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Studies on the association between dengue fever cases and climatic factors in Bhopal, India.

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Abstract
This study explores the association between climatic factors and the incidence of dengue fever in Bhopal, India, from 2021 to 2023. Given the rise in dengue fever cases linked to climate-sensitive Aedes mosquitoes, understanding these relationships is vital for public health strategies. An approach was employed, incorporating meteorological data (temperature, relative humidity, and rainfall) and dengue case reports, alongside Aedes mosquito larval collections. The analysis revealed a significant positive correlation between Aedes larval abundance and relative humidity as well as a strong association between dengue fever cases and Aedes density and rainfall. The peak incidence of dengue cases was observed during the post-monsoon months of September to November, characterized by elevated temperatures and high humidity levels. These findings highlight the critical influence of climatic factors on the dynamics of Aedes mosquito populations and dengue transmission, underscoring the need for effective urban planning and public health interventions to mitigate the impact of climate variability on dengue outbreaks in Bhopal.

Keywords: Mosquitoes, dengue fever, temperature, humidity, rainfall, climatic factors.

Introduction
Mosquitoes are small two-winged insects which are most prominent of many bloods sucking ectoparasites distributed throughout the world and the most annoying creatures for humans and other warm-blooded animals. Mosquito borne diseases are the major cause of over one million deaths and millions of infections (WHO, 2020) [24]. Many species of mosquitoes are vector for tropical diseases including dengue fever, Chikungunya, Rift valley fever, West Nile virus, yellow fever, Zika virus, encephalitis, malaria & filariasis etc. (Rozendal JA, 1997; Jupp, 1996; Service, 1980) [21, 11, 23]. Mosquito species are climate sensitive (Al Ghamdi *et al*, 2009) [5]. Vector borne diseases closely associated with climatic factors such as temperature, Relative humidity and precipitation. Many research workers reported the relationship between climate change and density of mosquitoes. (Hopp MJ and Foley JA, 2003) [10]. Climate is influenced by global warming which results into speeding up the virus activity and its development in the mosquito vectors and the adoptability into different habitats and climatic factors (Abdalmagid MA & Alhusein; 2008) [1].
Dengue fever is a viral disease transmitted to humans by Aedes female mosquito species bite. The infected female of *Aedes aegypti* & *Aedes albopictus* when bite a person it transmits the virus. Dengue fever is an urban disease and continue to increase every year. According to WHO dengue fever is caused by arbovirus serotype DEN1, DEN 2, DEN 3, & DEN 4. There has been 30-fold increase in dengue fever cases in the last fifty years (WHO, 2019). Many researchers studied the relationship between climatic factors and dengue fever cases. (Promprou *et al.* 2005) [19] found a strong relationship of dengue fever cases with temperature, rainfall and moisture. Climate also plays an important factor in density of Aedes mosquito and dengue fever cases (Dibo MR. *et al*, 2008) [8].
Like many other countries India also witnessed an increase in dengue fever incidence. Due to high population and cross-country movement the dengue fever incidence spread to different parts of the country.

Bhopal being the capital of Madhya Pradesh, a central Indian State with a population of approximately 27 million. It is known as city of lakes due the presence of various natural and manmade water bodies. Bhopal has an average high temperature of 31.7C (Peak summer Max.40 C or more), average low temperature of 18.6 C and Rain about 40 inches with average Relative Humidity 45% (80% during rainy season). Coordinate; Latitude 23.1535 6N and Longitude 77. 2445 4 E.

Due to large number of water bodies in and around Bhopal many vectors borne diseases are prevalent especially dengue fever, Chikungunya and Malaria.

Dengue fever vectors *Aedes aegypti* and *Aedes albopictus* are breeding in the fresh water bodies, besides due to erratic water supply people in some areas store water in open tanks and other utensils. Prevailing conditions in the city such as lack of proper sewage disposal network, high humidity also contribute to the increasing population of Aedes mosquito species.

Aedes aegypti is considered as domestic mosquitoes as it is urban day time feeder and usually remain near human dwellings. These mosquitoes are widely distributed in south-east Asia and are recognized as dengue fever vector (Gratz, 2004) [9]. *Aedes albopictus* serve as primary vector in rural areas and contribute to dengue transmission (Kalra *et al*, 1997) [12].

The main objective of this study is to find out an association between local climatic factors, dengue fever incidence and Aedes mosquito density in the study area. Very little work is done to establish the correlation between dengue fever cases and prevailing local climatic factors in this area.

Methodology

Collected data for the year 2021 to 2023 was taken into account to corelate the weather parameters prevailing in Bhopal region with dengue fever cases and collected Aedes larvae. 3rd and 4th instar larvae were collected for the abundance and surveillance of Aedes mosquito in the region. In the larval collection no differentiation was done between *Aedes aegypti* and *Aedes albopictus* as both the species are responsible for the dengue fever incidence. Adult mosquitos were collected with help of light trap and aspirators for only identification purposes. Meteorological data for various weather parameters was taken from the records of Indian Meteorological Department. Complete 3-year work provided a useful information on the density of Aedes and dengue fever cases in Bhopal.

To determine the spearman's correlation coefficient between Aedes density, weather parameters and dengue fever cases statistical analysis was applied. Data was analyzed by using SAS statistic software.

The average temperature, high and low relative humidity, average rain fall during all three years were taken into consideration. Temperature is measured in Celsius and mean temperature is taken into account. Average Relative humidity is expressed in percentage and rainfall into millimeters.

Result & Discussion

The present analysis of the result explains the correlation between different local climatic factors, abundance of Aedes mosquito larvae and the dengue fever cases in time and space during three consecutive years (2021-2023)

Here are some key points and insights:

Temperature

- Average temperature during warm months was 33.8°C (Mid-March to mid-June).
- Average minimum temperature during cool months was 16°C (Mid-October to February).
- Highest dengue cases in October with an average temperature of 26°C.

Humidity

- Average relative humidity was 62% which was highest in August and lowest in April.
- Positive correlation between relative humidity and Aedes larvae population (0.300).

Rainfall

- Total average rainfall of the city was 1110 mm, with a peak of 350 mm in August and lowest of 5mm in April.
- Negative correlation between rainfall and Aedes larvae population (-0.154).

Dengue Fever Cases

- Total reported cases during the study period was 2280.
- Total number Of Aedes mosquito larvae collected was 5063 during three year survey.
- Highest number of cases were reported between September and November, peaking in October when average temperature was 26°C and relative humidity was 85-87%.

1. Pearson's Correlation Coefficients:

- Pearson's correlation coefficient values suggest significant positive correlation between Aedes larvae population with relative humidity (0.300), temperature (0.176) and rainfall (-0.154) show a negative correlation. (Table.3)
- Dengue fever incidence reported month wise (between 2021-2023) exhibit a positive correlation (0.027), with Aedes larval abundance (0.000), humidity (0.312), rainfall (0.788) & temperature (0.800). (Table.3)
- The 'p' value is significant with monthly larvae collection (P=0.014) and dengue fever cases (p=0.027). While it is non-significant with temperature (p=0.895) relative humidity (P=0.159) and rainfall (P=0.587). (Table-3).

The climatic variables in correlation with dengue fever cases and larval abundance is not studied in the study area. There is a lot of literature available on the correlation between dengue fever cases and climatic factors in different parts of the world (Patz *et al*, 1998; Chadee *et al*, 2007) [18, 7] studied the relationship between rainfall and dengue fever cases. (Promprou *et al*, 2005) [19] with moisture and rainfall (Dibo MR *et al*, 2008) [8] with mosquito density in relation to dengue fever cases, but there is very little-known literature available on the topic in this area. Therefore, this study was undertaken. Our study is based on the prevailing climatic factors in the city.

A similar observation was found by (Kumar, R., *et al*, 2020) he found a significant positive correlation between temperature (r = 0.78) and mosquito larvae in rural India. Humidity also showed a moderate correlation (r = 0.62). (Alemayehu, M., *et al*, 2018) [2] reported a strong positive Pearson correlation (r > 0.80) between temperature and

Anopheles mosquito larvae abundance in Ethiopian highlands. Humidity exhibited a weaker correlation (r = 0.52). (Chaves, L. F., *et al*, 2014) identified a significant correlation between humidity (r = 0.67) and *Aedes aegypti* larvae in urban tropical settings. Temperature showed a higher correlation (r = 0.85), indicating its dominant role. (Mutuku, F. M., *et al*, 2011) [16] Highlighted seasonal variations in correlation coefficients, with temperature having a stronger association (r = 0.82) during summer compared to humidity (r = 0.58). (Mogi, M., *et al*, 2007) [14] Demonstrated that high temperatures (27-32°C) were strongly correlated (r = 0.89) with increased Culex mosquito larvae, while moderate humidity levels (70-80%) showed a weaker correlation (r = 0.64).

Temperature plays a very crucial role in spreading the dengue fever cases and abundance of vector mosquito (Morin CE. *et al*, 2013) [15]. Temperature also helps in faster rate of viral replication and mosquito biting (Sarma DK *et al*, 2022) [22]. Rainfall increases the number of vector mosquitoes by providing enormous breeding places (Sarma *et al*, 2022) [22]. The dengue fever cases in the study area show an upward trend during and after monsoon season. (Sarma *et al* 2022) [22] suggested that the dengue incidence is positively associated with high rainfall, our study confirm this positive correlation. We also found a positive correlation between Relative humidity and dengue fever cases. Due to high humidity the activity of vector feeding and survival rate increases, besides the development and egg laying also increases. Humidity often correlates positively with mosquito larvae populations. Higher humidity levels help prevent desiccation of breeding grounds and maintain water availability, crucial for larval development. Variations in diurnal and seasonal humidity have been noted to influence breeding patterns. High humidity and ideal temperature also increased the viral activity during September and October when the number of dengue fever cases are recoded high. (Pakhare *et al*, 2014) [17] opined that temperature is responsible for vector density. Positive correlations have been widely observed between temperature and mosquito larvae abundance. Warmer temperatures can accelerate the lifecycle of mosquitoes and create favorable breeding conditions in stagnant water sources. A critical temperature threshold exists, beyond which the survival rate of mosquito larvae might decline. Our study also found a positive correlation between temperature and Aedes larvae abundance.

(Alikhan M. *et al*, 2021) [4] suggested that the indoor climate is more important than outdoor climate due to low temperature inside houses and high humidity in transmission in dengue fever virus and mosquito larval development.

It is observed that all the climatic factors are closely interrelated therefore, it is difficult to pinpoint the influence of any particular factor.

Increased in Aedes mosquito population may be attributed to the climatic factors, (Alikhan M. 2018) stress that but more on the irresponsible human behavior and their activities for flourishing the mosquito's species. Humans mostly provide the ideal breeding places for mosquito's development.

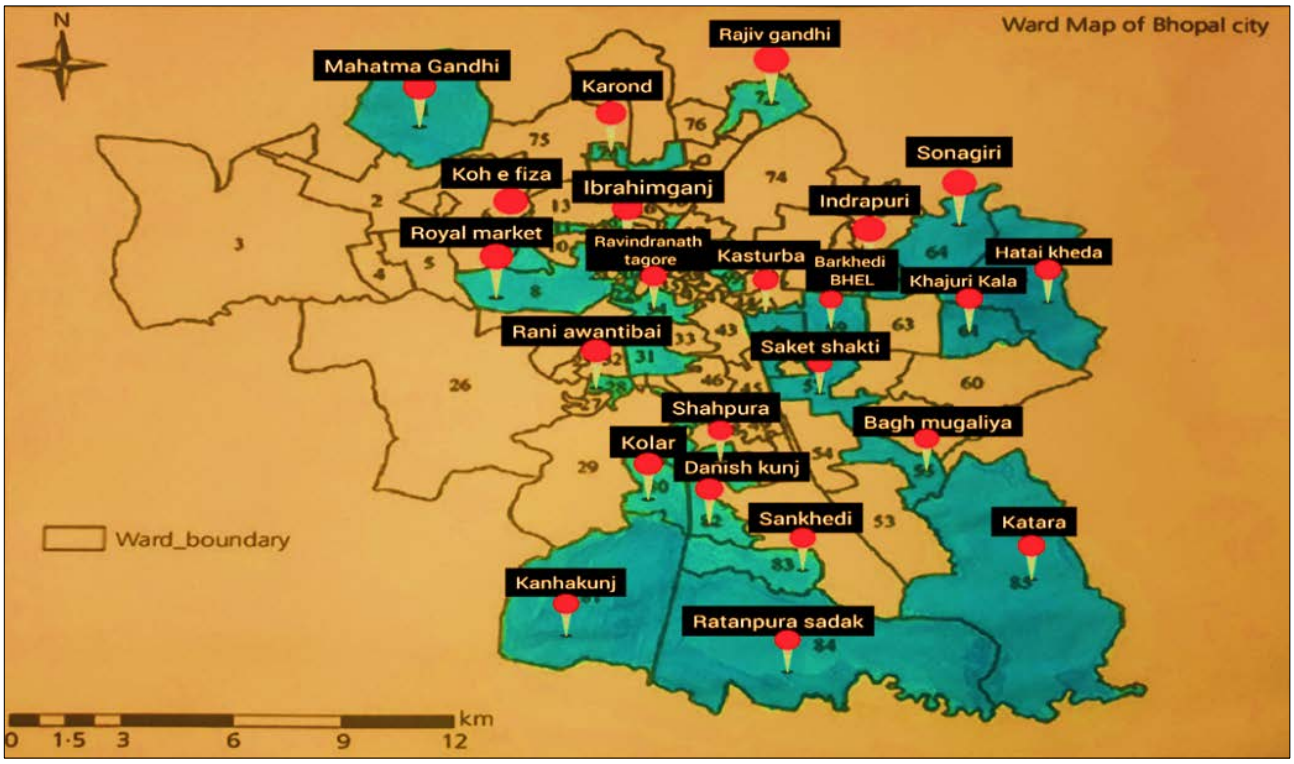

Fig 1: Bhopal map showing highest cases of dengue cases in the capital city.

Table 1: Total no of dengue fever cases, collected larvae, average temperature; humidity and rainfall

Months 2021 To 2023	Total Dengue Cases	Total Aedes Larvae collected	Average Temperature °C	Average Humidity %	Average Rainfall mm
January	21	154	16°	72%	0.002 mm
February	24	153	20°	52%	0.002 mm
March	38	110	26°	43%	0.377 mm
April	22	103	30°	31%	0.190 mm
May	25	134	32°	40%	0.202 mm
June	25	85	30°	62%	5.227 mm
July	52	164	27°	85%	15.739 mm
August	142	300	26°	87%	11.284 mm
September	555	889	26°	85%	5.563 mm
October	751	1562	25°	65%	0.568 mm
November	554	907	21°	63%	0.049 mm
December	71	502	18°	67%	0.057 m

Display of the total number of Aedes Larvae collected and the number of dengue cases reported from 2021 to 2023

Table 2: Compared the dengue cases of different months using ANOVA.

Source of variation	Sum of squares	Degree of Freedom	Variance or average	Statistical test	p-value
Between the groups	980.1667	2	490.0833	0.0563	0.9453
Within the groups	214748.3647	33	8700.4192		
Total	214748.3647	35			

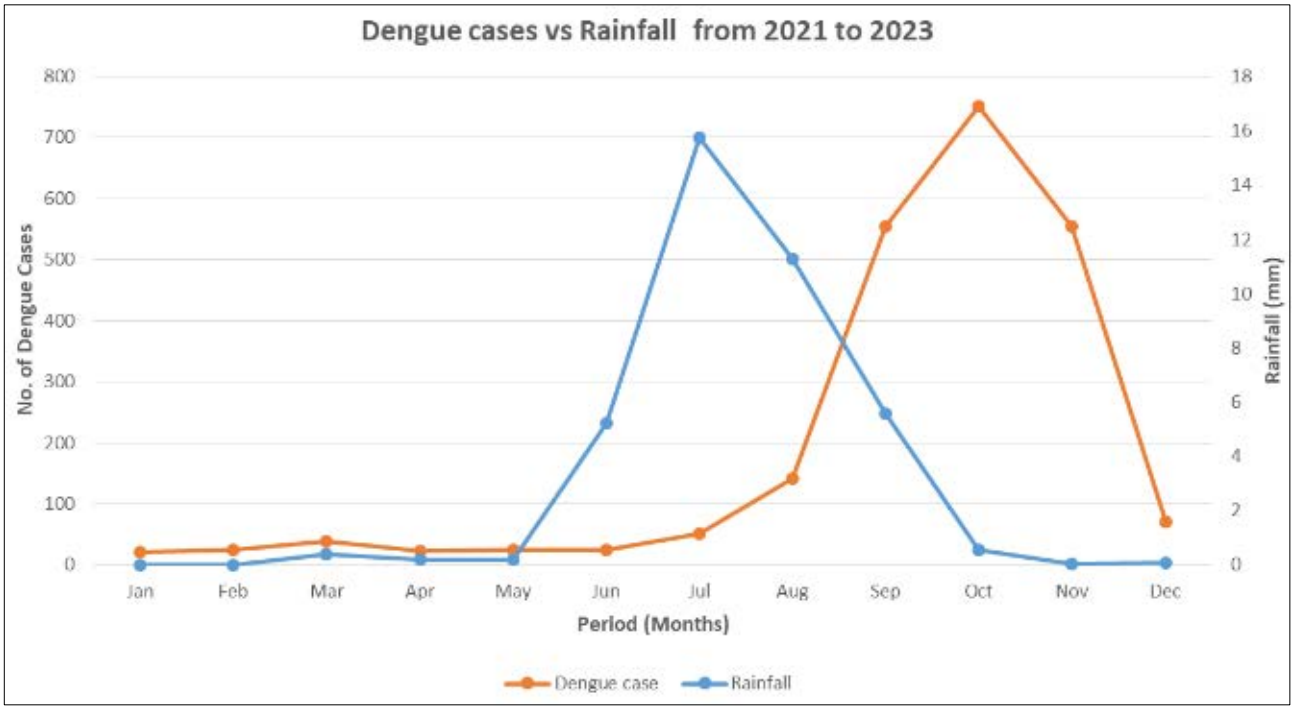

Fig 2: Graph showing the relationship between dengue cases and rainfall

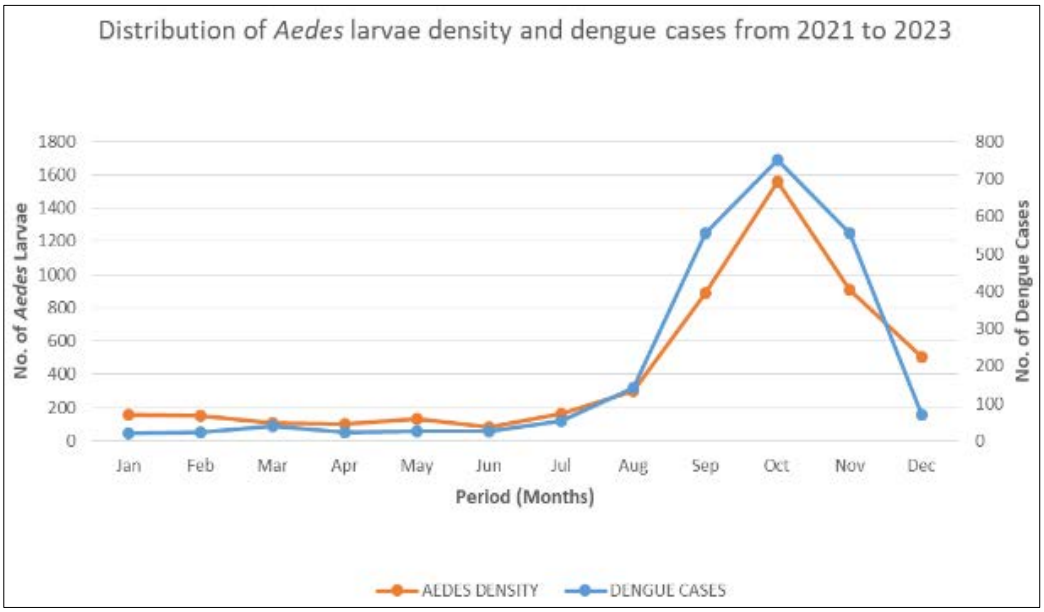

Fig 3: Graph showing the Aedes larvae density and dengue fever reported cases.

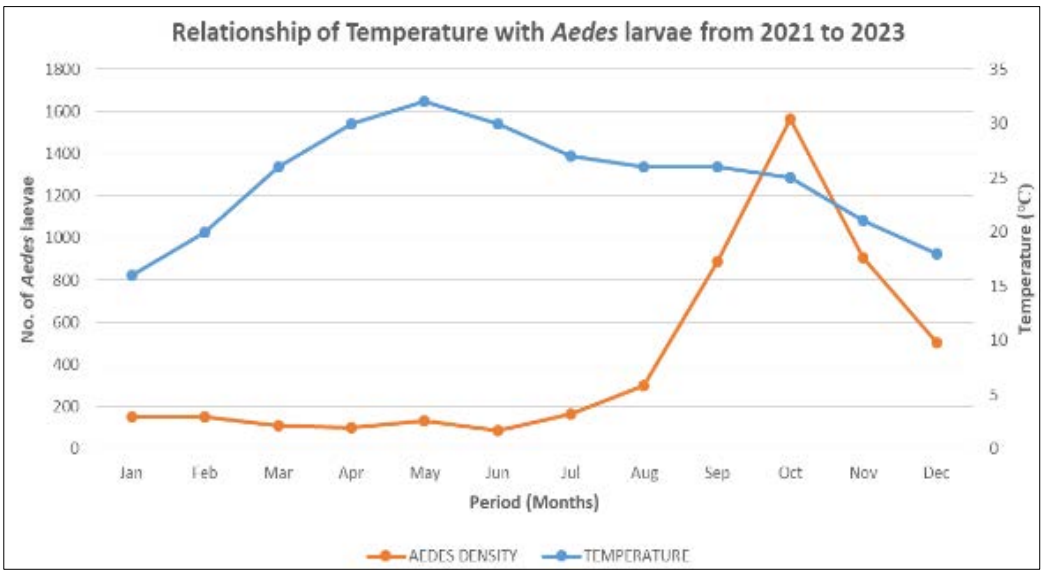

Fig 4: Graph showing the relationship between temperature with larval abundance

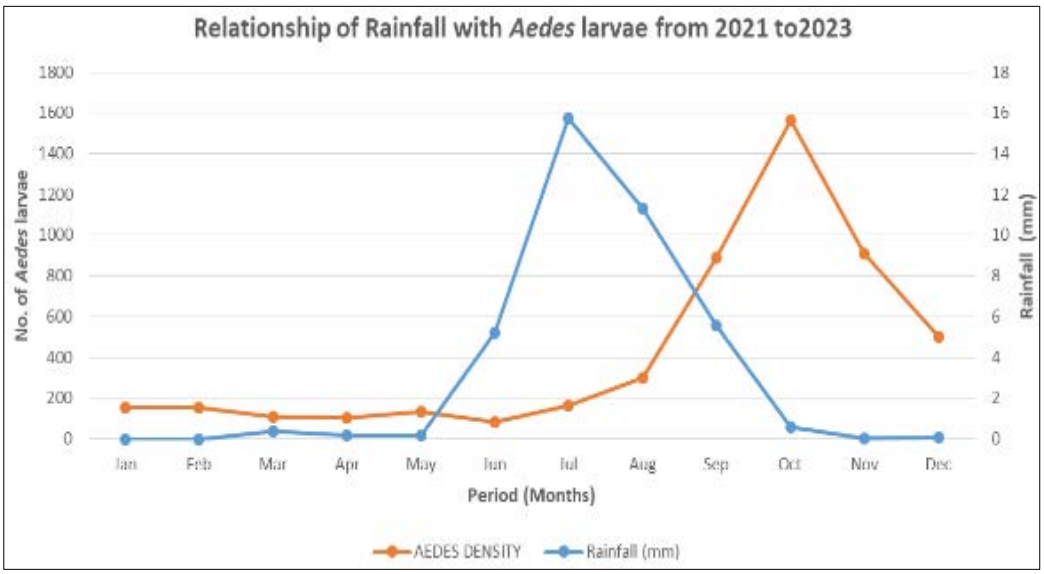

Fig 5: Graph showing relationship of Rainfall with Aedes larvae abundance.

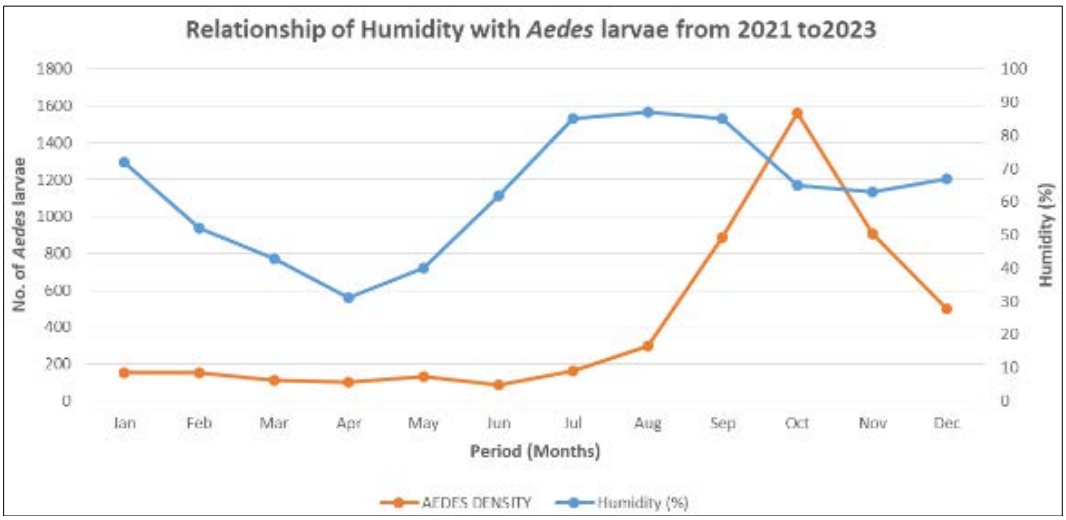

Fig 6: Graph showing the relationship between relative humidity and Aedes larvae.

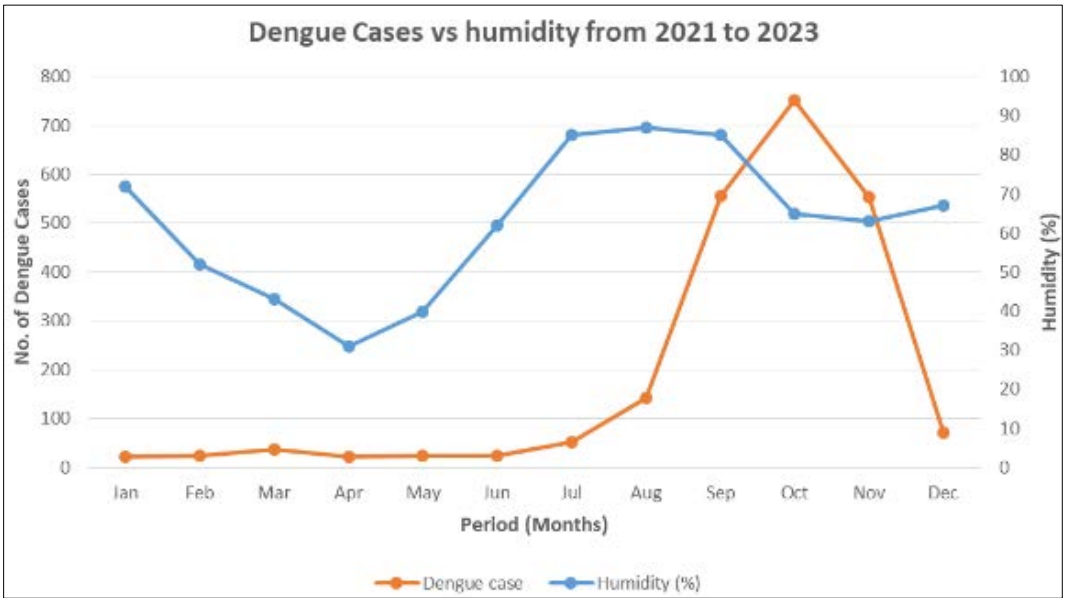

Fig 7: Graph showing the relationship between Dengue cases with Relative humidity

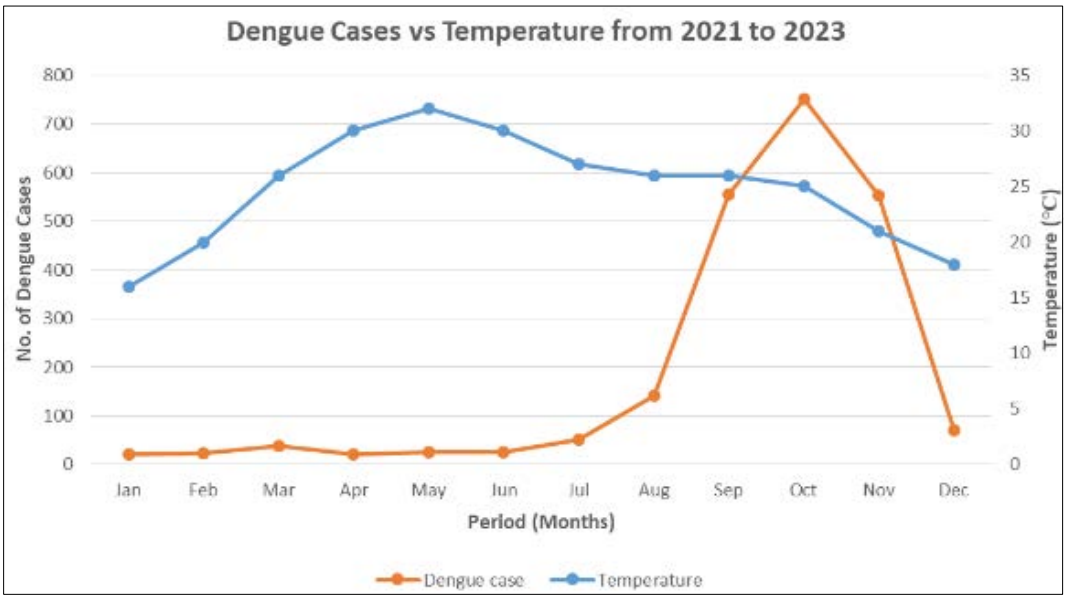

Fig 8: Graph showing the relationship between Dengue cases with Temperature

Table 3: Showing the Pearson's correlation with all the climatic parameters

		Month	Larvae	Temp	Humidity	Rainfall	Cases
Month	Pearson Correlation	1	.685*	-.043	.433	.175	.633*
	Sig. (2-tailed)		.014	.895	.159	.587	.027
	N	12	12	12	12	12	12
Larvae	Pearson Correlation	.685*	1	-.176	.300	-.154	.965**
	Sig. (2-tailed)	.014		.584	.343	.632	.000
	N	12	12	12	12	12	12
Temp	Pearson Correlation	-.043	-.176	1	-.307	.297	-.082
	Sig. (2-tailed)	.895	.584		.332	.348	.800
	N	12	12	12	12	12	12
Humidity	Pearson Correlation	.433	.300	-.307	1	.685*	.319
	Sig. (2-tailed)	.159	.343	.332		.014	.312
	N	12	12	12	12	12	12
Rainfall	Pearson Correlation	.175	-.154	.297	.685*	1	-.087
	Sig. (2-tailed)	.587	.632	.348	.014		.788
	N	12	12	12	12	12	12
Cases	Pearson Correlation	.633*	.965**	-.082	.319	-.087	1
	Sig. (2-tailed)	.027	.000	.800	.312	.788	
	N	12	12	12	12	12	12

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

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