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SURVEILLANCE OF *AEDES* DIVERSITY, SEASONAL PREVALENCE AND HABITAT CHARACTERIZATION IN BULANDSHAHR, UTTER PRADESH, INDIA

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Abstract

Mosquitoes have the ability to spread several parasites and pathogens that cause serious diseases in both humans and animals. In order to effectively control disease and mosquito populations, analysis of mosquito diversity, prevalence and habitat characterization in any location is frequently necessary. In order to compile comprehensive first-hand data on mosquitoes, the current study was carried out in the Khurja area of the Bulandshahar district in Utter Pradesh, India. The study was carried out over a period of one year. Ladle and dipping methods were used to collect the larvae of the *Aedes* mosquito. 48 human habitations were selected randomly from the Bulandshahar region. The accumulated data were used to compute the monthly and seasonal Relative Abundance (RA), Per Man Hour Density (PMHD), House Index (HI) and Container Index (CI) of *Aedes* species. Three species from the genus *Aedes* including *Aedes aegypti*, *Aedes albopictus*, and *Aedes vittatus* identified in the Bulandshahr region. The most prevalent species was *Aedes aegypti*. The RA, PMHD, HI and CI were highest for *Aedes aegypti* (53.33%, 36.67, 44.08) followed by *Aedes albopictus* (28.33%, 19.49, 32.98), and *Aedes vittatus* (18.33%, 12.62, 15.10) and CI=12.53%. In seasonal population dynamics of *Aedes* species in relation to meteorological factors, only temperature and rainfall are significant variables ($P \leq 0.05$) of climate that affect the density of mosquitoes in the study area, with no correlation with the relative humidity. According to the findings, there is a substantial probability of mosquito-borne disease outbreaks. There must be precautions taken because dengue fever outbreaks are frequent in the region. Interventions for prevention are necessary since the region is vulnerable to dengue fever outbreaks and other diseases spread by mosquitoes.

Keywords : *Aedes aegypti, Aedes albopictus, Aedes vittatus*, Bulandshahr, Mosquito diversity. Seasonal prevalence.

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Introduction

The *Aedes* mosquito (Diptera: Culicidae) is an insect that is responsible for a number of devastating infections, including the Dengue virus, yellow fever virus, Chikungunya virus, and Zika virus (WHO 2021). Dengue fever cases have increased rapidly in recent decades around the world (Waggoner *et al.*, 2016). In order to tackle dengue, we have been at war with mosquitoes since the 1950s. The campaign initially saw success, but it now seems to be faltering as epidemics of unearthed diseases like dengue fever and chikungunya in India have been brought on by a rise in mosquito population over the past two decades. The increasing population density, urbanization, development, and inappropriate waste management can all be responsible for the rise in mosquito populations. These elements, combined with the region's typical intense monsoon rains and hot, humid air, have made it the perfect place for mosquito breeding. The life cycle of a mosquito normally takes seven to eight days from the time the egg is laid to the time the adult mosquito emerges from the water collection. Every natural or artificial container that may store water for a specified period of time is potentially a mosquito breeding site. Both indoors and outside are where you can find these containers. The main indoor breeding locations are earthen water storage containers, concrete water storage tanks, open water storage tanks, metal drums, flower vases, saucers under decorative plant pots, soft drink bottles, water trays in refrigerators with automatic defrosting and air conditioners, and plastic containers. The most common outdoor breeding sites are tree holes, bamboo stumps, leaf axils, earthen pots, abandoned bottles, tins, or tyres, as well as metal water storage drums, rain barrels, clogged roof gutters, and other places. The *Aedes aegypti* mosquito, which is considered to be the main carrier of the dengue virus, breeds in naturally occurring containers but has recently evolved well to urban and semi-urban environments, where it mostly breeds in artificial containers. Thus, dengue fever is a sneaky illness in densely populated areas. The hours just before sunrise and just after dark in the evening are when *Aedes aegypti* (a daytime feeder) bites are most prevalent (Trpis *et al.*, 1973). In each egg-laying session, the female *Aedes aegypti* bites repeatedly, resulting in groups of infected people. The eggs that a female lays can remain dormant for several months until hatching when they come into contact with water (Caminade *et al.*, 2012).

Aedes albopictus (Stegomyia albopictus), popularly known as the Asian tiger mosquito, is a secondary dengue vector native to Southeast Asia's tropical and subtropical regions. Nonetheless, this species has spread to many nations through cargo shipping and international travel (Scholte and Schaffner, 2007). According to Hochedez *et al*. (2006), *Aedes albopictus* is an epidemiologically significant vector for the spread of a number of viral illnesses, such as the yellow fever virus, dengue fever, and chikungunya fever, as well as a number of filarial nematodes, including *Dirofilaria immitis* (Cancrini *et al.,* 2003). According to Wong (2013) and Grard (2014), *Aedes albopictus* can harbor the Zika virus and may act as a vector for human Zika transmission. The adaptive *Aedes albopictus* is quite versatile. Because of its adult and egg endurance for cooler weather, it has a widespread range (Medlock *et al.,* 2006; Romi *et al.,* 2006). In a few outbreaks where *Aedes aegypti* is either absent or present in low numbers, *Aedes albopictus*, a day-biter similar to *Aedes aegypti*, has been identified as the main dengue virus vector (Metselaar *et al.*, 1980 and Paupy *et al.*, 2010).

The *Aedes vittatus* (Bigot) mosquito, formerly known as *Culex vittatus* and initially discovered in Corsica in Europe, has recently come to the attention of the public due to its connection to the Zika virus (ZIKV) (Jupp and Mclntosh, 1990 and Reinert, 2000). Also, the mosquito is known to be a major factor in the maintenance and spread of viruses that affect public health, such as the dengue virus, chikungunya virus, and the yellow fever virus (Sudeep and Shil, 2017).

At present, mosquito-borne diseases, particularly dengue, are spreading rapidly over India. Around 10 lakh cases and thousands of fatalities were reported in India during the past few years (2015–2021), according to the National Vector Borne Disease Control Program (NCVBDC, 2021). Programs for vector control are crucial in managing diseases spread by mosquitoes. The most crucial decision factors for implementing any vector management strategy are data on species diversity, prevalence, and the ecology of their habitats. The varying environmental conditions in India allow for a diverse mosquito faunal composition across the country (Kalra *et al.,* 1997; Sharma *et al.,* 2021).

There are approximately 3,590 mosquito species worldwide, with over 410 mosquito fauna found in India (Tyagi *et al.*, 2015; Suman *et al.,* 2022). These studies can provide a baseline for mosquito-borne virus activity, enabling long-term monitoring due to variation. However, the Koppen climate classification (Koppen, 1884) states that the majority of Uttar Pradesh's (U.P.) climate is humid subtropical with dry winter (Cwa) type, with some areas of Western U.P. being hot semi-arid (BSh) type and frequently referred to as tropical monsoon type (Mathur, 2022).

In the current investigation, efforts have been undertaken to collect data on the identification of *Aedes* species diversity, seasonal prevalence, and habitat characterization in Bulandshahr, Utter Pradesh, India.

Material and Methodology

Study area and sampling

The current investigation was carried out in the Bulandshahr district of Uttar Pradesh between March 2021 and February 2022 (28.4070° N, 77.8498° E). The city of Bulandshahr is located in western Uttar Pradesh. The district's geographic area is 4353sq km i.e., approximately 1.48% of the total area of Uttar Pradesh. Temperature range of 4°C to 45°C, relative humidity of 32–80%, and rainfall of 60–65 mm is average. Throughout the survey, different *Aedes* species were collected using sampling techniques that were suggested by the WHO (1975) and adopted by many researchers with only minor modifications. After obtaining permission from the head of the house, larval stages were collected from 48 human habitations once a month for 10 minutes using the ladle (volume 350 ml) and dipping procedures. Larvae were collected and stored in plastic vials with 70% ethyl alcohol.

Identification

A binocular microscope was used to identify the morphological parameters of *Aedes* species (figure 1-2) by following the identification key of Christophers (1960), Tyagi *et al.* (2015), and the monograph of Rueda (2004).

Meteorological data

From the Indian meteorological department (2021-2022), monthly weather data were gathered. We determined the mean, minimum, and maximum values for the monthly statistics of temperature, relative humidity, and precipitation.

Statistical Analysis

Manual descriptive analysis was used to determine each species' relative abundance (RA), per man-hour density (PMHD), house index (HI), and container index (CI). "Microsoft Excel" was used for the other statistical analysis.

$$RA = \frac{\text{Total No. of Individual Species}}{\text{Total No. of All Species Population}} \times 100$$

$$PMHD = \frac{\text{Total No. of Individual Species}}{\text{Total Hour of Collection}}$$

$$HI = \frac{\text{No. of Positive House}}{\text{Total No. of House Surveyed}} \times 100$$

Result and Discussion

Table 1 : The total number of *Aedes* species captured each month in Bulandshahar.

Species	Months												Annual
	Summer			Rainy				Post – Rainy		Winter			
	Mar	Apr	May	June	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	
Aedes aegypti	350	430	370	320	375	425	370	350	290	65	55	125	**3525**
Aedes albopictus	210	180	150	130	145	195	205	210	235	70	47	95	**1872**
Aedes vittatus	115	135	145	120	125	125	135	115	95	25	18	59	**1212**
Total	**675**	**745**	**665**	**570**	**645**	**745**	**710**	**675**	**620**	**160**	**120**	**279**	**6609**

Table 2 : Bulandshahar month-by-month meteorological data, from March 2021 to February 2022.

Species	Months											
	Summer			Rainy				Post – Rainy		Winter		
	Mar	Apr	May	June	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb
Temperature (Min-max) Average (^{0}C)	(11-39^{0}C) 25^{0}C	(19-43^{0}C) 31^{0}C	(18-44^{0}C) 32^{0}C	(25-44^{0}C) 34^{0}C	(25-38 ^{0}C) 31 ^{0}C	(26-37^{0}C) 31^{0}C	(24-37^{0}C) 29^{0}C	(17-35^{0}C) 25^{0}C	(9-32^{0}C) 20^{0}C	(7-27^{0}C) 15^{0}C	(4-25^{0}C) 13^{0}C	(18-31^{0}C) 10^{0}C
Relative humidity (Min-max)	(14-95%) 62%	(13-76%) 41%	(15-100%) 53%	(12-100%) 51%	(49-100%) 79%	(48-100%) 77%	(42-100%) 78%	(31-100%) 77%	(29-95%) 73%	(29-100%) 77%	(30-100%) 80%	(22-100%) 67%
Rainfall (mm)	15mm	12mm	6mm	24mm	130mm	141mm	64mm	9mm	2mm	5mm	13mm	12mm

Table 3 : *Aedes* species relative abundance (RA) month-to-month in Bulandshahr

Species	Months												Annual
	Summer			Rainy				Post – Rainy		Winter			
	Mar	Apr	May	June	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	
Aedes aegypti	51.85	57.71	55.63	56.14	58.13	57.02	52.11	51.85	46.77	40.62	45.83	44.80	**53.33%**
Aedes albopictus	31.11	24.16	22.56	22.80	22.48	26.20	28.87	31.11	37.90	43.75	39.16	34.05	**28.33%**
Aedes vittatus	17.03	18.12	21.80	21.05	19.37	16.77	19.01	17.03	15.32	15.62	15.00	21.14	**18.33%**
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**

Table 4 : *Aedes* species' monthly Per Man Hour Density (PMHD) in Bulandshahr

Species	Months												Annual
	Summer			Rainy				Post – Rainy		Winter			
	Mar	Apr	May	June	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	
Aedes aegypti	43.75	53.75	46.25	40.00	46.87	53.12	46.25	43.25	36.25	8.12	6.87	15.62	**36.67**
Aedes albopictus	26.25	22.50	18.75	16.25	18.12	24.37	25.62	26.25	29.37	8.75	5.87	11.87	**19.49**
Aedes vittatus	14.37	16.87	18.12	15.00	15.62	15.62	16.87	14.37	11.87	3.12	2.25	7.37	**12.62**
Total	**84.37**	**93.12**	**83.12**	**71.25**	**80.61**	**93.11**	**88.74**	**83.87**	**77.49**	**19.99**	**14.99**	**34.86**	**68.79**

Table 5 : The number of houses positive for *Aedes* species larvae.

Species	Total number of houses surveyed (48)												Annual
	Summer			Rainy				Post – Rainy		Winter			
	Mar	Apr	May	June	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	
Aedes aegypti	32	37	25	17	29	31	22	17	15	9	7	13	**21**
Aedes albopictus	21	18	15	13	16	19	20	23	24	7	5	9	**16**
Aedes vittatus	11	13	10	12	8	9	7	6	5	3	1	2	**7**

Table 6 : Monthly House Index (HI) of *Aedes* species in Bulandshahr

Species	Months												Annual
	Summer			Rainy				Post – Rainy		Winter			
	Mar	Apr	May	June	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	
Aedes aegypti	66.66	77.08	52.08	35.41	60.41	64.58	45.83	35.41	31.25	18.75	14.58	27.03	44.08
Aedes albopictus	43.75	37.50	31.25	27.08	33.33	39.58	41.66	47.91	50.00	14.58	10.41	18.75	32.98
Aedes vittatus	22.91	27.08	20.83	25.00	16.66	18.75	14.58	12.50	10.41	6.25	2.08	4.16	15.10

Table 7 : Location of several collections with possible breeding sites for *Aedes* species and the percentage of containers containing larvae.

Types of Natural and Artificial water collections	Potential water collection	Positive for larvae	Percentage of total positive containers n=207	Container Index (207/1652x100)
Tins	205	40	19.32	
Flowerpots	320	12	5.79	
Fridge tray	40	8	3.86	
Terrace	25	2	0.96	
Drums	95	21	10.14	
Earthenware pots	78	11	5.31	**12.53%**
Plastic container	180	24	11.59	
Cement tank	150	37	17.87	
Discarded tires	52	5	2.41	
Mud ditches	165	14	6.76	
Tree holes	64	0	0	

Puddles	45	3	1.44	
Soft drink bottles	120	9	4.34	
Bamboo stumps	53	0	0	
Clogged roof gutters	12	5	2.41	
Others	48	16	7.72	
Total	**1652**	**207**	**100**	

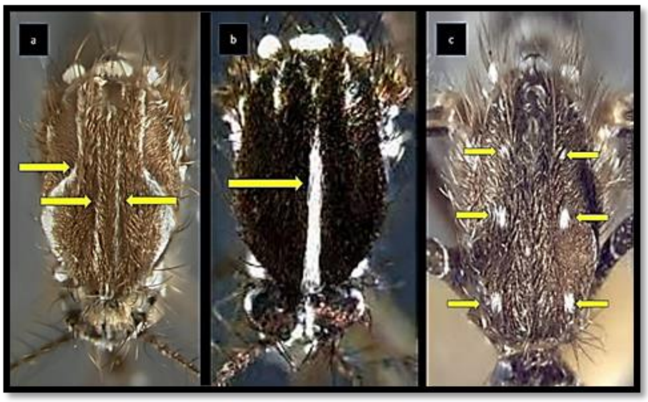

Fig. 1 : Microscopic identification of *Aedes* species, dorsal view of the thorax. a) In *Aedes aegypti*, mesonotum is marked with a pair of lateral curved white lines (Half-moon shape). b) In *Aedes albopictus*, mesonotum with a narrow median silvery white line. c) In *Aedes vittatus*, mesonotum with 4 to 6 small white spots.

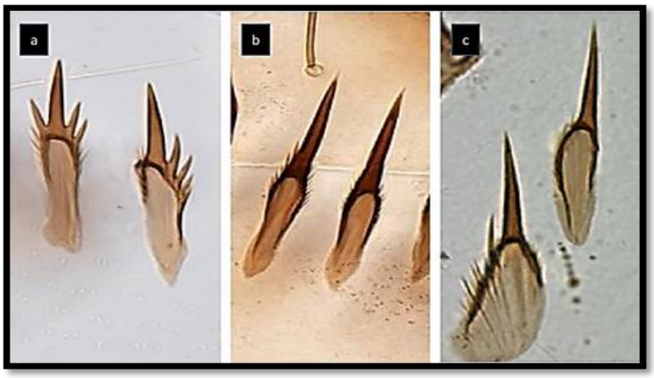

Fig. 2 : Microscopic identification of larvae of *Aedes* species (Scale 25 µm.) a single, straight row of comb scales found in *Aedes aegypti*, *Aedes albopictus*, and *Aedes vittatus* on the 8th abdominal segment. a) In *Aedes aegypti*, comb scales with the long medial spine with short subapical spines (pitch-fork shaped). b) In *Aedes albopictus*, comb scales with long medial spines and subapical spines are absent (Straight thorn-like shape). c) In *Aedes vittatus*, comb scales with a broad base and long median spines.

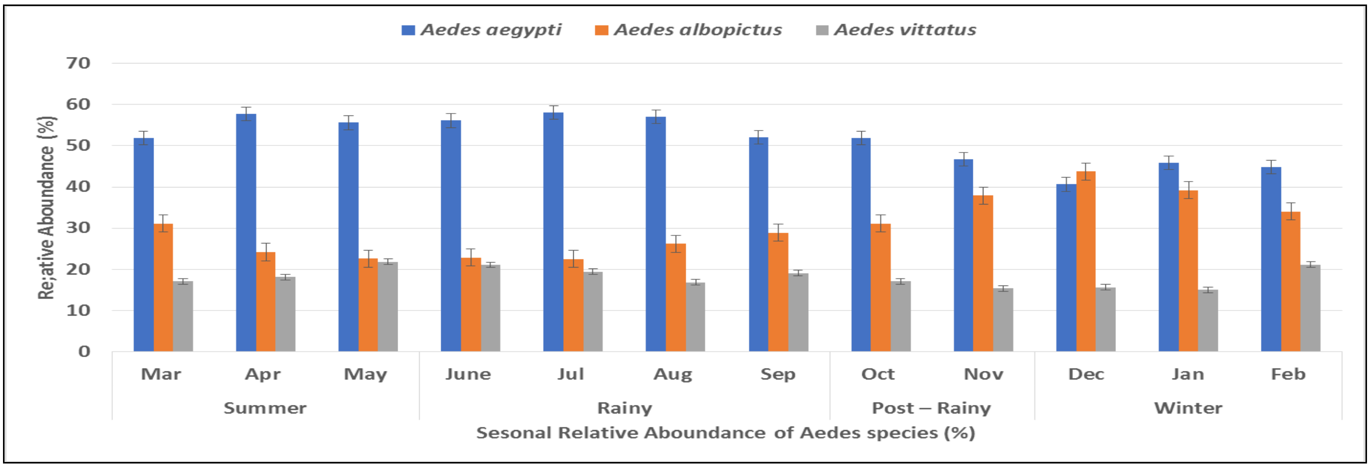

Fig. 3 : Seasonal relative abundance of *Aedes* species in Bulandshahr.

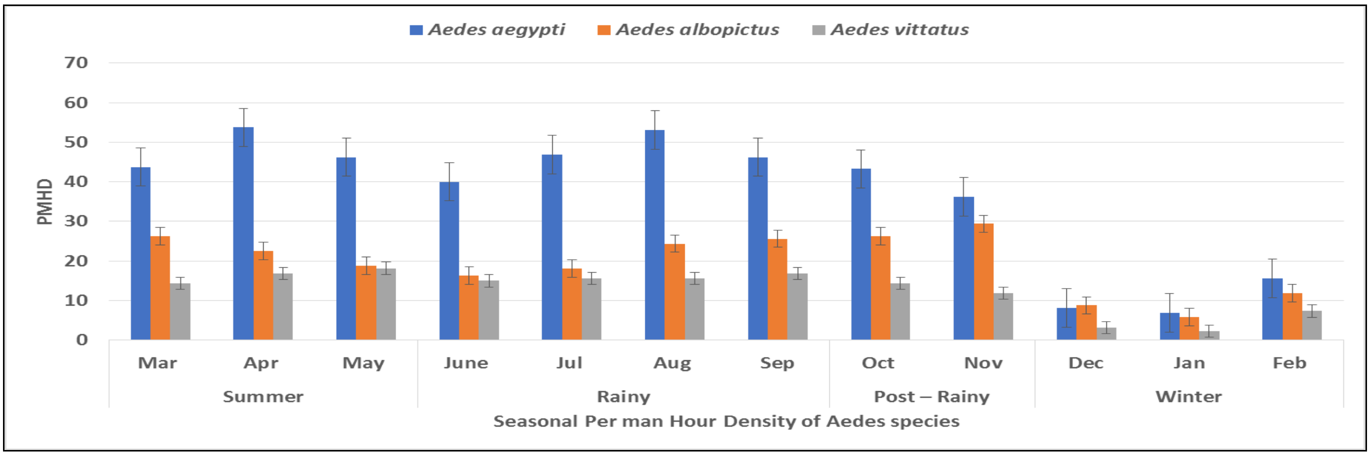

Fig. 4 : Seasonal Per man hour density of *Aedes* species in Bulandshahar.

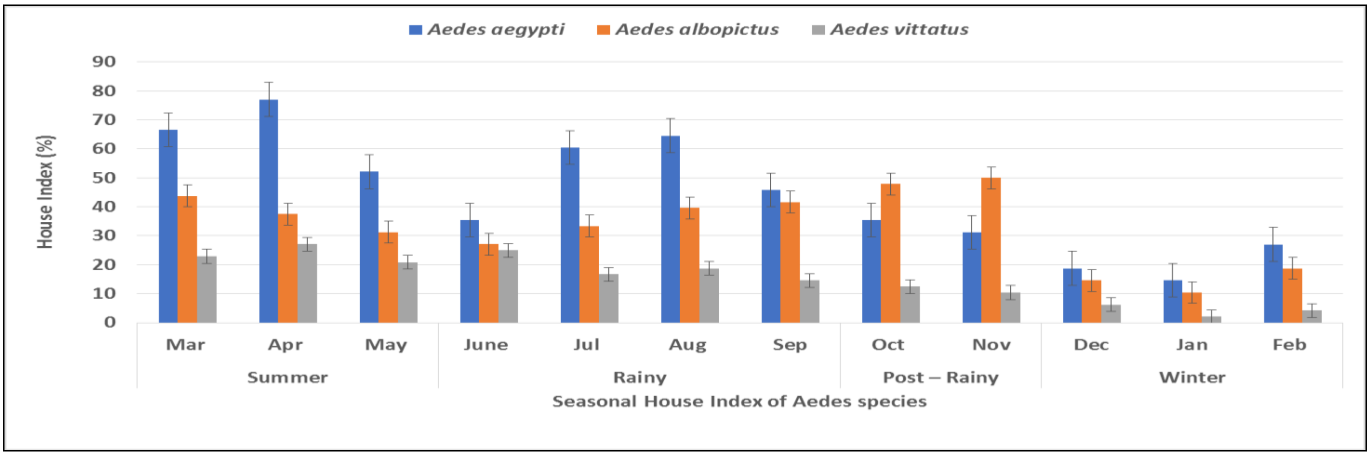

Fig. 5 : Seasonal house index of *Aedes* species in Bulandshahar.

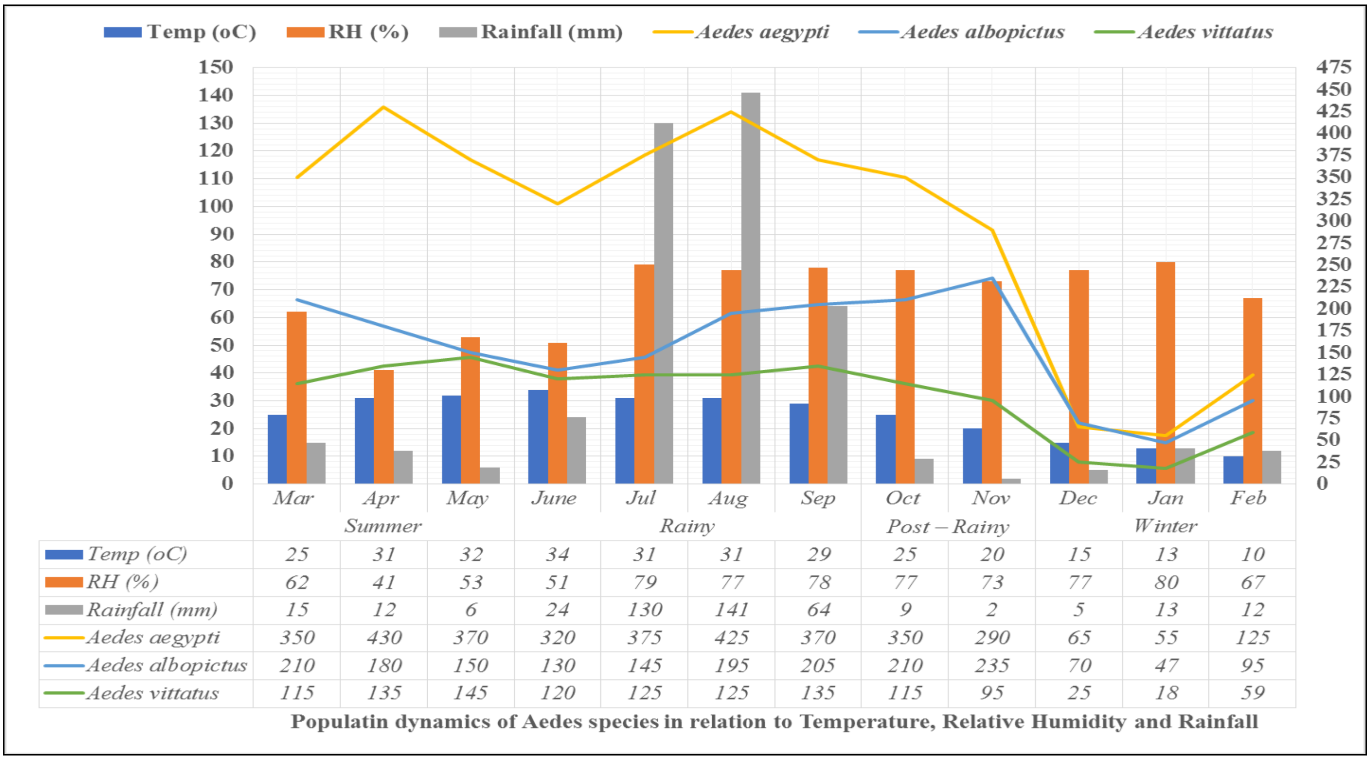

Fig. 6 : Population dynamics of *Aedes* species in relation to temperature, relative humidity and rainfall in Bulandshahar region.

Result and Description

Three *Aedes* species—*Aedes aegypti*, *Aedes albopictus*, and *Aedes vittatus*—belonging to the subgenera Stegomyia and Fredwardsius—have been identified in the Bulandshahr district region. A total of 6609 specimens were collected from the Bulandshahr region (Table 1). *Aedes aegypti*. *Aedes albopictus* and *Aedes vittatus* contributed 53.33%, 28.33%, and 18.33% part of all *Aedes* species, respectively (Table 3). *Aedes aegypti* is a more abundant species than *Aedes albopictus* and *Aedes vittatus*.

Aedes species in the region, along with their per man hour density, monthly diversity, relative abundance (RA), and house index. The year-round relative abundance (RA) ranking of *Aedes aegypti* is the highest (53.33), with the peak abundance occurring in July (58.13) and the lowest in December (40.62). The second-most common *Aedes* species there, *Aedes albopictus*, peaked in December (43.75), and it reached its lowest value in July (22.48) (Table 3). The least abundant *Aedes* species, *Aedes vittatus*, peaked in May (21.80) and lows in January (15.00).

Per Man Hour Density is frequently used to calculate vector density in any given area. One insect collector in the study region gathered an average of 68.79 indoor resting *Aedes* mosquitoes per hour during the study year. The PMHD of *Aedes aegypti* ranged from 6.87 to 46.87, with an average of 36.67, in different months. *Aedes albopictus* had an average density of 19.49 and varied in different months (5.87 to 26.25). The PMHD of *Aedes vittatus* was 12.62, varying from 2.25 to 18.12 in different months (Table 4).

The frequency of human shelters invaded by vectors, which may be directly correlated to the danger of transmitting vector-borne diseases in any location, is revealed by the house index (HI), another significant statistic. A total of one or more mosquitoes were discovered in 92% of the assessed human habitations. *Aedes aegypti* 44.08 (14.58-77.08) showed a higher HI with a statistically significant difference between them (P<0.05). HI for *Aedes albopictus* and *Aedes vittatus* was 32 (10.41-47.91) and 15.10 (2.08-27.08), respectively (Table 5-6).

The container index (CI) solely indicates the proportion of water-holding containers that have larvae present. Larvae were found in 207 of the 1652 natural or artificial water collections that had the ability to support *Aedes* breeding, resulting in a container index of 12.53% (Table 7). The common artificial and natural breeding habitats of *Aedes* species are tins, flowerpots, fridge trays, plastic containers, cement tanks, discarded tyres, mud ditches, soft drink bottles, clogged roof gutters, and earthenware pots.

Analyzing the seasonal prevalence, *Aedes* species were caught in the largest number during the rainy season, 2670 (40.39%), followed by the summer, 2085 (31.54%), the post-rainy, 1295 (19.59%), and the winter, 559 (8.45%). RA of *Aedes aegypti* was comparatively higher in the summer season, rainy season, post-rainy, and winter season than the *Aedes albopictus* and *Aedes vittatus* (Table 3 and figure 3-5). Mosquito density decrease during the winter season, and increases during the summer and rainy season due to the higher temperature and precipitation.

Population dynamics of *Aedes* species in relation to temperature, relative humidity, and rainfall were noticed in the study area. The results showed a relationship between mosquito population and temperature and rainfall. There is no relationship between mosquito population and other meteorological parameters such as relative humidity (less significant) (Figure 6). A higher number of *Aedes* species was noticed at temperatures of 25-31^{0}C during the summer and rainy season (24-141mm) and low at 10^{0}C during the winter season. The range of relative humidity in the study area was (41 to 80%), which is not significantly affect the density of mosquitoes.

In Uttar Pradesh and other Indian states, it is recognized that all *Aedes* species can spread dengue and chikungunya. These vectors spread these diseases, along with others like yellow fever, zika, etc., to other regions of the globe.

The survey resulted in the collection of a number of *Aedes* species, all of which are clinically significant and serve as important vectors for diseases like dengue, yellow fever, Japanese encephalitis, chikungunya, and filariasis. The main vector species for dengue and chikungunya in India are *Aedes aegypti* and *Aedes albopictus* (Thenmozhi *et al.,* 2007; Jansen and Beebe, 2010). (Kumar *et al.,* 2012). Several people can contract the dengue virus from an *Aedes* species during a single gonotrophic cycle. According to Paupy *et al*. (2003), mosquitoes are poikilothermic by nature and rely heavily on the local environment. Earlier studies revealed that the strain of *Aedes aegypti* followed more r-strategies in terms of biological characteristics like survival and fertility (Sharma *et al.,* 2022).

The geographical range of *Aedes aegypti* is primarily restricted to tropical and subtropical regions, where the average annual temperature is above 10°C. Mosquito seasons vary according to various tropical and subtropical climates. With occasionally variable results, numerous studies have examined the impact of temperature, precipitation, and even relative humidity on mosquito populations around the world. Rainfall can occasionally have a negative impact on mosquito populations. Precipitation helps to create new breeding locations, but it can also make oviposition traps less attractive, which results in reduced catching rates. It is also crucial to note that using regression analysis to separate out the effects of each element is challenging due to the strong correlation between temperature and precipitation.

In our study, the mosquito population peaked during the summer months and rainy seasons and drastically dropped during the winter. Temperature and rainfall also showed a correlation with the mosquito index. The mosquito population showed less correlation with relative humidity.

According to studies, ecological and climatic factors affect the seasonal occurrence of the dengue virus and its vector, *Aedes aegypti* (Sukri *et al.,* 2003). Furthermore, according to reports of Chakravarti and Kumaria, (2005), the three main and significant environmental variables—rain, temperature, and relative humidity—could each individually or collectively be responsible for an epidemic. The majority of serologically positive cases in north India have been identified during the post-monsoon season.

Due to increasing population density and other factors, what was formerly thought to be an urban issue has now spread to rural areas as well. Because of high vector density, the disease occurs throughout the year with a peak during rainy and post-rainy seasons. In north India, there have been significant outbreaks (Dash *et al.,* 2005). In our study, *Aedes* vector density increases during the rainy season and is followed by the post-rainy season and summer season and decreases during the winter season.

Conclusion

The current study offers details on the distribution of *Aedes* species in the Bulandshahr ecological zone of Uttar Pradesh. Three *Aedes* species, including *Aedes aegypti*, *Aedes albopictus*, and *Aedes vittatus*, are found, according to the investigation. Compared to other *Aedes* species, *Aedes aegypti* is more prevalent. In order to prevent vector-borne diseases in the area, this highlights the need for vector surveillance strategies.

Conflict of interest

The authors declare that they have no conflicts of interest.

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