International Journal of Mosquito Research

ISSN: **2348-5906**
CODEN: **IJMRK2**
IJMR 2020; 7(3): 38-41
www.dipterajournal.com

Received: 19-03-2020
Accepted: 21-04-2020

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Aggregation of mosquitoes on black colour

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Abstract
Mosquitoes are the nuisance creatures for human being all over the world, as they are the causal agents for spreading various fatal diseases in the human population. Mosquitoes are said to be colour-blind, but, generally it is being observed that in the evening, they aggregate over the head of human beings with black hairs, black cars, and black clothes also. To study, whether there is any relation between the colour and aggregation of mosquitoes, an experiment was designed. Black, blue, green, red, white, orange, yellow, violet, and pink colour's chambers were used. The used colours have the wave length as; *viz.* black (0 nm) blue (450-495nm), green (495-570nm), red (620-750nm), white (400 -700 nm), orange (590-620 nm), yellow (570–590 nm), violet (350-450 nm), and pink (0 nm), colours were used as attractant to observe the maximum and minimum attraction of mosquitoes on different colours. The species of Culex and Anopheles mosquitoes were selected for present experiment. Large number of Culex and Anopheles mosquitoes was collected from field by aspirator, brought alive to laboratory in polythene bags, sorted out separately and specific number was released in the central chamber. Two trials were made with 500+10 and 600±10 mosquitoes. In first observation, out of the 500+10 mosquitoes, 465 ± 2 were found to be aggregated on black colour, on blue and green 10±1and 15±2 respectively, while other colours; red, white, orange yellow, violet and pink had no aggregation of mosquitoes. The second observation also showed that out of 600±10 mosquitoes, 565±5 were reported on black colour, while on blue and green colour 20±2, 14±2 respectively, no mosquito were found on the other colours, except the white having a single mosquito only. Which perception stimulates, the olfactory, visual or sensory organs helping in this behaviour? It needs further extensive investigations.

Keywords: Aggregation, mosquitoes, black colour

1. Introduction

The mosquitoes (Diptera: Culicidae) are medically important insects and the most widely spread in tropical and subtropical regions in the world. More than 500 million people are currently infected with mosquito-borne diseases, and more than 3 million people die every year from these infections [1]. Mosquitoes are one of the deadliest animals in the world which have the capability to carry and spread diseases in human beings around the world, and cause millions of deaths every year. In 2015, malaria alone caused 438 000 human deaths around the world. The worldwide incidence of dengue has risen up to 30-fold in the past 30 years due to the mosquitoes. Zika, dengue, chikungunya, and yellow fever diseases, all are transmitted to human beings by the *Aedes aegypti* mosquitoes.

There are more than 3,000 species of mosquitoes, but the members of three bear primary responsibility for the spread of human diseases. *Anopheles* mosquitoes are the only species known to carry malaria. They also transmit filariasis (also called elephantiasis) and encephalitis. *Culex* mosquitoes carry encephalitis, filariasis, and the West Nile virus. And *Aedes* mosquitoes, of which the voracious Asian tiger is a member, carry yellow fever, dengue, and encephalitis. They use olfactory cues for locating food sources (usually nectar), locating appropriate egg-laying sites, and, most importantly, finding human hosts [2]. A number of compounds secreted by humans have been shown to be mosquito attractants, including lactic acid from human skin and exhaled breath, 1-octen-3-ol from human sweat and breath, and carbon dioxide-human breath is ~4% CO_2, with traces expired from skin.

Several laboratory and field studies have been conducted to determine the behaviour of adult Diptera in response to visual stimuli, with special attention given to the modification of light wavelength and intensity in Culicidae, [3-7], first observed the impact of varying light intensities on catch size after noting that increased numbers of mosquitoes were attracted to within certain proximity of traps. Previous studies have also demonstrated the effects of wavelength variation on field populations of Culex and Psorophora. Higher proportions of *Culex nigripalpus* Theobald, *Culex erraticus* Dyar and Knab, *Psorophora columbiae* Dyar and Knab, and *Psorophora ciliata* Fabricius were collected with New Jersey light traps modified with incandescent blue lights than with traps modified with yellow, orange, green, red, or white lights [8].

Colour is produced from white light when some of the wavelengths are eliminated usually by absorption, and the remainder are reflected or transmitted. The wavelengths of the reflected or transmitted components determine the colour which is seen. If all wavelengths are reflected equally the reflected surface appears white, if all are absorbed, the colour is black [9]. Due to absorption of light waves, black colour absorbs more heat and white colour none or very less. Insect eye appears to be better adapted for movement perception than far from perception [10]. Colour is important in the lives of those insects which possess colour vision. Most flower visiting insects such as *Apis* and *Eristalis* exhibit preference for blue or yellow colour. Some butterflies also attracted to specific colours, and is also important in the feeding of leaf eating and nectar feeding insects. The reaction of insect to colour may vary depending on its physiological state. *Pieris*, at first, show a preference for blue, purple and yellow colours of flowers on which they feed.

Much research has been carried out to determine the stimulus involved in food location by different insects. Visual and olfactory stimulus is probably the main ones used in food location in general. Visual stimulus is important in host location in mosquitoes, tset-tse and other haematophagus flies. Research carried out so far on mosquitoes indicated that olfactory stimulus plays a role in host location in mosquitoes.

During last several years by the authors it was observed that in the evening time in a herd of cows and buffalos mosquitoes used to make aggregation during flight on black coloured instead of white or red or brown coloured cattle. It was further observed that during evening time when we are sitting in a lawn or garden, mosquitoes remain in aggregated flight restlessly around our head hairs (Black coloured). Another incidence was observed that mosquitoes attracted toward a person wearing black coloured pant or shirt. These incidences prompted us to perform simple experiment for attraction of mosquitoes towards specific colour.

2. Materials and Methods

A round box of the diameter 1 meter was prepared. In the centre of it another box of 30 cm diameter was fitted. The peripheral round part was divided into 8 compartments. The compartments or chamber were connected with the central chamber by round open windows. The interior of eight chambers was provided with black, yellow, green, red, orange, blue, violet and pink colours respectively. Central chamber was kept white. Each chamber was covered by an openable lid and a 0.5 watt LED bulb of specific colour matching with chamber's colour was lighted in each (Fig. 1). The species of Culex and Anopheles mosquitoes were selected for present experiment. These have biological clock and take flight in the evening in search of host. Aedes is diurnal also. Large number of Culex and Anopheles mosquitoes was collected from field by aspirator, brought alive to laboratory in polythene bags and sorted out separately. Specific numbers were released in the central chamber. Light was on and observations were made after two hours. The box was placed 1 meter height on the table. Two trials were made with 500+10 and 600±10 mosquitoes. The attraction of mosquitoes towards a specific colour and wavelength was noted keenly.

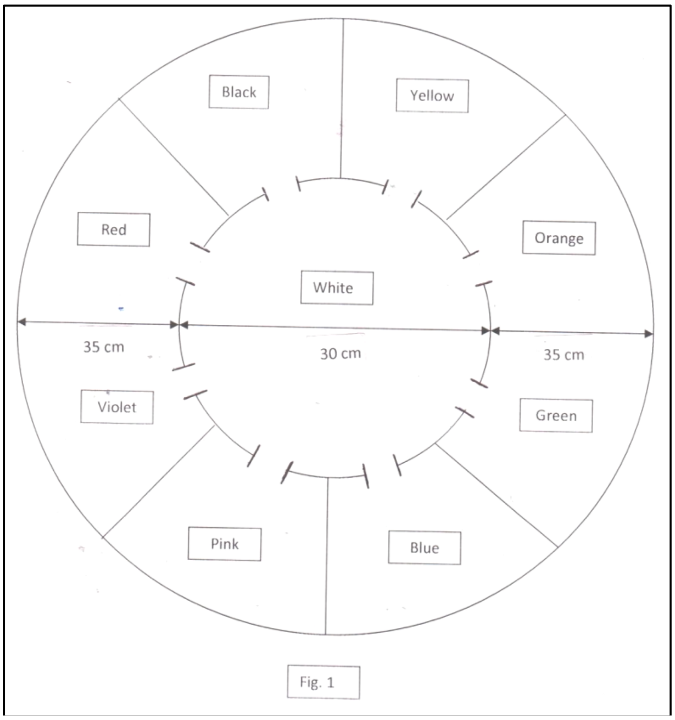


Fig 1: Experimental Design

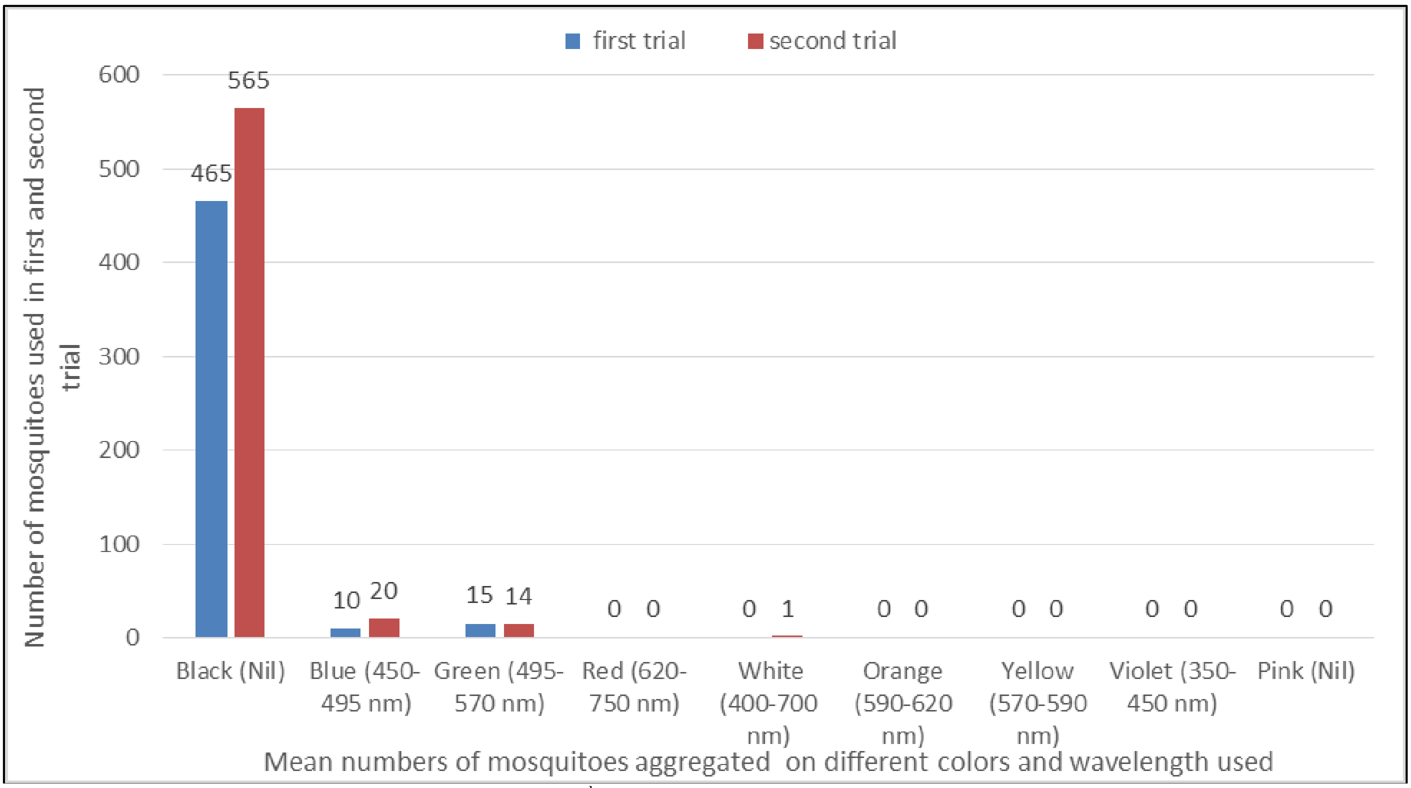
3. Results

It was observed that from the central chamber, most of the mosquitoes migrated to other chambers. In black chamber maximum 465 ± 2 mosquitoes, in blue 10±1 mosquitoes and in green chamber 15±2 were counted. No mosquitoes were seen in other chambers. The experiment was repeated again on next day using 600±10 mosquitoes. These were released in the central white chamber in evening time. After two hrs observation revealed that there were 565±5 mosquitoes in black, 20±2 in blue and 14±2 in green chamber only one in white coloured chamber and no more in other (Table-1& Graph-1).

As we know, that black as well as dark colour absorbs more heat in comparison to other light colours, and the mosquitoes have sophisticated and highly sensitive heat sensors, hence they tend to be more attracted and aggregated, where more heat is. The results of first trial show that, out of the 500+10 mosquitoes, 465 ± 2 were found to be aggregated in black colour's chamber, in blue and green 10±1and 15±2 respectively, while in other colour's chambers *viz*. red, white, orange yellow, violet and pink had no aggregation of mosquitoes at all. Even, the results of second trial also show that out of 600±10 mosquitoes, 565±5 were reported in the black colour's chamber, while in blue and green colour 20±2, 14±2 respectively, no mosquito were found in the other colour's chambers, except the white having a single mosquito only. The possible reason behind this behaviour of mosquitoes is the intensity and the wavelength of the particular colour and light used in the experimental design; the wavelength of the colours attracts and distracts the mosquitoes to a particular colour. We know that every colour has its own wavelength, and the colours used in the experiment has the different wavelength *viz.;* black (0 nm) blue (450-495nm), green (495-570nm), red (620-750nm), white(400 -700 nm), orange (590-620 nm), yellow (570–590 nm), violet (350-450 nm), and pink(0), which indicates that mosquitoes mostly prefer the black colour light, which have no wavelength, and secondly on the blue colour which have the wavelength (450-495nm), and thirdly on green colour having the wavelength (495-570nm). Since, the remaining colours; red (620-750nm), white (400 -700 nm), orange (590-620 nm), yellow (570–590 nm), violet (350-450 nm), and pink (0) are light, and have the higher wavelength than the black, blue and green colour, hence there is no aggregation on them, at all. The results show that mosquitoes have the colour vision, rather than the colour blind and aggregate mostly on black colour only. Furthermore, mosquitoes use thermal sensory information to detect body heat, as we know that black (or dark) colour absorbs more heat in comparison to other light colours, so the object having black colours get heated easily, mosquitoes sense the heat and get attracted to it. There is need of more research regarding this colour aggregation behaviour in mosquitoes.

Table 1: Aggregation of mosquitoes on different colours and wavelength

S.N.	Colours used	Wavelength of the colours	Number of mosquitoes released in first trial	Number of mosquitoes released in second trial	Number of mosquitoes observed on colours in first trial	Number of mosquitoes observed on colours in second trial
1	Black	Nil	500+10	600+10	465 + 2	565+5
2	Blue	450-495 nm			10+1	20+2
3	Green	495-570 nm			15+2	14+2
4	Red	620-750 nm			0	0
5	White	400 -700 nm			0	1
6	Orange	590-620 nm			0	0
7	Yellow	570–590 nm			0	0
8	Violet	350-450 nm			0	0
9	Pink	Nil			0	0



X axis denotes the number of mosquitoes used in 1st and 2nd trial, and Y axis mean number of mosquitoes aggregated on different colours and wavelength.

Graph 1: Aggregation of mosquitoes on different colours and wavelength

4. Discussion

Mosquitoes have compound eyes as well as simple eyes or ocelli. Compound eyes are for vision and ocelli for differentiate between dim and bright light. According to entomologist at the University of Florida, mosquitoes rely on their vision to find hosts. The finding of the researchers at the California University of Technology suggests that mosquitoes can see their host from about 16-32 feet away.

Among the insects butterflies and honey bees have colour vision [11], has stated that ultraviolet light also guide Monarch butterflies in their extra ordinary two thousand mile migration. Our findings indicate that mosquitoes are not colour blind and these love dark colour than light but, we are not sure it is an instinctive reaction to dark colour as a camouflage device or a natural feeding mechanism.

The study revealed that mosquitoes are attracted and aggregated maximum to black colour, because black colour absorbs more heat as compared to other colours. Since, mosquitoes have sophisticated and highly sensitive heat sensors, they tend to be more attracted and aggregated, where more heat is. In first trial, out of the 500+10 mosquitoes, 465 + 2 were found to be aggregated on black colours, while on blue and green 10±1and 15±2 respectively, while other colours, red, white, orange yellow, violet and pink had no aggregation of mosquitoes. The second trial showed that out of 600±10 mosquitoes, 565±5 were reported on the black colour while on blue and green colour 20±2, 14±2 respectively, no mosquito were found on the other colours, except the white having a single mosquito only. The possible reason behind this is the wavelength of the colours used in the experiment; the wavelength of the colours attracts and distracts the mosquitoes to a particular colour. The colours used in the experiments has the wavelength as follows black (0 nm) blue (450-495nm), green (495-570nm), red (620-750nm), white(400 -700 nm), orange (590-620 nm), yellow (570–590 nm), violet (350-450 nm), and pink(0), which indicates that mosquitoes most prefer the black light, which have no wavelength, and secondly on the blue colour which have the wavelength (450-495nm), and thirdly on green colour having the wavelength (495-570nm). [12], studied the response of adult mosquitoes to 4 light-emitting diode (LED) blue (470 nm), green (502 nm), red (660 nm), and infrared (IR) (860 nm). [13], said that more Aedes were captured on blue diode treatment. [14 and 8], determined that shorter blue - green wavelength (400-600nm) and (430-550nm) respectively attracted significantly more Culex. However, our findings suggest more attraction on black colour and second place goes to blue colour.

Generally, mosquitoes use thermal sensory information to detect body heat, as we know that black (or dark) colour absorbs more heat in comparison to other light colours so the object having black colours get heated easily, mosquitoes sense the heat and get attracted to it. Hence, the more research is required pertaining to colour aggregation in mosquitoes. It is clear from the study that mosquitoes have the colour vision, and mostly attract towards the black colour, it may be very helpful in preparing a device using black colour as attractant. Furthermore, wearing the lighter colours white, yellow, pink, orange, blue, khaki olive beige, which can help reduce your appeal and keep the mosquitoes away, while the dark colours attracts the mosquitoes as they replicate shadows.

5. Conclusion

Mosquitoes are responsible for a variety of diseases. Despite the advances in techniques and products used for their control, the mosquitoes continue to pose serious public health problems. Therefore, use of colour based attractant could be helpful in reducing the population of mosquitoes rather than using hazardous chemicals. Though, mosquitoes are said to be colour blind, but it is concluded by the experiment that mosquitoes have colour vision specially attracted to black colour. A device can be prepared to kill the mosquitoes using black colour as an attractant, harmless to humans as well as providing a means of personal protection. This opens door for further investigations. It is further suggested to wear light coloured clothes while going in open.

6. Acknowledgement

The authors are thankful to the Head of the Department, and Principal M.S. College, Saharanpur for providing lab facilities, and to the director N.I.M.R., New Delhi for identification of mosquitoes.

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