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The Potential of visible light spectra as control measure of Mosquito, the vector of *Plasmodium*

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ABSTRACT

The control and or eradication of Mosquito, the vector of *Plasmodium*, is a major aspect of the prevention or eradication of malaria. The study investigated the potential of visible light spectra in the control of mosquito. Mosquito larvae were irradiated with light (blue, green, yellow, red and white lights) two hours daily (8am – 10am) for fourteen days. Ambient light served as the Control treatment. The irradiation (640 lux) was by 25 watts incandescent bulbs inside aluminum foil wrapped in plastic containers. 10 newly hatched mosquito larvae were exposed under each treatment replicated thrice. Development of larvae to pupae, pupae to adult and mortality of larvae, pupa and adult were recorded daily. Data obtained were expressed as percentages, mean(\pm SD) and compared by analysis of variance; significant means were separated by Duncan multiple range test at $p < 0.05$. Larvae mortality was significantly ($p < 0.05$) higher under the coloured lights compared to the control; yellow light elicited the highest significant ($p < 0.05$) larvae mortality (8.17 ± 4.08 ; 81.7%), followed by white (5.33 ± 5.16), blue (5.17 ± 4.08), green (4.83 ± 4.08) and red (4.00 ± 8.94) lights. The percentage of undeveloped larvae was significantly ($p < 0.05$) the highest under blue light. While yellow light resulted in highest larvae mortality and blue light suppressed larvae development. Yellow and blue light therefore, have the potential for use as environment friendly means of controlling mosquito.

Key word: light spectra, mosquito, malaria control, larvae mortality

1. INTRODUCTION

Artificial light is recently being researched upon due to the discovery of its potential in influencing animal physiology, psychology and behavior. Artificial light is sometime considered as a pollutant because of its interruption with the activities of some nocturnal animals mostly invertebrate like insects, moth, turtle and some vertebrates like bats and migrating birds. Artificial light is sometime considered as enhancing agent, and on this view, it has been used extensively in poultry to boost egg production, meat quality, growth and immune system. A good number of researchers have documented the ecological consequences of artificial light in the areas of causing habitat fragmentation, aggregating insects making them vulnerable to predation, reducing the population of insect as well as preventing some nocturnal animals from foraging (Moore *et al.*, 2000; Longcore and Rich, 2004; Wise and Buchanan, 2006; Elena and Paolo,



2010; Charlotte and Matt, 2011 and Davies *et al.* 2012). Also in entomology, artificial lights have been used extensively to control pest (Shimoda and Honda, 2013).

The effect of light on animals to a large extent is spectra specific (Fabio *et al.*, 2011 and Masatoshi *et al.*, 2014). This is evidence from series of researches conducted and for instance, in an experiment conducted by Fabio *et al.* (2011), it was discovered that the amount of light pollution is strongly dependent on the spectral characteristics of the lamps. Though, some of these effects were as a result of visual impairment imposed by a specific spectrum as the case of migrating birds that could not migrate under red light (Poot *et al.*, 2008) and mice that could not forage on exposure to yellow and red light at night (Wise and Buchanan, 2006). Direct physiological responses of animals to light have been attributed to the effect of light like suppression of melatonin by blue and green light in mammals (Cajochen *et al.*, 2005, Hardt, 2011 and Fabio *et al.*, 2011), red light increasing female reproductive hormone in geese (Chang *et al.*, 2016) and white light prevent metamorphosis in tadpole (Wise, 2007).

Moreover, Blue light was reported to increase oxidative stress in insects such as the cotton bollworm *Helicoverpa armigera* (Meng *et al.*, 2009). Blue light was also reported to kill the eggs, larvae, pupae, and adults of *Drosophila melanogaster* and pupae of mosquito, *Culex pipiens molestus* (Masatoshi *et al.* (2014).

Mosquitoes are insects and all belong to the family – Culicidae. The family Culicidae is divided into three Sub Families, Namely; *Toxorhynchitinae*, *Anophelinae* and *Culicinae*, (Service, 1993). There are more than 4500 species of mosquitoes distributed throughout the world in 34 genera; but mostly belongs to *Aedes*, *Anopheles* and *Culex* (Ghosh *et al.*, 2013). Mosquitoes are widely distributed throughout the world and they utilize different water bodies for their breeding (WHO, 1982). Mosquitoes exploit almost all types of lentic aquatic habitats for breeding and larvae of mosquitoes have been found to thrive in aquatic bodies such as fresh or salt water marshes, mangrove swamps, rice fields, grassy ditches, the edges of streams and rivers and small, temporary rain pools (Afolabi *et al.*, 2013). Unplanned urban growth, inadequate waste disposal, irrigation and poor drainage usually alter ecosystem and thus promote prolific breeding of mosquitoes (Adeleke *et al.*, 2013).

Mosquitoes are blood sucking insect for its ability to transmit several dreadful pathogens. This is made possible through the female mosquito that feed predominantly on blood. Some of the mosquito-borne diseases include; malaria which is caused by *Apicomplexa plasmodium*, yellow fever caused by virus, Encephalitis, dengue fever called breakbone fever also a viral disease. Others pathogen transmitted by mosquito include; Canine Heartworm, West Nile and Sentinel Chicken Flocks (Technical Learning College, 2017).

Of all the aforementioned diseases, malaria is more predominant and found throughout the tropical and sub-tropical regions of the world. Zaki and Shanbag (2011) reported that 300–500 million people contract malaria each year and resulting in 1.5–2.7 million deaths annually. Several measures have been put in place to prevent malaria by controlling the vector responsible for its transmission. Some of the methods used to control mosquito include; chemical method, these are insecticides that are active against the adult (adulticides) as well as the larva (larvicides) and pupa. Examples of adulticides include organophosphates, natural pyrethrins and synthetic pyrethroids (Technical Learning College, 2017). One of the limitations to chemical method is that some mosquitoes have developed resistance to insecticides.

Biological methods employed include; predators like fish (*Gambusia* species), tadpoles, frogs and toads (Collins & Blackwell, 2000) and pathogens which include viruses (iridescent and cytoplasmic polyhedrosis viruses), bacteria (*Bacillus thuringiensis* and *B. Sphaericus*), Protozoa

(*Nosema* and *Thelomania*) and fungi (*Coelomomyces*, *Lagenidium* and *Culicinomyces*) (Service, 1980). Biological methods are effective in controlling the larvae.

Environmental management is another mean used in controlling mosquito of all stages. It aimed in reducing the number of mosquito habitats or reducing biting by adult mosquitoes. A simple form of control consists of filling in of all available mosquito larval habitats with soil and gravels. All the above mention methods are with their various implications on non target organisms and cost implication.

Recently, in a research conducted by Sheppard *et al.* (2017), light was used to manipulate the behaviour of mosquito. Mosquitoes were exposed to a pulse of white light for 6 - 10 minutes at night and the result obtained showed that there was a significant reduction in mosquito bite over a period of two hours after the exposure (Sheppard *et al.*, 2017). Their resolution when embarking on the research was that there is need to discover 'new methods' to address the control of mosquito and prevention as well. This is because the systems and tools currently in use such as global distribution and usage of insecticide-treated bed nets and spraying are not enough (Science Daily, 2017). Therefore, this study was aimed to examine the potential effects of light spectra on various stages of development of mosquito.

2. MATERIALS AND METHODS

2.1 Study Area

The research was conducted in Pure and Applied Zoology Laboratory of Federal University of Agriculture Abeokuta, Ogun State Nigeria.

Larvae Breeding

Mosquito larvae were bred at Oluwo Keesin, a community opposite FUNAAB Zoo Park. 10 litres capacity bucket were fill with rain water to about 5/6 of its capacity and were placed in bushy area for about 8 – 11 days, this served as breeding site for adult mosquitoes. They were observed daily as from day 4 for egg clustering and emergence of larva. Larvae started emerging day 10 and were collected, transferred to the laboratory for light treatment using two clean 4 litres bowls. On collection of the larvae, water was first decanted from the bucket to the level that the larvae were collected with spoon to avoid stress. Picking method was adopted; spoon was used to collect the larvae into the bowl containing water.

2.2 Description of Containers for Light Exposure/Treatment

18 white round plastic of 18 by 20cm dimension were procured for the research. 15 of the plastic were wrapped with aluminium foil each so as to avoid external source of light from the environment into plastic. Lamp holders were attached to the centre portion of the covers and bulbs were fixed so as to distribute light uniformly within the plastic. To ensure ventilation, parts of the covers were removed and replaced with wire mesh which prevented adult mosquito from escaped. Cables were connected with the lamp holder and finally connected to a switch in a parallel circuitry. Also there were perforations on the top of the cover where thermometer was inserted to monitor the temperature.

2.3 Light treatment

25 watt incandescent bulbs of various colours were used for the exposure. The colours include; blue, green, yellow, red and white. The light intensity was regulated at 640lux and monitored using light meter. Light exposure was done for 14 day and on daily basis the mosquito larvae were irradiated with artificial light for two hours between 8 am and 10 am. There were six

exposures include the ambient condition which serves as the control and per each treatment there were three replicates. The experiment was run for two consecutive times which resulted into six replicate per treatment.

Introduction of larvae into the experimental container

The containers were fill with water up to 8 centimeter from the bottom, 10 mosquito larvae were gently introduced into each container. This was done the evening prior to the irradiation in the second day. The temperature was taken and recorded before and after the irradiation.

Records of stages of development and mortality of larva, pupa and adult

On daily basis after the irradiation, the following parameters were taken; mortality of larva, development into pupa, development into adult, pupa mortality and adult mortality, and at the end of 14, the undeveloped were also recorded. The readings were taken by viewing through the lid and the counting done and recorded accordingly in a pre-ruled booklet with the appropriate headings. The reading was taken for fourteen days and the research ran twice.

2.4 Statistical analysis

The data obtained were subjected to descriptive analysis, test of variance was done using ANOVA and the means were separated by Duncan multiple comparisons using SPSS version 20 package.

3. RESULTS

Table 1.0 shows the effect of light spectra on various stages of mosquito development on exposure for 14 days. Larva mortality was significantly ($P < 0.05$) high on exposure to monochromatic and polychromatic light as compared to the control. Mortality on exposure to yellow light recorded the highest significant value ($8.17 \pm .408$), followed by white ($5.33 \pm .516$), blue ($5.17 \pm .408$), green ($4.83 \pm .408$) and red ($4.00 \pm .894$) lights. Development of larva to pupa was significantly high ($P < 0.05$) control ($9.83 \pm .408$) compared to light treatment, the least and significant was recorded on exposure to yellow light ($1.33 \pm .516$). Pupa mortality was not significantly different among the treatments as compared with control but the highest value was recorded on exposure to green light ($0.33 \pm .816$). The development of pupa to adult and adult mortality recorded the highest significant ($P < 0.05$) value in control ($9.83 \pm .408$) and the least significant ($P < 0.05$) was recorded on exposure to yellow light ($1.17 \pm .408$). Undeveloped larva recorded the highest significant ($P < 0.05$) value on exposure to blue light ($2.00 \pm .632$) and the lowest significant value was recorded in ambient condition (control) (0.00 ± 0.000) in which there was no larva that did not develop to pupa.

Fig. 1.0 showed daily mortality in mosquito larva on exposure to light of varying wavelength for fourteen days. Mortality began in day 2 under green blue and yellow lights. Mortality increased sharply under yellow light from day 2 till day 4 and dropped till day 6. The peak in mortality on exposure to yellow light was in day 8 and as at day nine all the larvae had died. Peak in mortality of larva under red light was in day 4 and all died by day 10. The peak mortality under blue light was recorded in day 8. Mortality ended on exposure to green light on day 6 and the shortest so far among the light treatments. Peak mortality under white light was in day 6.

Fig. 2.0 showed the trend in daily mortality of mosquito larva on exposure to light of varying wavelength for fourteen days. The pattern observed among the light colours was similar except for yellow light which shoot up as from day 8 and continued persistently till day 10. The trend observed under control remained at the base since only one larva died. The figure showed the

Table 1: Effect of light spectra on various stages of mosquito development on exposure for 14 days

Light treatments	Larva mortality	Development of larva to Pupa	Pupa mortality	Development of pupa to Adult	Adult mortality	Undeveloped larva
Ambient	0.17±.408 ^a	9.83±.408 ^c	0.00±0.000 ^a	9.83±.408 ^c	9.83±.408 ^d	0.00±0.000 ^a
Blue	5.17±.408 ^c	2.83±.753 ^b	0.17±.408 ^a	2.67±.816 ^b	2.67±.816 ^b	2.00±.632 ^d
Green	4.83±.408 ^c	3.67±.816 ^c	0.33±.816 ^a	3.33±1.366 ^{bc}	3.33±1.366 ^{bc}	1.50±.837 ^{cd}
Red	4.00±.894 ^b	5.17±.753 ^d	0.00±0.000 ^a	5.17±.753 ^d	4.33±2.251 ^c	0.83±.753 ^{bc}
White	5.33±.516 ^c	3.83±.753 ^c	0.00±0.000 ^a	3.83±.753 ^c	3.83±.753 ^{bc}	0.83±.408 ^{bc}
Yellow	8.17±.408 ^d	1.33±.516 ^a	0.17±.408 ^a	1.17±.408 ^a	1.17±.408 ^a	0.50±.548 ^{ab}

Means with different superscript in a column are significantly different (P < 0.05)

Note: n = 6

highest mortality of larva on exposure to yellow light followed by white light, blue light, green light, green light and red light in that order.

Fig. 3.0 showed daily development of pupa to adult of mosquito on exposure to light of varying wavelength for fourteen days. Development from pupa to adult began in day 4 across the light exposure. Development of pupa increased sharply from day 4 till day 6 and dropped sharply till day 8, and as at day 8 all have developed to adult. Development of pupa to adult was consistent from day 4 till day 10 under red light. Development of pupa to adult was inconsistent under blue, yellow and white light. It decreased under green light from day 5 till day 9 raised little till day 10.

Fig. 4.0 shows the daily trend in development of mosquito pupa to adult on exposure to light of varying wavelength for fourteen days. It increased sharply from day 4 till day 7 and thereafter increased slightly till day 8 under ambient condition. it increased consistently gradually from day 4 till day 10 under red light. The trend observed under red light was also the same under white light till day 7 after which it dropped gradually till day 10. The development of pupa to adult increased slightly under green and yellow lights from day 4 till day 10. It increased slightly from day 4 till day 7 and thereafter increased gradually too day 8.

Fig. 5.0 shows the percentage of larva of mosquito, that developed to adult, mortality, and undeveloped on exposure to light of varying wavelength for fourteen days. Under ambient condition, the development of larva to adult was 98.3%, 1.67% mortality and 0% undeveloped.

Percentage mortality, development to adult and undeveloped larva under yellow light is (81.7, 11.7 and 5.0% respectively). The undeveloped larva at the end of 14 days exposure had the highest percentage under blue light (20%). Fig. 6 shows the daily mortality of adult mosquito on exposure to light of varying wavelength for fourteen days. Mortality of adult mosquito started in day four under yellow and blue light and all adults under yellow light died by day 9. Mortality started in day five under other treatments and continued till day 14. As at day 14 the only surviving adult was under red light. Mortality reached the peak in day 7 under yellow and green lights. Two peak mortality periods were recorded under red and white light, both have peak in day 8, and day 10 and 14 under white and red respectively. Mortality reached the peak in day 9 under ambient condition and continued till day 14.

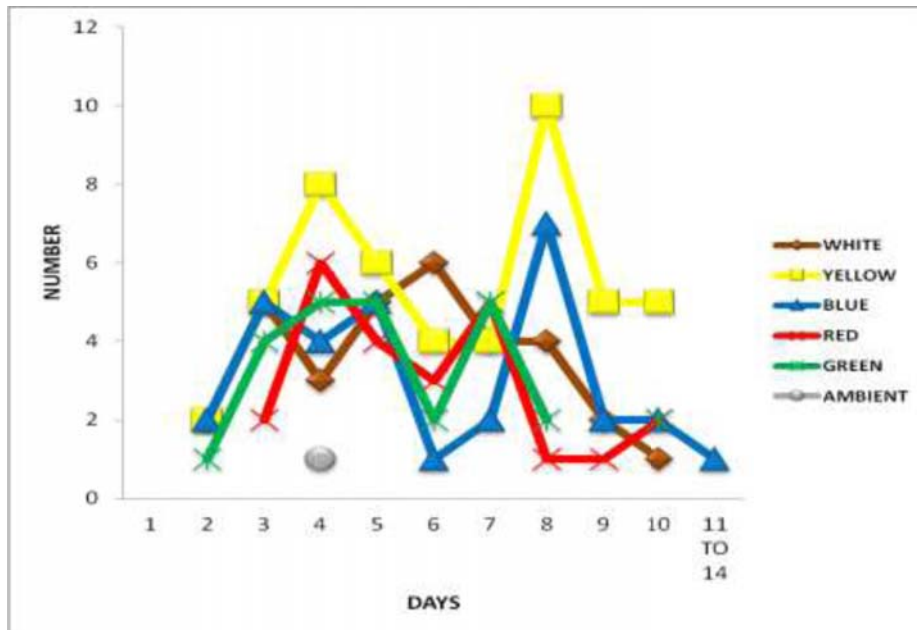


Fig. 1.0 Daily mortality in mosquito larva on exposure to light of varying wavelength for fourteen days

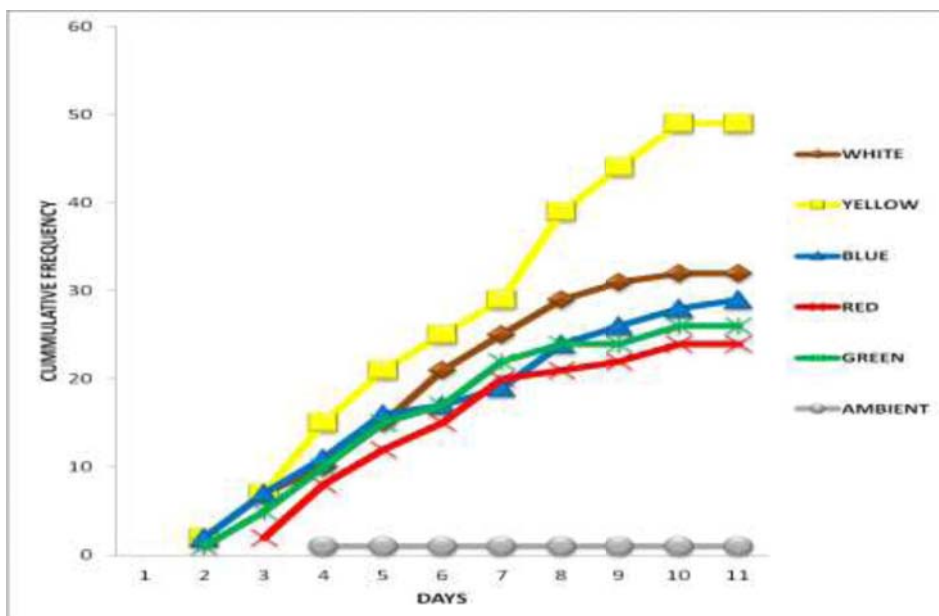


Fig. 2.0 Trend in daily mortality of mosquito larva on exposure to light of varying wavelength for fourteen days

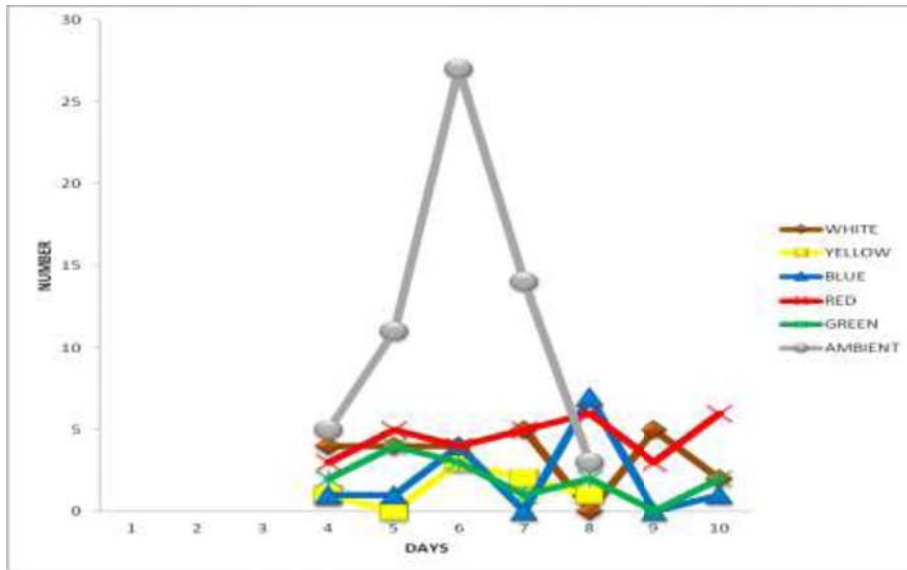


Fig. 3.0 Daily development of pupa to adult of mosquito on exposure to light of varying wavelength for fourteen days

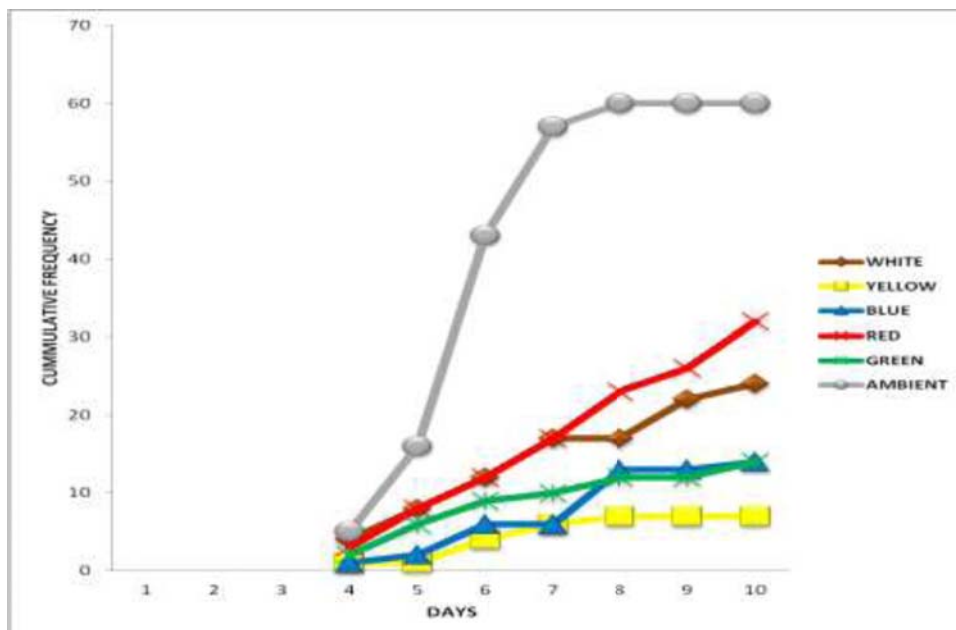


Fig. 4.0 Daily trend in development of mosquito pupa to adult on exposure to light of varying wavelength for fourteen days

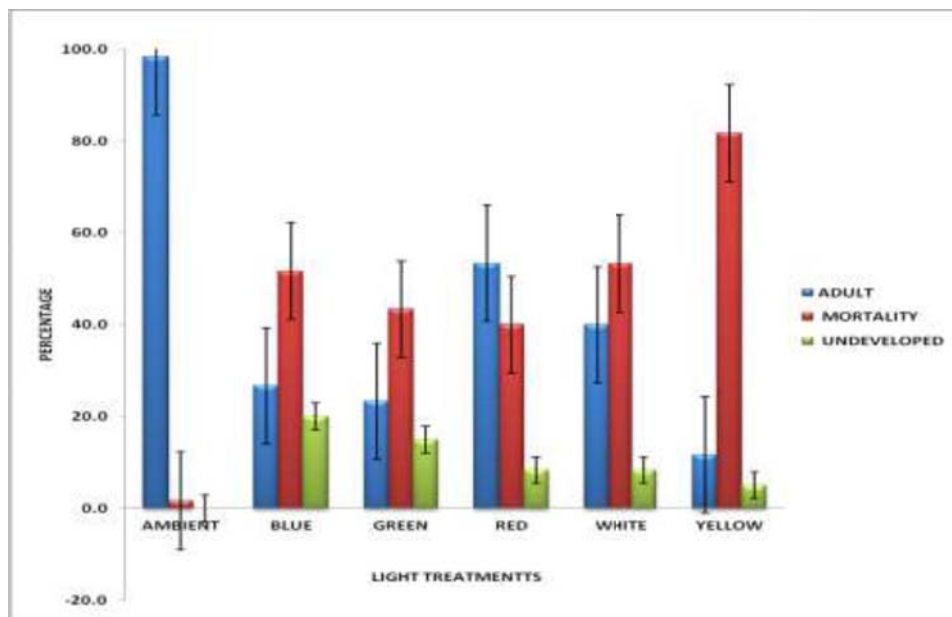


Fig. 5.0 Percentage of larva of mosquito that developed to adult, mortality, and undeveloped on exposure to light of varying wavelength for fourteen days

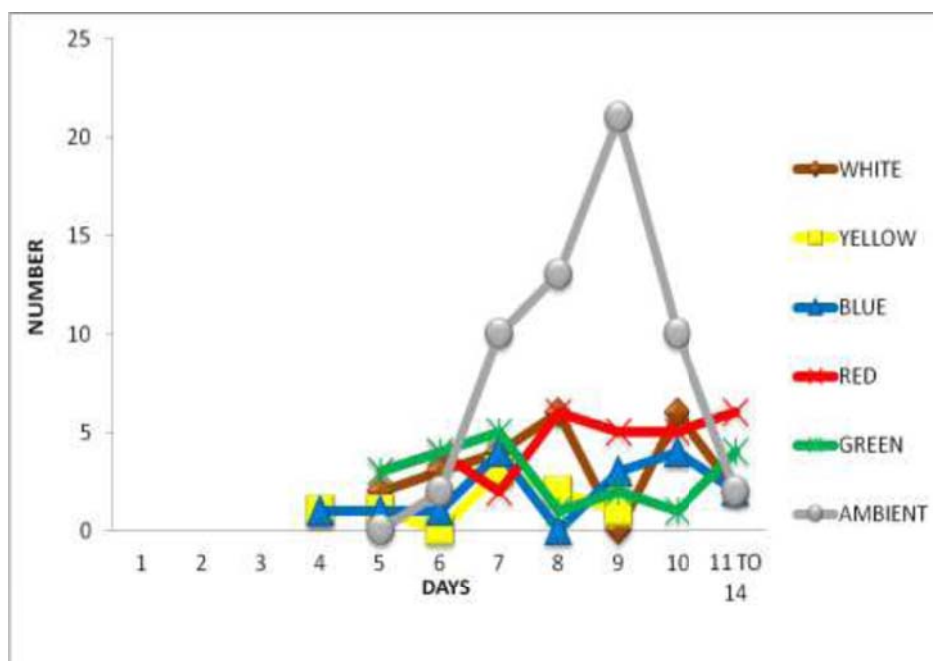


Fig. 6.0 Daily adult mortality on exposure to light of varying wavelength for fourteen days

4. DISCUSSION

Toxicity of visible light to insect was first reported by Masatoshi *et al.* (2014) in their study where they discovered that irradiation with blue light was lethal to all stages of drosophila (*Drosophila melanogaster*) developments, mosquito pupae (*Culex pipiens molestus*), and flour beetles pupae (*Tribolium confusum*). They submitted that blue light was lethal to these insects and that the light spectra effect was species-specific. Artificial light particularly blue light have

been reported to generate reactive oxygen species (ROS) in animals (Meng *et al.*, 2009, Lee *et al.*, 2014, Masatoshi *et al.*, 2014, Yoshida *et al.*, 2015 and Nakashima *et al.*, 2017). Most of the studies conducted to this effect did not investigate all the spectral of light but limited their investigation to blue, green and red lights. Dedeker *et al.* (2017) also reported that yellow and blue light reduced ($P < 0.05$) the activities of acetylcholinesterase in Giant Africa Land Snail.

This study investigated the light colour that could be used in controlling mosquito at various stages of development. The result showed that yellow light was more lethal to mosquito larva and adult than any other colour followed by blue, white, and green light. Mortality of larvae under coloured lights was significantly higher than the control. Mortality of larvae under yellow light was significantly higher than that of other coloured light. There was no significant difference in larva mortality between white, blue and green but higher value was recorded under white light than blue and green. Also development to adult recorded the least significant value under yellow light. This is obvious from this study because more larvae have died before reaching the adult stage on exposure to yellow light. Apart from high mortality of larva under yellow light, the survival of adult was greatly reduced by yellow light as well. Mortality of adult extended till day 14 under other light treatment include the control and even went further under red light but by day 9 all adults have died under yellow light.

The high mortality of larva under yellow light was probably due to oxidative stress that might be induced by yellow light. This could be true as a result of clear cut demarcation between the mortality reported under coloured light as compared to the control. Red light recorded close margin with the control, this is probably due to its high wavelength and have been reported not to cause oxidative stress in live skin and mammal (Nakashima *et al.*, 2017).

Worth of note is also the undeveloped larva which was recorded under the coloured light. The highest and significant value was recorded under blue light followed by green light and the least under yellow light. Wise (2007) reported that tadpole exposed to white light did not undergo metamorphosis. The suppression of metamorphosis was probably as a result of suppression of hormone responsible for metamorphosis or interruption in the metabolic pathway of the metamorphosis hormone. Wise (2007) concluded that the undeveloped tadpole was as a result of suppression of metamorphosis hormone.

5. CONCLUSION

In conclusion, the toxicity of light spectra to the different stages of mosquito development is in order $Y > B > W > G > R > C$. Yellow light increased the rate of larva mortality and shorten longevity of adult, and blue light suppressed larva development. Yellow light produced more toxic effect on both the larva and adult mosquito and could be used as alternative means in controlling of mosquitoes. Blue light also suppressed the development of larvae but their future fate cannot be ascertained whether they will die or develop into next stage.

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