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Influence of environmental factors on dengue fever in Delhi

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Abstract
Dengue is a major public health challenge with population density, inadequate water supply, improper solid waste management, climate change and poor socio-economic status are identified key determinants for Dengue /Severe Dengue. Environmental conditions such as temperature, humidity and precipitation etc. also play a vital role in the incidence of Dengue. The present study was carried out with aim to find correlations between incidence of dengue fever and environmental factors from 2011 to 2016 in Delhi.
No linear correlation was observed between rainfall and dengue cases, however the peaks of rain fall and the dengue cases had some lag period difference of about two months. When this lag period is adjusted the high positive correlation (r=0.9868) was seen that both peaks perfectly matched which suggest the cases are related to rainfalls in spite of indoor breeding of mosquitoes. High correlation was observed between average rain fall with average cases (97%; r= 0.986)
The study shows a clear dependency of dengue cases with climatic factors and further revealed that there is a lag phase between rains and appearance of cases which provides an opportunity to programme managers to carry out vector control measures along with source reduction. This window of opportunity provides enough time to mobilize resources for the implementation of interventional measures to lower the impact of the epidemic.

Keywords: Dengue, temperature, rainfall, Delhi

1. Introduction

Dengue fever is an arboviral illness transmitted by bite of infected female *Aedes* mosquito. Dengue has predominantly affected Tropical and Sub Tropical regions with recent transition from rural to semi urban and urban areas. WHO has reported the increase in number of dengue affected countries with increase in the incidences as well. Dengue is endemic in more than 128 countries across all regions of WHO especially South East Asia and Western Pacific regions are affected more [1]. Epidemics of dengue are increasing in frequency.

Dengue is a major public health challenge in Delhi. Outbreaks have been reported during 2006, 2010, 2013 and 2015, it is quite evident that gaps between outbreak years is decreasing [2]. Dengue infection can manifest as undifferentiated fever or severe dengue which leads to hospitalization and may cause mortality in some cases. Delhi has reported all 4 serotypes during different years also raises concern for outbreak of Severe Dengue in future years [3, 4]. Madhok Committee was constituted in 1969, to review malaria control in urban areas and subsequently, Urban Malaria Scheme (UMS) was launched in 1971–72 and civic bodies were entrusted with control measures in urban areas. Under UMS, Civic bodies have been entrusted with implementation of Malaria/Dengue control activities. The strategies advocated included source reduction, anti-larval measures, minor engineering interventions, legislative measures, building bye laws and limited spraying of indoor residual spray in peri-urban and hutments [5]. Since 2003, Dengue control has been brought under umbrella of National Vector Borne Disease Control Programme launched by Government of India [6]. At present 5 civic bodies of Delhi namely north Delhi Municipal Corporation, South Delhi Municipal Corporation, East Delhi Municipal Corporation, New Delhi Municipal Council& Delhi Cantonment Board are involved in activities for prevention and control of Dengue.

Epidemiology of dengue in Delhi, has revealed that there is transition in age groups of patients from childhood to adult and spread from urban to rural settings who get dengue infections.

In the absence of specific treatment and vaccine of dengue, control of mosquito breeding remains only strategy of the choice to prevent transmission of Dengue. Several factors are associated for dengue prevalence and spread i.e. population density, inadequate water supply, improper solid waste management, climate change and poor socio-economic status are identified as key determinants for DHF [7]. Socio-economic factors like intermittent water supply leading to more water storage in containers without proper lids, improper solid waste management, lack of civic amenities all influence breeding of *Aedes aegypti* [8, 9]. In rural areas risk of dengue has been found to be higher than in urban settings due to lack of piped water supply [10].

Environmental conditions such as temperature, humidity and precipitation etc. also play a vital role in the incidence of Dengue [11]. Global climate change leading to global warming is becoming an issue of major concern. Climatic factors such as rainfall, humidity and temperature favour the spread of the mosquito and the disease transmission. Impact of climate change on dengue has also revealed increase in transmission with 2ºC rise in temperature in northern India. Impact of Global warming has been observed and Dengue cases have been reported even during winter months [12].Favourable temperature and humidity conditions in the rainy season leads to increase in the survival rate of the adult vector that enables mosquito to complete the extrinsic incubation period of virus in mosquito [13]. Present paper is focussed on association of climatic factors like rainfall, temperature, and humidity with dengue cases in the metropolitan setup of Delhi.

2. Materials and methods

2.1 Study Area

Delhi is spread over an area of 1483 square kilometre and located at 28.38 NL - 77.12 EL. Delhi is a merger of main three ecological zones i.e. Delhi ridge, Yamuna flood plain and central plains of India. Delhi experiences tropical steppe type of climate and seasons are marked with extreme temperatures ranging (2 to 47 °C), average rainfalls of 886 mmper annum. Monsoon period is from July to mid-September when the climate remains wet &humid [14].

2.2 Study Design

This is a descriptive study carried out in Delhi. This study has been carried out with objective to establish correlation between incidence of dengue fever and environmental factors from 2011 to 2016. Dengue Data were collected from MIS Cell (Vector Borne Diseases) of South Delhi Municipal Corporation (SDMC) while Meteorological data of Delhi was collected from Directorate of Economics and Statistics, Government of National Capital Territory (GNCTD). The data represent monthly averages for each year during the study period from 2011 to 2016. Limitation remains that data is for entire Delhi and not area specific hence dengue cases have been taken for entire Delhi. Therefore, accessing climate data and Dengue cases for Municipalities wise is not feasible.

3. Results

Data compiled by MIS Cell (Management Information System for Vector Borne Diseases) shows year wise Dengue cases and deaths notified in Delhi. Dengue has been made Notifiable disease under Section 2 (9) (b) of DMC Act 1957 by the erstwhile Municipal Corporation of Delhi in 1997 following major outbreak of dengue in 1996 when more than 10000 dengue cases were reported and case fatality rate of 4.1% was observed. Analysis of above data shows outbreaks of dengue were reported in 2006, 2010, 2013 and 2015. The gap between the outbreak years is decreasing (Fig 1).

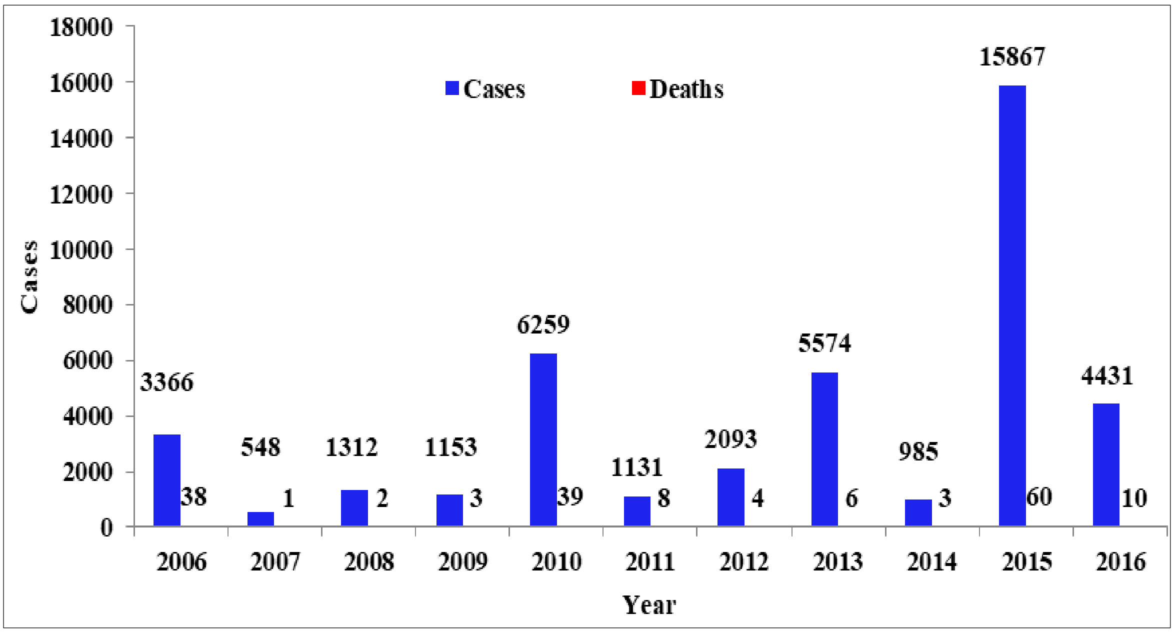

Fig 1: Year wise Dengue Cases & Death Notified in Delhi.

Table 1 shows month wise Dengue cases as in, notified in Delhi. Graphical representation in above fig.2 shows average cases occurring during transmission season of dengue in Delhi which starts in the month of July and peaks in months of September and October. The cases decline in November and transmission stops in December every Year. Analysis of data of 2013 and 2015 shows that transmission window is increased when cases have been reported in the month of January and February respectively.

Table 1: Year wise and Month-wise Dengue Cases notified In Delhi.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2010	0	0	0	0	0	1	51	885	2360	2246	678	33
2011	0	0	1	3	0	1	10	51	179	512	328	46
2012	0	0	0	2	0	3	4	4	55	951	1005	69
2013	2	2	0	3	0	2	11	142	1962	2442	889	119
2014	0	0	2	0	3	10	7	11	87	318	444	113
2015	0	3	1	3	4	6	36	778	6775	7283	841	137
2016	0	0	2	5	6	15	91	652	1362	1517	655	126
Avg	0.29	0.71	0.86	2.29	1.86	5.43	30.00	360.43	1825.71	2181.29	691.43	91.86

Our data showed that there was no linear correlation observed between rainfall and dengue cases (Fig 2; Table 2). However different peaks suggest that there is relation between both. The peaks of rain fall and the dengue cases had some lag period difference of about two months. When this lag period is adjusted the high positive correlation (r=0.9868) was seen as both peaks perfectly matched which suggest the cases are related to rainfalls in spite of indoor breeding of mosquitoes (fig 3; Table 2). The cases lag behind rainfall due to several reasons like mosquito cycle from egg to larvae about 7-10 days, extrinsic incubation period about 8-12 days and intrinsic incubation period in patients 5-8 days, time taken for reporting of Dengue cases by hospitals to SDMC, and investigation by concerned zones and notification by SDMC. Therefore, about two months were adjusted as lag period.

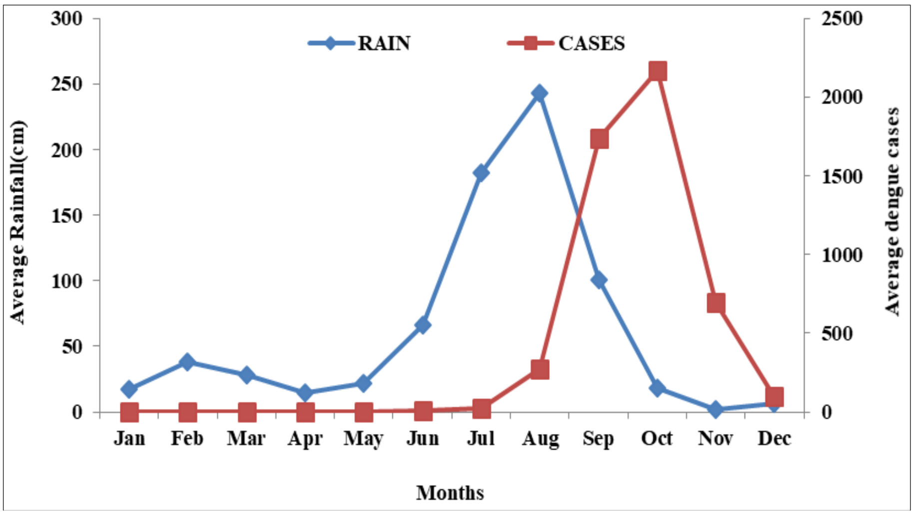

Fig 2: Correlation between Rain fall and Dengue cases without lag phase adjustment

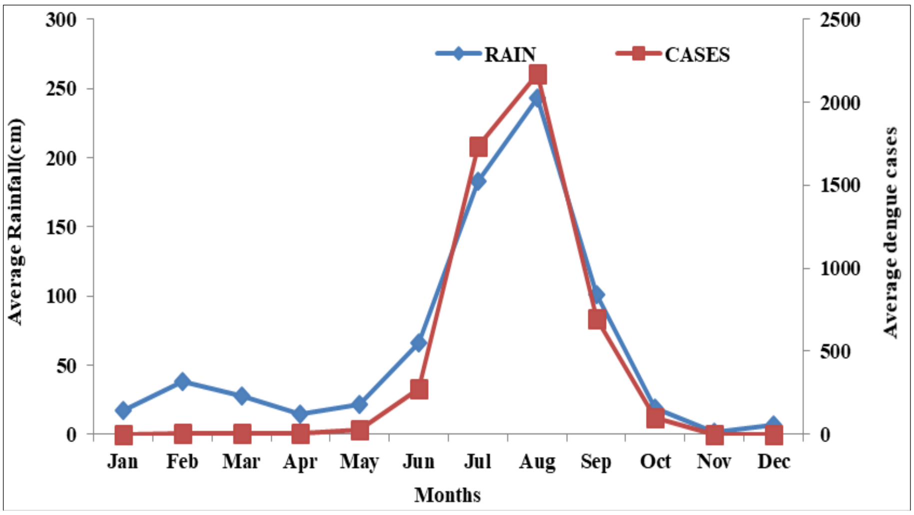

Fig 3: Correlation between Rain fall and Dengue cases with lag phase adjusted for two months

Table 2: Correlation between Rain Fall and Dengue Cases

Correlation (r)	2011	2012	2013	2014	2015	2016	Average
Without lag phase adjustment	-0.106	-0.203	-0.140	-0.357	-0.284	-0.121	-0.031
With lag phase adjustment	0.899	0.713	0.932	0.634	0.913	0.809	0.986

High correlation was observed between average rain fall with average cases (97%; r= 0.986) whereas when the data was analysed yearly in 2013 there was highest correlation (86%; r=0.932) followed by year 2015 (83%; r=0.913) followed in 2011 correlation (80%; r=0.899), whereas the years 2014 & 2012 shows low% correlation with the rainfall (40%; r=0.634) & (50%; r=0.733). In the year 2012 & 2014, low correlation was observed may be due to inter outbreak period when less cases are reported due to herd immunity. It was also observed that pattern of cases in Delhi shows alternate peaks which is found to be in correlation with the amount of rainfall received in that year i.e. High rainfall, high cases (Fig 4).

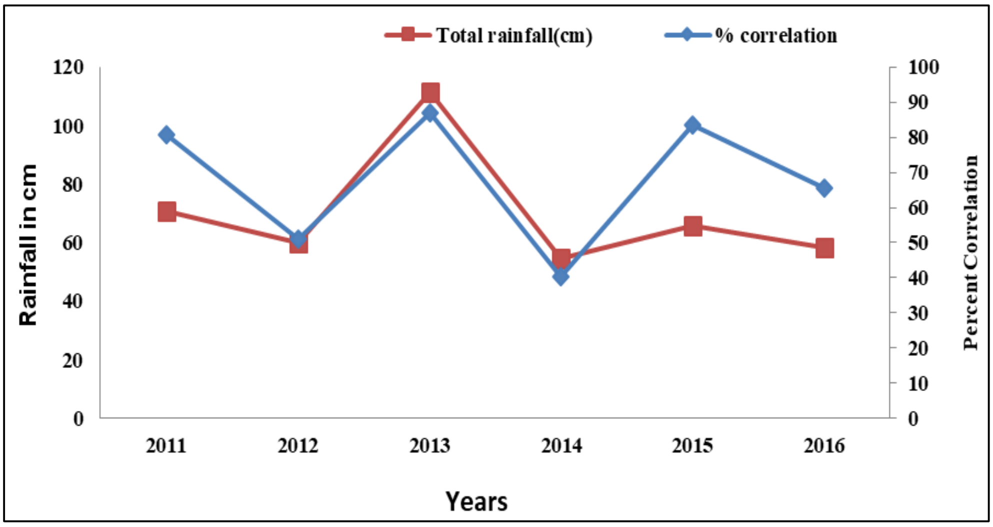

Fig 4: Showing correlation and rain fall and percent association between Dengue cases

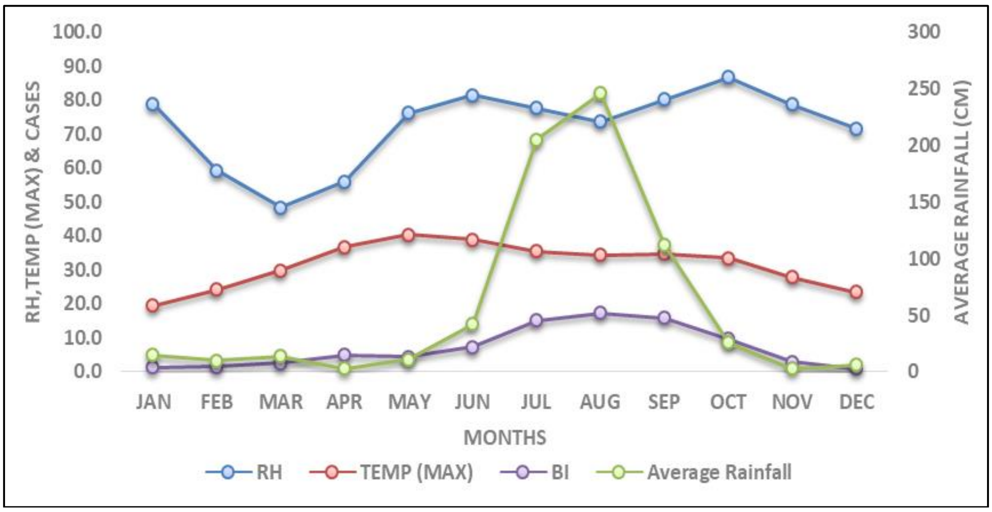

Fig 5: Month wise temperature and Dengue case distribution

Above table shows that in the month of April & May when the temperature is high and in the month of December & January with low temperature (Max & Min) the emergence of adult mosquito is reduced as a result of which adult density is reduced which in term reduced the local transmission therefore the cases are seen reduced in the month of November, December, January & February. During the ambient temperature in the month of July to October it favours ideal temperature for emergence of adult as a result adult density is increased and high cases are reported (Fig.5 & Table 3)

Humidity favours the life span of mosquitoes therefore with rise in humidity, the life days of mosquito is increased leading to completion of extrinsic incubation period of Dengue virus in *Aedes*. However, temperature and other favourable climate conditions are also required for effective transmission of disease.

Table 3: Showing correlation between climatic conditions (Relative Humidity, Rain Fall, Temperature and cases)

		2011	2012	2013	2014	2015	2016	AVG
RH	Correl (r)	0.471	0.472	0.120	0.710	0.403	0.471	0.5150
	% Correl.	22.18	22.35	1.45	50.46	16.30	22.22	26.52
Rainfall	Correl (r)	0.899	0.713	0.932	0.634	0.913	0.809	0.986
	% Correl.	80.91	50.94	86.88	40.19	83.38	65.60	97.37
Temperature	Correl (r)	0.054	-0.240	0.096	-0.076	0.260	0.132	0.132
	% Correl.	0.30	5.79	0.93	0.58	6.76	1.75	1.74

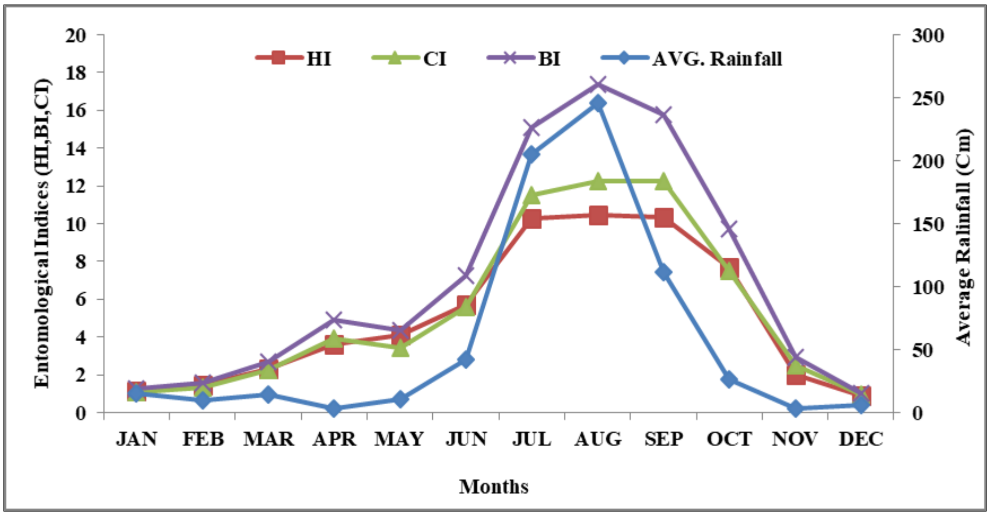

Fig 6: Monthly association of entomological indices with Rainfall

As observed in fig. 2 & 3, there was lag period between rainfall and dengue cases but breeding indices correlated with rainfall. Though rainfall decreased after August but breeding indices persisted and declined after October.

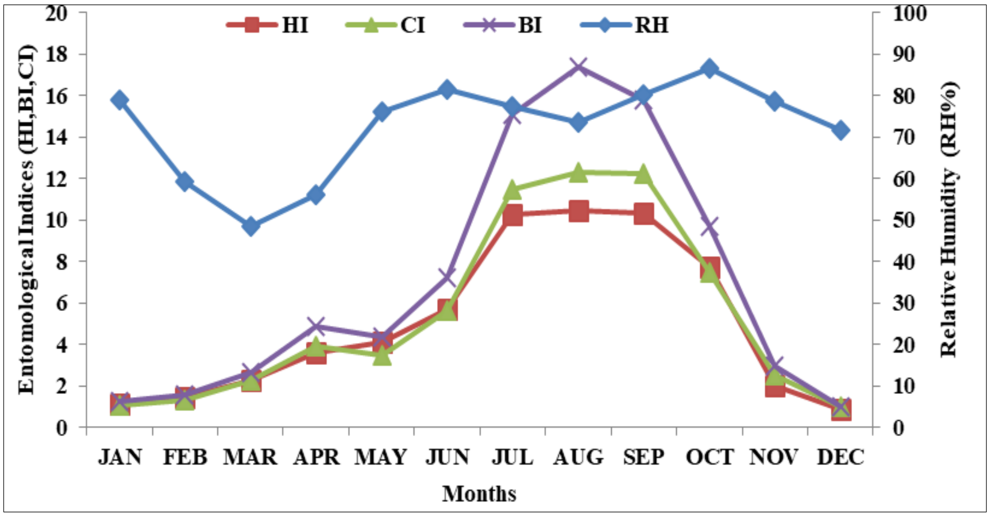

Fig 7: Monthly association of entomological indices with Relative humidity

Relative humidity (RH) has not shown significant correlation although it was positively correlated with the breeding indices as the indices are mostly on aquatic life of mosquito where RH has a little role to play except fast evaporation during low RH.

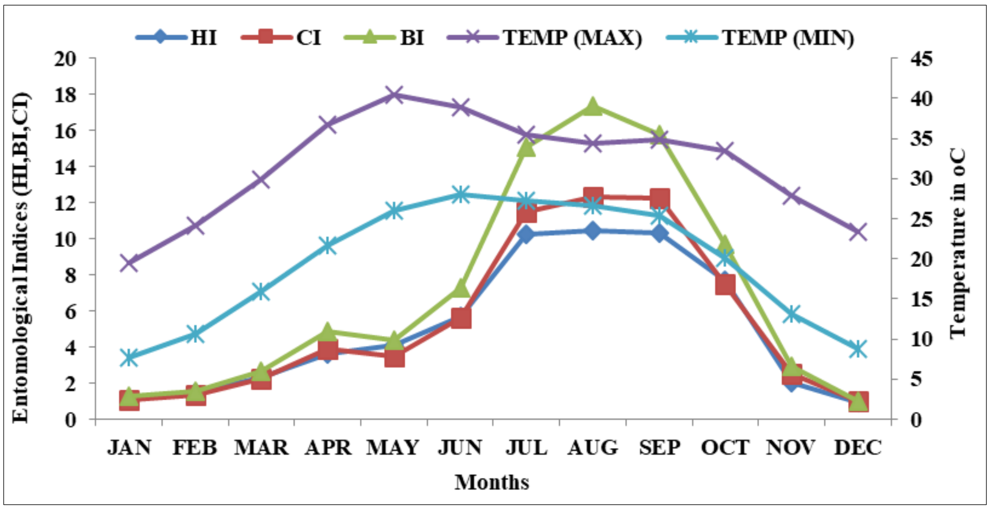

Fig 8: Monthly association of entomological indices with Temperature

Table 4: Correlation between entomological indices and environmental factors

Correlation (r)	House Index	Container Index	Breteau Index
Rainfall	0.839	0.872	0.890
Humidity	0.433	0.401	0.394
Temperature	0.621	0.560	0.551

The cases were highly correlated with rainfall. Rainfall leads to multification of breeding sites and shift of breeding sites from domestic to peri-domestic areas. The relative humidity also showed low positive correlation whereas the temperature was found to be least correlated may be due to conditioning of internal environment by the community throughout year as breeding and resting habits of *Aedes* are mostly indoors (Fig 6-8 & Table 4).

4. Discussion

Analysis of Dengue data of Delhi shows in 2013 and 2015 transmission window was found to be increased as cases have been reported in the month of January and February also. The extension of transmission window may sometime lead to perennial transmission which may pose more risk. Variations in climate patterns may favour increased incidence of dengue with loss of man day and productivity. Delhi being the capital city has large number of economic avenues and treatment facilities. A patient who may have acquired infection outside Delhi at place of work and or residence may be notified in Delhi or treated in Delhi and reported to Directorate of NVBDCP for cross notification may also lead to variation in incidence of cases.

Present study highlighted high correlation between rainfall and dengue cases the lag phase of about 2 months was observed which may be attributed to inherent delays between weather conditions and their impact on mosquito populations, virus replication and subsequent impact on transmission patterns. Similar pattern of lag phase was observed in a study on heterogeneous effect of lagged meteorological variables on dengue fever between the provinces of Cambodia [15]. In a similar study of correlation between seropositive dengue cases and climatic factors in Delhi after 2003 outbreaks it was observed that difference between serological positive cases as compared to serological negative cases in post monsoon period was significantly higher ($p<0.001$). The study also highlighted rain, temperature and relative humidity as the major climatic factors which alone or collectively are responsible for outbreak situations [16], similar conditions are observed in Delhi cases data when compared to rainfall and humidity. In Brazil during a study of climatic factors, only rainfall-lag per three months showed a positive association with the number of cases dengue. Relation between rainfall and dengue cases was significant with a lag of three months [17]. In a study in North Australia, significant correlation ($p>0.01$) was at one month in Cairns and at three months in Townsville [18]. In other studies, a correlation was seen with a lag time of five to twenty weeks and three months [19]. However, it was seen that rainfall was positively correlated with breeding indices and there was no lag period observed. It was also seen that rainfall the breeding persisted for some period of time after stopping of rains during October may be due to availability of outdoors fresh surface water in leftover containers and manmade housing structures /containers, in addition to this, relative humidity and temperature also provides ambient conditions outdoors till October month thereafter, low temperature reduces the outdoor breeding as the breeding trend is seen in fig. 6.

In the present study temperature was found to be least correlated may be due to conditioning of internal environment of their houses by the community throughout year as breeding and resting habits of *Aedes* are mostly indoors. However, no significant correlation between the incidence of dengue and temperature was also reported in study by Carnciro*et.al.*[13]. The presence of air pollutants also interferes with the life cycle of the dengue mosquito. A study on time gap between exposure to weather conditions and subsequent occurrence of dengue cases was carried out in Singapore. Correlation between temperature and dengue showed sine wave oscillating at about 24 weeks cycle or interval with stronger positive association between lag week 9 and 17 [20].

In the present study it was found that maximum rainfall was observed in Aug 2012 but highest number of Dengue cases were reported in 2015 and least number were reported in 2012. Possible explanation for 2015 can be the months in that year were warmer and wetter all over. In a study in Brazilit was quoted that temperature interferes with dengue virus incubation period and it drops from 10 to 7 days whenever temperature rises from 27 °C to 37 °C [13]. Viana *et al* [21] in their study of review of studies from 1991 to 2010, reported that Dengue cases appear after weeks of peak temperature and rainfall, a time during which the mosquito can develop and contaminate the population. In a study in Colombia it was observed that average and maximum temperatures greater than 28 °C and 32 °C, respectively, had an inversely related relationship to DENV incidence, which is in accordance with areas where higher temperatures are recorded in Colombia [22].In another study in Brazil, it was reported that at low temperatures, the mosquito does not live long enough, and the virus does not develop properly. High temperature reduces virus replication and the extrinsic period in mosquito and may magnify epidemics [23]. In another study in East Delhi it was observed that large number of Dengue cases was reported during the post-monsoon period each year. Temperature, rainfall, and humidity varied significantly across the pre-monsoon, monsoon, and post-monsoon periods. The best correlation between these three climatic factors and dengue occurrence was at a time lag of two months [24].

In the present study low correlation between humidity and dengue cases was observed as compared to rainfall. Humidity favours the life span of mosquitoes therefore with rise in humidity, the life days of mosquito is increased leading to completion of extrinsic incubation period of Dengue virus in *Aedes.* However, temperature and other favourable climate conditions are also required for effective transmission of disease. In a study in Kolkata, relative humidity (%) showed a statistically significant ($p<0.001$) positive correlation with dengue cases in the year 2014, *i.e.* with increased humidity dengue cases increased in 2014. It was observed that an increase in the number of rainy days and relative humidity were associated with an increase of dengue cases in Kolkata [25]**.** A relationship between dengue and climatic factors was studied in Metro Manila from 1996 to 2005. It was suggested that rainfall is significantly correlated to dengue incidence ($r^2 = 0.377$, $p < 0.05$). No significant correlation was established between dengue incidence and temperature ($p > 0.05$). It was concluded that dengue incidence in Metro Manila varies with changing rainfall patterns and intensified surveillance and control of mosquitoes during periods with high rainfall were recommended [26].

In another study in Delhi, maximum number of containers were found with *Aedes* breeding during the rainy season followed by summer, autumn, winter and spring, respectively. In all seasons dengue vector preferred to breed in peri-domestic area with peaks during summer and monsoon. Breeding in outdoor containers increased during rainy season and breeding in indoor containers was found maximum during summer. During winter and spring season not a single container was found positive in outdoor area except one positive container recorded in late winter it might be due to low outdoor temperature. This showed a correlation between climatic factors and dengue cases [27]

Aedes aegypti have adapted indoor conditions therefore in extreme climatic conditions also it can survive and it becomes difficult to control. Eggs can withstand desiccation during the low temperature even up to many months. Favourable temperature and other ecological conditions and presence of fresh water lead to egg hatching and emergence of adult. This lead to a sudden spurt of *Aedes* density as a result of that increase in Dengue cases is observed [28].

5. Conclusion

The study shows a clear dependency of dengue cases with climatic factors and has revealed that there is a lag phase between rains and appearance of cases which provides an opportunity to Programme managers to carry out vector control measures along with source reduction. This window of opportunity provides enough time to mobilize resources for the implementation of interventional measures to minimize the impact of the epidemic. There is need to develop a weather-based dengue forecasting model that will assist programme managers in forecasting and control measures and reduce the size of an outbreak, thereby decreasing disease transmission and possibly the resulting mortality, leading to reductions in the healthcare burden and operating costs. Bush *et al* also recommended need to improve environmental monitoring and surveillance systems in low- and middle-income countries such as India. New research initiatives should focus on collecting high-quality, long-term data on climate-related health outcomes with the dual purpose of understanding current climate–health associations and predicting future scenarios [29].

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