptera	Leaf miner	3	9	1	3	4
	Pink bollworm	11	14	7	20	13
	American bollworm	12	9	7	11	9.75
Diptera	Mosquitoes	0	0	0	0	0
Coleoptera	Lady bird beetle	0	0	0	0	0
Total		54	106	34	55	

Table D17: Total number of insects representing each order in blue light on 17th day

Insect order	Insect name	Time (h)				Population mean
		19-20	20-21	21-22	04-06	
Hemiptera	Red cotton bug	3	5	0	0	2
	Aphides	5	13	3	2	5.75
	Whitefly	11	39	11	9	17.5
	Leaf hopper	5	13	4	8	7.5
	Dusky cotton bug	0	0	0	0	0
Lepidoptera	Leaf miner	3	9	1	3	4
	Pink bollworm	11	15	7	20	13.25
	American bollworm	12	9	7	11	9.75
Diptera	Mosquitoes	0	0	0	0	0
Coleoptera	Lady bird beetle	0	0	0	0	0
Total		50	103	33	53	

Table D18: Total number of insects representing each order in blue light on 18th day

Insect order	Insect name	Time (h)				Population mean
		19-20	20-21	21-22	04-06	
Hemiptera	Red cotton bug	3	5	0	0	2
	Aphides	4	13	3	2	5.5
	Whitefly	11	25	11	7	13.5
	Leaf hopper	5	11	4	8	7
	Dusky cotton bug	0	0	0	0	0
Lepidoptera	Leaf miner	3	9	1	3	4
	Pink bollworm	9	11	7	18	11.25
	American bollworm	12	9	7	11	9.75
Diptera	Mosquitoes	0	0	0	0	0
Coleoptera	Lady bird beetle	0	0	0	0	0
Total		47	83	33	49	

Table D19: Total number of insects representing each order in blue light on 19th day

Insect order	Insect name	Time (h)				Population mean
		19-20	20-21	21-22	04-06	
Hemiptera	Red cotton bug	3	5	0	0	2
	Aphides	3	11	2	1	4.25
	Whitefly	9	21	11	7	12
	Leaf hopper	5	11	4	8	7
	Dusky cotton bug	0	0	0	0	0
Lepidoptera	Leaf miner	3	9	1	3	4
	Pink bollworm	9	11	7	15	10.5
	American bollworm	11	9	7	11	9.5
Diptera	Mosquitoes	0	0	0	2	0.5
Coleoptera	Lady bird beetle	0	0	0	0	0
Total		43	77	32	47	

Table D20: Total number of insects representing each order in blue light on 20th day

Insect order	Insect name	Time (h)				Population mean
		19-20	20-21	21-22	04-06	
Hemiptera	Red cotton bug	3	5	0	0	2
	Aphides	3	9	2	1	3.75
	Whitefly	9	19	11	7	11.5
	Leaf hopper	5	11	3	8	6.75
	Dusky cotton bug	0	0	0	0	0
Lepidoptera	Leaf miner	0	4	1	3	2
	Pink bollworm	7	10	7	10	8.5
	American bollworm	7	9	4	11	7.75
Diptera	Mosquitoes	0	0	0	0	0
Coleoptera	Lady bird beetle	0	0	0	0	0
Total		34	67	28	40	

Table D21: Total number of insects representing each order in blue light on 21st day

Insect order	Insect name	Time (h)				Population mean
		19-20	20-21	21-22	04-06	
Hemiptera	Red cotton bug	1	3	0	0	1
	Aphides	3	7	2	1	3.25
	Whitefly	9	10	11	7	9.25
	Leaf hopper	3	9	3	5	5
	Dusky cotton bug	0	0	0	0	0
Lepidoptera	Leaf miner	0	1	0	0	0.25
	Pink bollworm	3	9	5	7	6
	American bollworm	5	9	4	11	7.25
Diptera	Mosquitoes	0	0	0	0	0
Coleoptera	Lady bird beetle	0	0	0	0	0
Total		24	48	25	31	

Table D22: Total number of insects representing each order in blue light on 22nd day

Insect order	Insect name	Time (h)				Population mean
		19-20	20-21	21-22	04-06	
Hemiptera	Red cotton bug	0	0	0	0	1.75
	Aphides	1	5	0	1	7.25
	Whitefly	7	8	7	7	5
	Leaf hopper	3	9	3	5	0
	Dusky cotton bug	0	0	0	0	0
Lepidoptera	Leaf miner	0	0	0	0	4
	Pink bollworm	1	7	3	5	5.25
	American bollworm	1	6	5	9	0
Diptera	Mosquitoes	0	0	0	0	0
Coleoptera	Lady bird beetle	0	0	0	0	1.75
Total		13	35	18	27	

Table D23: Total number of insects representing each order in blue light on 23rd day

Insect order	Insect name	Time (h)				Population mean
		19-20	20-21	21-22	04-06	
Hemiptera	Red cotton bug	0	0	0	0	0
	Aphides	1	1	0	1	0.75
	Whitefly	5	7	7	5	6
	Leaf hopper	1	7	2	5	3.75
	Dusky cotton bug	0	0	0	0	0
Lepidoptera	Leaf miner	1	0	0	0	0.25
	Pink bollworm	1	3	2	3	2.25
	American bollworm	1	4	5	4	3.5
Diptera	Mosquitoes	0	0	0	0	0
Coleoptera	Lady bird beetle	0	0	0	0	0
Total		10	22	16	18	

Table D24: Total number of insects representing each order in blue light on 24th day

Insect order	Insect name	Time (h)				Population mean
		19-20	20-21	21-22	04-06	
Hemiptera	Red cotton bug	0	0	0	0	0
	Aphides	0	1	0	1	0.5
	Whitefly	3	7	6	5	5.25
	Leaf hopper	1	7	2	5	3.75
	Dusky cotton bug	0	0	0	0	0
Lepidoptera	Leaf miner	0	0	0	0	0
	Pink bollworm	0	2	1	3	1.5
	American bollworm	0	3	1	3	1.75
Diptera	Mosquitoes	0	0	0	1	0.25
Coleoptera	Lady bird beetle	0	0	0	0	0
Total		4	20	10	18	

Table D25: Total number of insects representing each order in yellow light on 1st day

Insect order	Insect name	Time (h)				Population mean
		19-20	20-21	21-22	04-06	
Hemiptera	Red cotton bug	5	7	0	2	3.5
	Aphides	9	13	3	2	6.75
	Whitefly	23	40	13	17	23.25
	Leaf hopper	6	19	7	13	11.25
	Dusky cotton bug	0	1	0	1	0.5
Lepidoptera	Leaf miner	13	9	7	5	8.5
	Pink bollworm	11	36	9	26	20.5
	American bollworm	13	20	7	16	14
Diptera	Mosquitoes	0	2	8	7	4.25
Coleoptera	Lady bird beetle	0	0	0	0	0
Total		80	147	54	89	

Table D26: Total number of insects representing each order in yellow light on 2nd day

Insect order	Insect name	Time (h)				Population mean
		19-20	20-21	21-22	04-06	
Hemiptera	Red cotton bug	4	7	0	2	3.25
	Aphides	9	13	3	2	6.75
	Whitefly	23	39	13	17	23
	Leaf hopper	5	19	7	13	11
	Dusky cotton bug	0	1	0	1	0.5
Lepidoptera	Leaf miner	14	9	5	3	7.75
	Pink bollworm	13	36	7	26	20.5
	American bollworm	13	20	7	16	14
Diptera	Mosquitoes	0	3	8	10	5.25
Coleoptera	Lady bird beetle	0	0	0	0	0
Total		81	147	50	90	

Table D27: Total number of insects representing each order in yellow light on 3rd day

Insect order	Insect name	Time (h)				Population mean
		19-20	20-21	21-22	04-06	
Hemiptera	Red cotton bug	5	7	0	3	3.75
	Aphides	9	13	3	2	6.75
	Whitefly	23	39	13	17	23
	Leaf hopper	5	19	7	13	11
	Dusky cotton bug	0	1	0	1	0.5
Lepidoptera	Leaf miner	15	9	7	5	9
	Pink bollworm	13	37	7	27	21
	American bollworm	15	20	7	16	14.5
Diptera	Mosquitoes	0	0	8	10	4.5
Coleoptera	Lady bird beetle	0	0	0	0	0
Total		85	145	52	94	

Table D28: Total number of insects representing each order in yellow light on 4th day

Insect order	Insect name	Time (h)				Population mean
		19-20	20-21	21-22	04-06	
Hemiptera	Red cotton bug	4	7	0	3	3.5
	Aphides	9	13	3	2	6.75
	Whitefly	23	39	13	17	23
	Leaf hopper	5	19	7	13	11
	Dusky cotton bug	0	1	0	1	0.5
Lepidoptera	Leaf miner	14	9	7	5	8.75
	Pink bollworm	11	35	7	26	19.75
	American bollworm	15	22	7	16	15
Diptera	Mosquitoes	0	5	8	10	5.75
Coleoptera	Lady bird beetle	0	0	0	0	0
Total		81	150	52	93	

Table D29: Total number of insects representing each order in yellow light on 5th day

Insect order	Insect name	Time (h)				Population mean
		19-20	20-21	21-22	04-06	
Hemiptera	Red cotton bug	5	7	0	3	3.75
	Aphides	9	15	3	2	7.25
	Whitefly	23	39	13	18	23.25
	Leaf hopper	5	19	7	13	11
	Dusky cotton bug	0	1	0	1	0.5
Lepidoptera	Leaf miner	17	9	7	5	9.5
	Pink bollworm	11	37	7	28	20.75
	American bollworm	13	21	7	17	14.5
Diptera	Mosquitoes	0	3	8	10	5.25
Coleoptera	Lady bird beetle	0	0	1	0	0.25
Total		83	151	53	97	

Table D30: Total number of insects representing each order in yellow light on 6th day

Insect order	Insect name	Time (h)				Population mean
		19-20	20-21	21-22	04-06	
Hemiptera	Red cotton bug	7	9	0	5	5.25
	Aphides	9	17	3	2	7.75
	Whitefly	23	39	13	18	23.25
	Leaf hopper	5	19	7	13	11
	Dusky cotton bug	0	1	0	1	0.5
Lepidoptera	Leaf miner	17	9	7	5	9.5
	Pink bollworm	11	37	7	26	20.25
	American bollworm	15	21	7	19	15.5
Diptera	Mosquitoes	0	2	8	10	5
Coleoptera	Lady bird beetle	1	0	1	0	0.5
Total		88	154	53	99	

Table D31: Total number of insects representing each order in yellow light on 7th day

Insect order	Insect name	Time (h)				Population mean
		19-20	20-21	21-22	04-06	
Hemiptera	Red cotton bug	9	11	0	5	7.25
	Aphides	9	17	3	2	7.75
	Whitefly	23	39	13	19	23.5
	Leaf hopper	5	19	7	13	11
	Dusky cotton bug	0	1	0	1	0.75
Lepidoptera	Leaf miner	19	9	7	5	11.5
	Pink bollworm	11	37	7	27	20.5
	American bollworm	15	21	7	19	15.75
Diptera	Mosquitoes	0	0	8	16	6.75
Coleoptera	Lady bird beetle	0	0	1	1	0
Total		93	158	57	111	

Table D32: Total number of insects representing each order in yellow light on 8th day

Insect order	Insect name	Time (h)				Population mean
		19-20	20-21	21-22	04-06	
Hemiptera	Red cotton bug	9	11	2	7	7.25
	Aphides	9	17	3	2	7.75
	Whitefly	23	39	13	19	23.5
	Leaf hopper	5	19	7	13	11
	Dusky cotton bug	0	2	0	1	0.75
Lepidoptera	Leaf miner	21	9	9	7	11.5
	Pink bollworm	11	37	7	27	20.5
	American bollworm	15	21	8	19	15.75
Diptera	Mosquitoes	0	3	8	16	6.75
Coleoptera	Lady bird beetle	0	0	0	0	0
Total		93	158	57	111	

Table D33: Total number of insects representing each order in yellow light on 9th day

Insect order	Insect name	Time (h)				Population mean
		19-20	20-21	21-22	04-06	
Hemiptera	Red cotton bug	11	13	4	9	9.25
	Aphides	9	17	3	3	8
	Whitefly	23	39	13	21	24
	Leaf hopper	5	19	7	13	11
	Dusky cotton bug	0	2	0	1	0.75
Lepidoptera	Leaf miner	23	9	9	7	12
	Pink bollworm	11	37	7	29	21
	American bollworm	15	21	8	19	15.75
Diptera	Mosquitoes	0	3	12	20	8.75
Coleoptera	Lady bird beetle	0	1	1	1	0.75
Total		97	161	64	123	

Table D34: Total number of insects representing each order in yellow light on 10th day

Insect order	Insect name	Time (h)				Population mean
		19-20	20-21	21-22	04-06	
Hemiptera	Red cotton bug	17	19	7	12	13.75
	Aphides	11	19	5	5	10
	Whitefly	23	39	13	21	24
	Leaf hopper	5	19	9	13	11.5
	Dusky cotton bug	0	2	0	2	1
Lepidoptera	Leaf miner	25	9	9	7	12.5
	Pink bollworm	11	39	7	31	22
	American bollworm	15	21	8	19	15.75
Diptera	Mosquitoes	0	3	15	20	9.5
Coleoptera	Lady bird beetle	0	1	2	1	1
Total		107	171	75	131	

Table D35: Total number of insects representing each order in yellow light on 11th day

Insect order	Insect name	Time (h)				Population mean
		19-20	20-21	21-22	04-06	
Hemiptera	Red cotton bug	17	20	7	12	14
	Aphides	11	19	5	5	10
	Whitefly	24	39	13	21	24.25
	Leaf hopper	6	19	9	13	11.75
	Dusky cotton bug	0	2	0	2	1
Lepidoptera	Leaf miner	30	11	11	9	15.25
	Pink bollworm	13	41	9	33	24
	American bollworm	15	21	9	19	16
Diptera	Mosquitoes	0	2	20	20	10.5
Coleoptera	Lady bird beetle	0	1	2	2	1.25
Total		116	175	85	136	

Table D36: Total number of insects representing each order in yellow light on 12th day

Insect order	Insect name	Time (h)				Population mean
		19-20	20-21	21-22	04-06	
Hemiptera	Red cotton bug	15	20	7	12	13.5
	Aphides	11	19	5	5	10
	Whitefly	21	39	13	21	23.5
	Leaf hopper	6	18	9	13	11.5
	Dusky cotton bug	0	2	0	2	1
Lepidoptera	Leaf miner	33	11	13	9	16.5
	Pink bollworm	13	41	9	33	24
	American bollworm	17	21	11	19	17
Diptera	Mosquitoes	0	1	18	20	9.75
Coleoptera	Lady bird beetle	0	0	0	0	0
Total		116	172	85	134	

Table D37: Total number of insects representing each order in yellow light on 13th day

Insect order	Insect name	Time (h)				Population mean
		19-20	20-21	21-22	04-06	
Hemiptera	Red cotton bug	11	17	7	9	11
	Aphides	9	17	5	5	9
	Whitefly	19	33	13	17	20.5
	Leaf hopper	6	18	9	13	11.5
	Dusky cotton bug	0	0	0	0	0
Lepidoptera	Leaf miner	29	11	13	9	15.5
	Pink bollworm	13	41	9	33	24
	American bollworm	15	19	11	18	15.75
Diptera	Mosquitoes	0	1	17	22	10
Coleoptera	Lady bird beetle	0	0	0	0	0
Total		102	157	84	126	

Table D38: Total number of insects representing each order in yellow light on 14th day

Insect order	Insect name	Time (h)				Population mean
		19-20	20-21	21-22	04-06	
Hemiptera	Red cotton bug	9	15	5	7	9
	Aphides	9	15	5	5	8.5
	Whitefly	19	31	13	17	20
	Leaf hopper	6	18	9	11	11
	Dusky cotton bug	0	0	0	0	0
Lepidoptera	Leaf miner	21	11	13	9	13.5
	Pink bollworm	13	39	9	31	23
	American bollworm	15	19	11	16	15.25
Diptera	Mosquitoes	0	1	8	3	3
Coleoptera	Lady bird beetle	0	0	0	0	0
Total		92	149	73	99	

Table D39: Total number of insects representing each order in yellow light on 15th day

Insect order	Insect name	Time (h)				Population mean
		19-20	20-21	21-22	04-06	
Hemiptera	Red cotton bug	7	12	5	7	7.75
	Aphides	9	15	3	5	8
	Whitefly	19	31	11	15	19
	Leaf hopper	6	17	9	11	10.75
	Dusky cotton bug	0	0	0	0	0
Lepidoptera	Leaf miner	19	9	11	7	11.5
	Pink bollworm	13	35	9	29	21.5
	American bollworm	15	19	10	15	14.75
Diptera	Mosquitoes	0	0	0	3	0.75
Coleoptera	Lady bird beetle	0	0	1	0	0.25
Total		88	138	59	92	

Table D40: Total number of insects representing each order in yellow light on 16th day

Insect order	Insect name	Time (h)				Population mean
		19-20	20-21	21-22	04-06	
Hemiptera	Red cotton bug	6	11	5	7	7.25
	Aphides	9	15	3	5	8
	Whitefly	15	29	11	13	17
	Leaf hopper	6	17	9	11	10.75
	Dusky cotton bug	0	0	0	0	0
Lepidoptera	Leaf miner	15	9	11	7	10.5
	Pink bollworm	12	31	9	20	18
	American bollworm	15	18	10	15	14.5
Diptera	Mosquitoes	0	0	0	0	0
Coleoptera	Lady bird beetle	0	0	0	0	0
Total		78	130	58	78	

Table D41: Total number of insects representing each order in yellow light on 17th day

Insect order	Insect name	Time (h)				Population mean
		19-20	20-21	21-22	04-06	
Hemiptera	Red cotton bug	5	9	5	7	6.5
	Aphides	9	15	3	5	8
	Whitefly	15	25	11	13	16
	Leaf hopper	6	17	9	11	10.75
	Dusky cotton bug	0	0	0	0	0
Lepidoptera	Leaf miner	11	9	11	7	9.5
	Pink bollworm	11	29	9	19	17
	American bollworm	15	18	10	13	14
Diptera	Mosquitoes	0	0	0	0	0
Coleoptera	Lady bird beetle	0	0	0	0	0
Total		72	122	58	75	

Table D42: Total number of insects representing each order in yellow light on 18th day

Insect order	Insect name	Time (h)				Population mean
		19-20	20-21	21-22	04-06	
Hemiptera	Red cotton bug	5	7	5	7	6
	Aphides	7	11	3	5	6.5
	Whitefly	11	20	11	13	13.75
	Leaf hopper	6	17	9	9	10.25
	Dusky cotton bug	0	0	0	0	0
Lepidoptera	Leaf miner	9	7	11	5	8
	Pink bollworm	11	29	9	17	16.5
	American bollworm	15	18	8	11	13
Diptera	Mosquitoes	0	0	0	6	1.5
Coleoptera	Lady bird beetle	0	0	0	0	0
Total		64	109	56	73	

Table D43: Total number of insects representing each order in yellow light on 19th day

Insect order	Insect name	Time (h)				Population mean
		19-20	20-21	21-22	04-06	
Hemiptera	Red cotton bug	3	7	5	7	5.5
	Aphides	7	9	3	5	6
	Whitefly	11	17	11	13	13
	Leaf hopper	6	15	9	9	9.75
	Dusky cotton bug	0	0	0	0	0
Lepidoptera	Leaf miner	5	7	9	5	6.5
	Pink bollworm	9	25	9	17	15
	American bollworm	11	14	8	11	11
Diptera	Mosquitoes	0	0	0	1	0.25
Coleoptera	Lady bird beetle	0	0	0	0	0
Total		52	94	54	68	

Table D44: Total number of insects representing each order in yellow light on 20th day

Insect order	Insect name	Time (h)				Population mean
		19-20	20-21	21-22	04-06	
Hemiptera	Red cotton bug	0	3	0	5	2
	Aphides	7	9	3	5	6
	Whitefly	11	17	11	13	13
	Leaf hopper	6	15	9	9	9.75
	Dusky cotton bug	0	0	0	0	0
Lepidoptera	Leaf miner	5	7	9	5	6.5
	Pink bollworm	5	21	9	15	12.5
	American bollworm	9	12	7	11	9.75
Diptera	Mosquitoes	0	0	0	0	0
Coleoptera	Lady bird beetle	0	0	0	0	0
Total		43	84	48	63	

Table D45: Total number of insects representing each order in yellow light on 21st day

Insect order	Insect name	Time (h)				Population mean
		19-20	20-21	21-22	04-06	
Hemiptera	Red cotton bug	0	0	0	0	0
	Aphides	5	7	3	5	5
	Whitefly	10	17	11	13	12.75
	Leaf hopper	6	15	9	9	9.75
	Dusky cotton bug	0	0	0	0	0
Lepidoptera	Leaf miner	0	7	9	0	4
	Pink bollworm	5	21	9	15	12.5
	American bollworm	9	9	7	11	9
Diptera	Mosquitoes	0	0	0	0	0
Coleoptera	Lady bird beetle	0	0	0	0	0
Total		35	76	48	53	

Table D46: Total number of insects representing each order in yellow light on 22nd day

Insect order	Insect name	Time (h)				Population mean
		19-20	20-21	21-22	04-06	
Hemiptera	Red cotton bug	0	0	0	0	0
	Aphides	0	2	3	0	1.25
	Whitefly	10	14	11	13	12
	Leaf hopper	6	15	9	9	9.75
	Dusky cotton bug	0	0	0	0	0
Lepidoptera	Leaf miner	0	1	3	6	2.5
	Pink bollworm	2	18	7	11	9.5
	American bollworm	7	6	5	7	6.25
Diptera	Mosquitoes	0	0	0	0	0
Coleoptera	Lady bird beetle	0	0	0	0	0
Total		25	56	38	46	

Table D47: Total number of insects representing each order in yellow light on 23rd day

Insect order	Insect name	Time (h)				Population mean
		19-20	20-21	21-22	04-06	
Hemiptera	Red cotton bug	0	0	0	0	0
	Aphides	0	0	3	0	0.75
	Whitefly	8	14	11	13	11.5
	Leaf hopper	6	15	9	9	9.75
	Dusky cotton bug	0	0	0	0	0
Lepidoptera	Leaf miner	0	1	3	3	1.75
	Pink bollworm	2	11	7	11	7.75
	American bollworm	5	5	3	7	5
Diptera	Mosquitoes	0	0	0	0	0
Coleoptera	Lady bird beetle	0	0	0	0	0
Total		21	46	36	43	

Table D48: Total number of insects representing each order in yellow light on 24th day

Insect order	Insect name	Time (h)				Population mean
		19-20	20-21	21-22	04-06	
Hemiptera	Red cotton bug	0	0	0	0	0
	Aphides	0	0	1	0	0.25
	Whitefly	3	11	7	11	8
	Leaf hopper	6	15	9	9	9.75
	Dusky cotton bug	0	0	0	0	0
Lepidoptera	Leaf miner	0	0	0	0	0
	Pink bollworm	2	9	7	11	7.25
	American bollworm	2	5	3	7	4.25
Diptera	Mosquitoes	0	0	0	0	0
Coleoptera	Lady bird beetle	0	0	0	0	0
Total		13	40	27	38	

Table D49: Total number of insects representing each order on ultra-violet light in 1st day

Insect order	Insect name	Time (h)				Population mean
		19-20	20-21	21-22	04-06	
Hemiptera	Red cotton bug	31	39	11	21	25.5
	Aphides	19	33	7	7	16.5
	Whitefly	40	71	25	40	44
	Leaf hopper	7	29	11	21	17
	Dusky cotton bug	2	3	2	2	2.25
Lepidoptera	Leaf miner	46	17	13	14	22.5
	Pink bollworm	23	72	15	59	42.25
	American bollworm	29	35	13	34	27.75
Diptera	Mosquitoes	0	0	21	20	10.25
Coleoptera	Lady bird beetle	0	0	0	0	0
Total		197	299	118	218	

Table D50: Total number of insects representing each order on ultra-violet light in 2nd day

Insect order	Insect name	Time (h)				Population mean
		19-20	20-21	21-22	04-06	
Hemiptera	Red cotton bug	31	38	11	21	25.25
	Aphides	19	33	7	7	16.5
	Whitefly	40	71	25	40	44
	Leaf hopper	7	29	11	21	17
	Dusky cotton bug	2	3	2	2	2.25
Lepidoptera	Leaf miner	47	19	13	15	23.5
	Pink bollworm	23	73	15	59	42.5
	American bollworm	29	35	13	34	27.75
Diptera	Mosquitoes	0	0	21	19	10
Coleoptera	Lady bird beetle	0	0	0	0	0
Total		198	301	118	218	

Table D51: Total number of insects representing each order on ultra-violet light in 3rd day

Insect order	Insect name	Time (h)				Population mean
		19-20	20-21	21-22	04-06	
Hemiptera	Red cotton bug	32	39	11	23	26.25
	Aphides	19	33	7	7	16.5
	Whitefly	40	71	25	40	44
	Leaf hopper	7	29	11	21	17
	Dusky cotton bug	2	3	2	2	2.25
Lepidoptera	Leaf miner	47	19	14	15	23.75
	Pink bollworm	24	73	15	59	42.75
	American bollworm	29	36	13	34	28
Diptera	Mosquitoes	0	0	21	18	9.75
Coleoptera	Lady bird beetle	0	0	0	0	0
Total		200	303	119	219	

Table D52: Total number of insects representing each order on ultra-violet light in 4th day

Insect order	Insect name	Time (h)				Population mean
		19-20	20-21	21-22	04-06	
Hemiptera	Red cotton bug	33	41	13	23	27.5
	Aphides	19	33	7	7	16.5
	Whitefly	41	72	25	40	44.5
	Leaf hopper	7	29	11	21	17
	Dusky cotton bug	2	3	2	2	2.25
Lepidoptera	Leaf miner	47	21	14	15	24.25
	Pink bollworm	24	73	16	59	43
	American bollworm	29	37	13	34	28.25
Diptera	Mosquitoes	0	3	21	18	10.5
Coleoptera	Lady bird beetle	0	0	0	0	0
Total		202	312	122	219	

Table D53: Total number of insects representing each order on ultra-violet light in 5th day

Insect order	Insect name	Time (h)				Population mean
		19-20	20-21	21-22	04-06	
Hemiptera	Red cotton bug	37	43	13	23	29
	Aphides	19	33	7	7	16.5
	Whitefly	43	71	27	40	45.25
	Leaf hopper	7	29	11	21	17
	Dusky cotton bug	2	3	2	2	2.25
Lepidoptera	Leaf miner	51	23	17	16	26.75
	Pink bollworm	26	75	16	59	44
	American bollworm	29	38	14	34	28.75
Diptera	Mosquitoes	0	3	21	22	11.5
Coleoptera	Lady bird beetle	0	0	0	0	0
Total		214	318	128	224	

Table D54: Total number of insects representing each order on ultra-violet light in 6th day

Insect order	Insect name	Time (h)				Population mean
		19-20	20-21	21-22	04-06	
Hemiptera	Red cotton bug	39	43	13	23	29.5
	Aphides	19	35	7	7	17
	Whitefly	43	71	29	40	45.75
	Leaf hopper	7	29	11	21	17
	Dusky cotton bug	2	3	2	2	2.25
Lepidoptera	Leaf miner	50	21	15	13	24.75
	Pink bollworm	26	75	16	57	43.5
	American bollworm	29	38	13	34	28.5
Diptera	Mosquitoes	0	5	21	22	12
Coleoptera	Lady bird beetle	0	0	1	1	0.5
Total		215	320	128	220	

Table D55: Total number of insects representing each order on ultra-violet light in 7th day

Insect order	Insect name	Time (h)				Population mean
		19-20	20-21	21-22	04-06	
Hemiptera	Red cotton bug	39	44	13	23	29.75
	Aphides	19	35	7	7	17
	Whitefly	42	71	29	40	45.5
	Leaf hopper	7	29	11	21	17
	Dusky cotton bug	2	3	2	2	2.25
Lepidoptera	Leaf miner	51	21	15	13	25
	Pink bollworm	26	75	16	57	43.5
	American bollworm	29	38	13	34	28.5
Diptera	Mosquitoes	0	5	23	24	13
Coleoptera	Lady bird beetle	0	0	0	0	0
Total		215	321	129	221	

Table D56: Total number of insects representing each order on ultra-violet light in 8th day

Insect order	Insect name	Time (h)				Population mean
		19-20	20-21	21-22	04-06	
Hemiptera	Red cotton bug	41	47	13	23	31
	Aphides	19	35	7	9	17.5
	Whitefly	42	71	29	40	45.5
	Leaf hopper	7	29	11	22	17.25
	Dusky cotton bug	0	5	2	2	2.25
Lepidoptera	Leaf miner	53	23	17	17	27.5
	Pink bollworm	27	77	17	59	45
	American bollworm	29	38	13	34	28.5
Diptera	Mosquitoes	5	5	24	24	14.5
Coleoptera	Lady bird beetle	0	0	2	1	0.75
Total		223	330	135	231	

Table D57: Total number of insects representing each order on ultra-violet light in 9th day

Insect order	Insect name	Time (h)				Population mean
		19-20	20-21	21-22	04-06	
Hemiptera	Red cotton bug	41	49	13	23	31.5
	Aphides	19	35	7	9	17.5
	Whitefly	42	71	29	40	45.5
	Leaf hopper	7	29	11	22	17.25
	Dusky cotton bug	0	5	2	2	2.25
Lepidoptera	Leaf miner	51	21	15	13	25
	Pink bollworm	26	77	16	57	44
	American bollworm	29	38	13	34	28.5
Diptera	Mosquitoes	6	12	24	25	16.75
Coleoptera	Lady bird beetle	0	1	2	1	1
Total		221	338	132	226	

Table D58: Total number of insects representing each order on ultra-violet light in 10th day

Insect order	Insect name	Time (h)				Population mean
		19-20	20-21	21-22	04-06	
Hemiptera	Red cotton bug	47	51	17	28	35.75
	Aphides	19	37	7	11	18.5
	Whitefly	43	73	29	40	46.25
	Leaf hopper	7	29	11	22	17.25
	Dusky cotton bug	0	5	2	2	2.25
Lepidoptera	Leaf miner	53	21	15	13	25.5
	Pink bollworm	26	78	19	57	45
	American bollworm	29	38	13	34	28.5
Diptera	Mosquitoes	11	12	24	25	18
Coleoptera	Lady bird beetle	0	2	4	1	1.75
Total		235	346	141	233	

Table D59: Total number of insects representing each order on ultra-violet light in 11th day

Insect order	Insect name	Time (h)				Population mean
		19-20	20-21	21-22	04-06	
Hemiptera	Red cotton bug	47	53	17	29	36.5
	Aphides	21	39	11	17	22
	Whitefly	43	73	29	40	46.25
	Leaf hopper	11	31	11	22	18.75
	Dusky cotton bug	0	5	2	2	2.25
Lepidoptera	Leaf miner	53	21	16	13	25.75
	Pink bollworm	29	79	19	57	46
	American bollworm	31	39	13	35	29.5
Diptera	Mosquitoes	21	12	24	35	23
Coleoptera	Lady bird beetle	0	0	0	0	0
Total		256	352	142	250	

Table D60: Total number of insects representing each order on ultra-violet light in 12th day

Insect order	Insect name	Time (h)				Population mean
		19-20	20-21	21-22	04-06	
Hemiptera	Red cotton bug	44	53	17	29	35.75
	Aphides	21	39	10	17	21.75
	Whitefly	43	73	29	39	46
	Leaf hopper	10	31	11	22	18.5
	Dusky cotton bug	1	4	2	2	2.25
Lepidoptera	Leaf miner	55	21	17	16	27.25
	Pink bollworm	29	79	19	57	46
	American bollworm	33	41	13	35	30.5
Diptera	Mosquitoes	21	11	24	35	22.75
Coleoptera	Lady bird beetle	0	0	1	0	0.25
Total		257	352	143	252	

Table D61: Total number of insects representing each order on ultra-violet light in 13th day

Insect order	Insect name	Time (h)				Population mean
		19-20	20-21	21-22	04-06	
Hemiptera	Red cotton bug	43	52	17	29	35.25
	Aphides	21	39	9	17	21.5
	Whitefly	43	73	29	38	45.75
	Leaf hopper	10	31	11	22	18.5
	Dusky cotton bug	1	4	2	2	2.25
Lepidoptera	Leaf miner	51	21	17	16	26.25
	Pink bollworm	29	75	19	57	45
	American bollworm	33	41	12	35	30.25
Diptera	Mosquitoes	20	10	22	35	21.75
Coleoptera	Lady bird beetle	0	0	1	1	0.5
Total		251	346	139	252	

Table D62: Total number of insects representing each order on ultra-violet light in 14th day

Insect order	Insect name	Time (h)				Population mean
		19-20	20-21	21-22	04-06	
Hemiptera	Red cotton bug	39	49	15	27	32.5
	Aphides	21	39	9	15	21
	Whitefly	41	72	27	35	43.75
	Leaf hopper	9	29	11	22	17.75
	Dusky cotton bug	1	4	2	2	2.25
Lepidoptera	Leaf miner	49	21	17	14	25.25
	Pink bollworm	29	75	19	55	44.5
	American bollworm	33	41	12	35	30.25
Diptera	Mosquitoes	20	10	22	37	22.25
Coleoptera	Lady bird beetle	0	0	0	1	0.25
Total		242	340	134	243	

Table D63: Total number of insects representing each order on ultra-violet light in 15th day

Insect order	Insect name	Time (h)				Population mean
		19-20	20-21	21-22	04-06	
Hemiptera	Red cotton bug	30	41	14	25	27.5
	Aphides	21	39	9	14	20.75
	Whitefly	41	72	27	35	43.75
	Leaf hopper	9	29	11	22	17.75
	Dusky cotton bug	1	4	2	2	2.25
Lepidoptera	Leaf miner	40	21	17	14	23
	Pink bollworm	27	73	18	53	42.75
	American bollworm	33	41	12	35	30.25
Diptera	Mosquitoes	20	3	22	37	20.5
Coleoptera	Lady bird beetle	0	0	0	0	0
Total		222	323	132	237	

Table D64: Total number of insects representing each order on ultra-violet light in 16th day

Insect order	Insect name	Time (h)				Population mean
		19-20	20-21	21-22	04-06	
Hemiptera	Red cotton bug	15	31	14	25	21.25
	Aphides	21	39	9	14	20.75
	Whitefly	38	72	27	35	43
	Leaf hopper	9	29	11	22	17.75
	Dusky cotton bug	1	4	2	2	2.25
Lepidoptera	Leaf miner	38	21	17	14	22.5
	Pink bollworm	25	73	18	53	42.25
	American bollworm	33	39	12	33	29.25
Diptera	Mosquitoes	20	3	20	37	20
Coleoptera	Lady bird beetle	0	0	1	0	0.25
Total		200	311	131	235	

Table D65: Total number of insects representing each order on ultra-violet light in 17th day

Insect order	Insect name	Time (h)				Population mean
		19-20	20-21	21-22	04-06	
Hemiptera	Red cotton bug	11	29	11	21	18
	Aphides	21	39	9	14	20.75
	Whitefly	38	72	27	35	43
	Leaf hopper	9	29	11	22	17.75
	Dusky cotton bug	1	4	2	2	2.25
Lepidoptera	Leaf miner	38	21	17	14	22.5
	Pink bollworm	15	53	18	23	27.25
	American bollworm	33	39	12	33	29.25
Diptera	Mosquitoes	18	3	20	37	19.5
Coleoptera	Lady bird beetle	0	0	0	0	0
Total		184	289	127	201	

Table D66: Total number of insects representing each order on ultra-violet light in 18th day

Insect order	Insect name	Time (h)				Population mean
		19-20	20-21	21-22	04-06	
Hemiptera	Red cotton bug	11	21	12	20	16
	Aphides	21	39	9	14	20.75
	Whitefly	38	72	27	35	43
	Leaf hopper	9	29	11	22	17.75
	Dusky cotton bug	1	4	2	2	2.25
Lepidoptera	Leaf miner	30	21	17	14	20.5
	Pink bollworm	10	43	17	20	22.5
	American bollworm	31	30	12	33	26.5
Diptera	Mosquitoes	10	4	20	37	17.75
Coleoptera	Lady bird beetle	0	0	0	0	0
Total		161	263	127	197	

Table D67: Total number of insects representing each order on ultra-violet light in 19th day

Insect order	Insect name	Time (h)				Population mean
		19-20	20-21	21-22	04-06	
Hemiptera	Red cotton bug	9	21	11	18	14.75
	Aphides	21	39	9	13	20.5
	Whitefly	38	72	27	35	43
	Leaf hopper	9	29	11	22	17.75
	Dusky cotton bug	1	4	2	2	2.25
Lepidoptera	Leaf miner	30	21	17	14	20.5
	Pink bollworm	8	41	17	15	20.25
	American bollworm	31	28	11	31	25.25
Diptera	Mosquitoes	0	5	20	37	15.5
Coleoptera	Lady bird beetle	0	0	0	0	0
Total		147	260	125	187	

Table D68: Total number of insects representing each order on ultra-violet light in 20th day

Insect order	Insect name	Time (h)				Population mean
		19-20	20-21	21-22	04-06	
Hemiptera	Red cotton bug	9	18	7	15	12.25
	Aphides	21	39	9	13	20.5
	Whitefly	38	72	27	33	42.5
	Leaf hopper	9	29	11	22	17.75
	Dusky cotton bug	1	4	2	2	2.25
Lepidoptera	Leaf miner	30	21	17	13	20.25
	Pink bollworm	8	31	17	15	17.75
	American bollworm	30	25	11	30	24
Diptera	Mosquitoes	0	0	21	36	14.25
Coleoptera	Lady bird beetle	0	0	0	0	0
Total		146	239	122	179	

Table D69: Total number of insects representing each order on ultra-violet light in 21st day

Insect order	Insect name	Time (h)				Population mean
		19-20	20-21	21-22	04-06	
Hemiptera	Red cotton bug	9	18	7	15	12.25
	Aphides	20	30	8	13	17.75
	Whitefly	38	72	27	33	42.5
	Leaf hopper	9	29	11	22	17.75
	Dusky cotton bug	1	4	2	2	2.25
Lepidoptera	Leaf miner	15	21	17	13	16.5
	Pink bollworm	8	31	17	15	17.75
	American bollworm	29	26	11	30	24
Diptera	Mosquitoes	0	20	10	9	9.75
Coleoptera	Lady bird beetle	0	0	0	0	0
Total		129	251	110	152	

Table D70: Total number of insects representing each order on ultra-violet light in 22nd day

Insect order	Insect name	Time (h)				Population mean
		19-20	20-21	21-22	04-06	
Hemiptera	Red cotton bug	4	20	1	13	9.5
	Aphides	20	30	8	13	17.75
	Whitefly	38	72	27	33	42.5
	Leaf hopper	9	29	11	22	17.75
	Dusky cotton bug	1	4	2	2	2.25
Lepidoptera	Leaf miner	15	21	17	13	16.5
	Pink bollworm	3	26	10	15	13.5
	American bollworm	29	26	11	26	23
Diptera	Mosquitoes	0	0	10	13	5.75
Coleoptera	Lady bird beetle	0	0	0	0	0
Total		119	228	97	150	

Table D71: Total number of insects representing each order on ultra-violet light in 23rd day

Insect order	Insect name	Time (h)				Population mean
		19-20	20-21	21-22	04-06	
Hemiptera	Red cotton bug	4	18	1	13	9
	Aphides	18	30	8	13	17.25
	Whitefly	37	70	27	33	41.75
	Leaf hopper	9	29	11	22	17.75
	Dusky cotton bug	1	4	2	2	2.25
Lepidoptera	Leaf miner	15	21	17	13	16.5
	Pink bollworm	3	20	9	15	11.75
	American bollworm	29	16	11	26	20.5
Diptera	Mosquitoes	0	0	10	4	3.5
Coleoptera	Lady bird beetle	0	0	0	0	0
Total		116	208	96	141	

Table D72: Total number of insects representing each order on ultra-violet light in 24th day

Insect order	Insect name	Time (h)				Population mean
		19-20	20-21	21-22	04-06	
Hemiptera	Red cotton bug	4	10	1	13	7
	Aphides	15	28	8	13	16
	Whitefly	37	70	27	33	41.75
	Leaf hopper	9	29	11	22	17.75
	Dusky cotton bug	1	4	2	2	2.25
Lepidoptera	Leaf miner	14	19	17	11	15.25
	Pink bollworm	3	21	10	9	10.75
	American bollworm	19	16	11	26	18
Diptera	Mosquitoes	0	0	5	4	2.25
Coleoptera	Lady bird beetle	0	0	0	0	0
Total		102	197	92	133	

Table D73: Total number of insects representing each order on blue light

Order / Day	Lepidoptera	Hemiptera	Diptera	Coleoptera	Population mean
1st	150	162	16	0	82.00
2nd	156	160	20	0	84.00
3rd	171	164	21	0	89.00
4th	170	170	23	0	92.75
5th	172	178	23	1	95.75
6th	182	181	24	3	97.50
7th	179	169	27	5	95.00
8th	171	187	28	0	96.50
9th	169	191	31	7	99.50
10th	168	192	33	0	98.25
11th	184	195	31	1	101.25
12th	183	191	23	0	96.50
13th	136	187	12	0	83.75
14th	112	171	9	0	73.00
15th	109	156	7	0	68.00
16th	107	142	0	0	62.25
17th	108	131	0	0	59.75
18th	102	112	0	0	53.50
19th	96	101	2	0	49.75
20th	73	96	0	0	42.25
21st	54	74	0	0	32.00
22nd	37	56	0	0	23.25
23rd	24	42	0	0	16.50
24th	13	38	1	0	13.00
Total	3026	3446	331	17	

Table D74: Total number of insects representing each order on yellow light

Order Date	Lepidoptera	Hemiptera	Diptera	Coleoptera	Population mean
1st	172	181	17	0	92.50
2nd	169	178	21	0	92.00
3rd	178	180	18	0	94.00
4th	174	179	23	0	94.00
5th	179	183	21	1	95.75
6th	181	191	20	2	98.75
7th	184	196	24	2	101.50
8th	191	201	27	0	104.75
9th	195	213	35	3	111.50
10th	201	241	38	4	121.00
11th	221	244	42	5	128.00
12th	212	238	39	0	122.25
13th	203	210	40	0	113.25
14th	189	196	12	0	99.25
15th	173	184	3	1	90.25
16th	154	174	0	0	82.00
17th	144	167	0	0	77.75
18th	132	148	6	0	71.50
19th	112	139	1	0	63.00
20th	97	122	0	0	54.75
21st	84	109	0	0	48.25
22nd	56	91	0	0	36.75
23rd	41	87	0	0	32.00
24th	29	71	0	0	25.00
Total	3671	4123	387	18	

Table D75: Total number of insects representing each order on ultra-violet light

Order / Date	Lepidoptera	Hemiptera	Diptera	Coleoptera	Population mean
1st	370	421	41	0	208.00
2nd	375	420	40	0	208.75
3rd	378	424	39	0	210.25
4th	382	431	42	0	213.75
5th	397	442	46	0	221.25
6th	386	448	48	2	221.00
7th	387	451	52	0	222.50
8th	371	459	59	3	223.00
9th	389	461	67	4	230.25
10th	395	486	72	7	240.00
11th	402	510	92	0	251.00
12th	412	503	91	1	251.75
13th	403	496	87	2	247.00
14th	397	472	89	1	239.75
15th	381	451	82	0	228.50
16th	373	423	81	1	219.50
17th	323	410	79	0	203.00
18th	284	402	72	0	189.50
19th	270	396	63	0	182.25
20th	254	384	57	0	173.75
21st	239	372	39	0	162.50
22nd	218	361	23	0	150.50
23rd	191	354	14	0	139.75
24th	172	341	09	0	130.50
Total	8149	10318	1384	21	

APPENDIX (E)

Cash flow and outflow statement for solar photovoltaic insect light trap

Year	Cash Outflow	PW cash Outflow	Cash Inflow	PW of Cash Inflow	NPV
1	2	3	4	5	(5-3)
0	6000	6000.00	0	0	-6000.00
1	600	545.45	2856	2596.36	2050.91
2	600	495.87	2856	2360.33	1864.46
3	600	450.79	2856	2145.76	1694.97
4	600	409.81	2856	1950.69	1540.88
5	600	372.55	2856	1773.35	1400.80
6	600	338.68	2856	1612.14	1273.45
7	600	307.89	2856	1465.58	1157.68
8	600	279.90	2856	1332.35	1052.44
9	600	254.46	2856	1211.22	956.76
10	600	231.33	2856	1101.11	869.79
11	600	210.30	2856	1001.01	790.71
12	600	191.18	2856	910.01	718.83
		10088.22		19459.90	9371.69
				NPV	9371.69
				B:C ratio	1.93

Payback Periods for solar photovoltaic insect light trap

Year	PW of total cash outflow in 12 years, Rs	Cash Inflow Rs.	Present worth of cash inflow	Cumulative cash inflow
0	10088.22	-	-	-
1		2856	2596.36	2596.36
2		2856	2360.33	4956.69
3		2856	2145.76	7102.45
4		2856	1950.69	9053.14

Payback Period = 2 year, 1 month.

VITA

1. Name of Student : Gavhande Ajay Murlidhar
2. Date of Birth : 12/03/1993
3. Name of Collage : Post Graduate Institute
   Dr. PDKV, Akola
4. Residential address
   along with phone no. : At Post : Kherda
   Taluka : Jalgaon Jamod
   Dist : Buldana
   Pin : 443 402
   Mo.No : 9922668947
5. Email. : ajaygavhande3@gmail.com
6. Academic qualifications:

Sr. No	Name of degrees awarded	Year in which obtained	Division /class	Name of awarding university	Subjects
1.	B.Tech. (Agril. Engg.)	2015	Second	Dr. PDKV, Akola	RES,FMP,SWCE, IDE and APE

7. Field of interest : Research and Development

Place: Akola **(Gavhande Ajay Murlidhar)**

Date: / /2018 Signature of student