ISSN: 3064-9846
Research Article

Journal of Agricultural, Earth and Environmental Sciences

Prevalence of Aedes Mosquitoes during the Dengue Transmission Season in Haridwar City of Uttarakhand State, India

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Submitted: 01 May 2024 **Accepted:** 10 May 2024 **Published:** 24 May 2024

https://doi.org/10.63620/MKJAEES.2024.1036

Citation: *Singh, R. K., Akhtar, n., Siddiqui, n., & Singh, s. (2024). Prevalence of Aedes Mosquitoes during the Dengue Transmission Season in Haridwar City of Uttarakhand State, India. J of Agri Earth & Environmental Sciences, 3(3), 01-09.*

Abstract

An entomological investigation was conducted in the dengue-affected regions of Haridwar city, Uttarakhand, during the dengue transmission season. The purpose of the study was to determine the prevalence and distribution of Aedes mosquitoes and identify high-risk areas in Haridwar city for the control of dengue disease. Out of 1922 residential premises, commercial establishments, and public places only 244 localities were found positive for Aedes breeding. The House Index (HI), Container Index (CI), and Breteau Index (BI) in residential areas were 12.40, 8.08, and 20.68, respectively, while the CI in commercial and public places was 33.50. Aedes aegypti followed by Ae. albopictus and Ae. vittatus was the most dominating species and found in peri-domestic habitats. Larvae of Ae. aegypti was collected from junk materials, cemented tanks, pots, seepage water tanks, mud pots, discarded tires, tree holes, desert coolers, mani pots, plastic containers, tray of the domestic refrigerator, and flower pots. The average Man Hour Density (MHD) of Ae. aegypti, Ae. albopictus, and Ae. vittatus in residential areas were 10.77, 6.81, and 0.52, while in commercial/official areas, they were 4.75, 7.95, and 1.68. Five species of Aedes mosquitoes, namely Ae. aegypti, Ae. albopictus, Ae. vittatus, Ae. pseudotaeniatus, and Ae. thomsoni, were recorded during the study.

Keywords: Dengue Fever, Aedes Mosquito, Breeding, Entomological, Transmission Season

Introduction

Dengue infection a viral disease is one of the most common arthropods borne viral diseases across the world and majorly occurred in tropical and sub-tropical areas [1]. Dengue virus have four serotypes (DEN-1, DEN-2, DEN-3 and DEN-4) that cause infection in humans [2, 3]. All four serotypes can activate a broad range of illness, from in apparent or mild febrile Dengue fever (DF) to severe and fatal haemorrhagic disease [1, 4, 5]. The transmission of the disease is primarily attributed to Aedes aegypti and Ae. albopictus mosquitoes [4]. Many studies stated that Dengue fever has been identified as a significant disease burden in endemic countries [6]. In 1943, Dengue Virus (DENV) was first isolated from inoculated patient's serum samples in suckling mice from Japan and Calcutta (now Kolkata) in 1944 from serum samples of US soldiers [8]. Epidemically, the first case of clinical dengue-like illness was documented in Madras (now Chennai) in 1780, while the initial virologically confirmed epidemic of DF occurred in Calcutta and the Eastern Coast of India during 1963-1964 [9-12]. The first widespread epidemics of DHF occurred in India in 1996, specifically in areas surrounding Delhi and Lucknow, and dengue shock syndrome (DSS) followed in 2004 in Mumbai and other areas [13-15]. Subsequently, the disease spread throughout the entire country, infiltrating new regions and populations, and its magnitude as an epidemic continues to increase. The challenge posed by dengue viral infection is multifaceted, as the pathogenesis of severe dengue disease remains unknown, there is currently no available vaccine for protection, and the existing vector control measures are inadequate and insufficient [16, 17]. More than half of the world's population is at risk of dengue viral infection. Each year, an estimated 390 million dengue infections occur around the world, resulting in up to 36,000 deaths [18]. Delhi is also endemic to DF/ Dengue haemorrhagic fever (DHF) and has experienced several outbreaks [19-22]. Presently, DF/DHF has been reported as a re-emerging disease in India and in 2021 DF cases were reported from all over the country and all the states by

the National Center for Vector Borne Diseases Control (NCVBDC) [23-30]. During COVID-19 pandemic situation, the total number of DF cases seemingly decreased during years 2020 and 2021 including deaths as reported [31, 32]. In India in 2021, a total of 193245 DF/DHF cases with 306 deaths were reported while in Uttarakhand state, 738 DF/DHF cases with 2 deaths were also reported (NCVBDC 2022) [32]. Overall, the rising graph of DF/DHF, imposing a serious concern on the health of the country, including the state of Uttarakhand and in past few entomological studies were carried out on dengue surveillance in Uttarakhand state [27, 33, 37].

Dengue fever cases were regularly reported during the last decade, as 738 DF/DHF confirmed cases and 2 deaths were reported in 2021 and a few unreported DF/DHF cases also occurred during the study from the Uttarakhand state. The District Health Authority (DHA) made significant efforts to control the small dengue epidemic. National Institute Malaria Research (NIMR) field unit, Haridwar on request of the Chief Medical Officer (CMO) and District Malaria Officer (DMO) of Haridwar, to conduct an entomological investigation during the dengue transmission season. A study was conducted to gain insight into the breeding of Aedes mosquitoes, the distribution of adult mosquitoes, and the stratification of areas with Aedes mosquitoes. The study also aimed to identify high-risk areas in Haridwar city that are susceptible to dengue outbreaks. The results of this study are presented in this research article and a detailed report of the entomological survey was sent to the CMO and DMO, Haridwar to further follow-up and necessary action.

Materials and Methods

Study Site and Topography

Haridwar district, which came into existence on 28th December 1988, was formed by separating it from the Saharanpur district of Uttar Pradesh state. It is surrounded by Saharanpur district in the west, Dehradun district in the north, Pauri Garhwal district in the east, and Muzaffar Nagar and Bijnor districts of Uttar Pradesh in the south. The district's population, according to the 2011 census, is 18,90,422 [35]. Haridwar is located on the banks of the holy River Ganga and boasts abundant water resources. It is known for its agricultural productivity, with a wide variety of food grains being cultivated here. The weather in Haridwar is characterized by a temperature of 34 °C, a wind wave of 13 km/h, and a humidity level of 33% [35]. This district holds great significance as a Hindu pilgrimage site and is an ancient city in Uttarakhand state, North India. It is where the River Ganges emerges from the Himalayan foothills, making it one of the first towns where the sacred river touches the plains. Haridwar district spans an area of approximately 2360 km2 and is situated in the western part of Uttarakhand state, India. Its geographical coordinates are 29.58 degrees' north latitude and 78.13 degrees' east longitude. The district's elevation from sea level is 249.7 meters.

Entomological Surveys

The study site was selected based on the confirmed dengue cases reported over the past three years (2018-2020). From June 08, 2021, to December 23, 2021, an entomological study was conducted in 24 localities within Haridwar city and the BHEL complex area. In each selected site, a comprehensive survey was conducted in approximately 59-451 houses to collect larvae, employing the single larval technique simultaneously [36]. Both residential and commercial/official premises within the chosen localities were randomly screened to identify Aedes breeding sites in various types of containers found in and around the houses. A total of 1917 residential and 12 commercial/official premises were thoroughly screened in the dengue affected areas of Haridwar city to detect Aedes breeding within the houses and their surroundings. A door-to-door entomological survey was conducted to identify Ae. aegypti breeding habitats, including desert coolers, cemented tubs, cemented tanks, overhead tanks, iron/metal drums, junk materials, discarded tires, etc., in domestic and peridomestic areas of all selected localities, following the standard procedure outlined by the World Health Organization (WHO) for entomological techniques [37]. Larvae were collected from each locality using dipping and pipetting methods, and subsequent emergence was observed in the laboratory. Larger containers were searched using a 300 ml capacity dipper. The reared adult mosquitoes were identified using standard keys [37-39]. Additionally, the House Index (HI), Breteau Index (BI), Container Index (CI), and Pupal Index (PI) were recorded for these localities. The data collected on the types and locations of breeding habitats were properly documented and analysed, and various indices were calculated using larval techniques and the standard WHO procedure [2, 40]. Containers found to have Aedes breeding during the survey were further examined, and the Breeding Preference Ratio (BPR) was calculated to determine the percentage of species composition of Aedes mosquitoes.

Adult Mosquito Collection and Sampling

Adult mosquitoes were collected from both indoor and outdoor areas of the houses using a mouth aspirator and a torch (flashlight). This was done to determine the mosquito biting activity and identify the species up to the species level. The identification was carried out using standard identification keys [37-39]. The collection of adult mosquitoes took place during the early morning hours (0600-0900) by two insect collectors. These collectors visited two human dwellings, including cattle sheds, in dengue affected localities. The same field team was responsible for capturing the Aedes mosquitoes in each study locality. Once collected from all selected localities, the mosquitoes were placed in test tubes and separated based on the locality name, date, and time of collection. Subsequently, the adult mosquitoes were identified up to the species level and screened for infectivity.

For each locality, container-wise data were pooled to calculate indices like container index, house index, breteau index and man hour density (MHD) using the following formulae;

Container Index (CI)- i.e. percentage of water- holding containers infested with larvae or pupae.
CI=Number of Aedes larvae positive containers x 100 / Number of containers with water inspected

House Index (HI)- i.e. percentage of houses infested with larvae and/or pupae.
HI= Number of houses positive for Aedes larvae x 100/ Number of houses inspected

Breteau Index (BI)- i.e. number of positive containers per 100 houses inspected.
BI= Number of positive containers x 100 / Number of houses inspected

Man hour density (MHD) = Number of mosquitoes collected x 60/ Time spent in minute x Number of persons involved in collections

Results

Entomological surveys were carried out by NIMR Field team in both residential and commercial (office) premises of Haridwar city during the month of June 2021 to December 2021 to find out the breeding sites where mosquito breeds and infects the peoples. During the surveys, a total of 1922 house premises were surveyed and out of which 1910 houses were screened from residential areas and 12 from commercial areas. In Residential areas out of 1910 houses, 237 houses were found to be positive with Aedes breeding while out of 12 commercial areas, only 7 were found to be positive with Aedes breeding. Inside both the premises, a total of 5081 water containers were screened for larval presence and out of 5081 water containers, 4884 water containers were found positive from residential areas and 197 water containers from commercial area with Aedes breeding (Table 1 & 2).

During survey, in residential areas (4884 water containers), only 395 water containers were found positive with breeding of Aedes mosquito. When calculated its overall House Index (HI), Container Index (CI), and Breteau Index (BI), it was observed that the HI (12.40), CI (8.08) and BI (20.68) of water containers were observed (Table 1). While in commercial areas (197 water containers), only 66 water conatiners were witnessed with Aedes breeding and their CI (33.50) were calculated during the survey (Table 2). During investigation in both study areas (Haridwar city and BHEL complex), different stages of larvae and adult of Aedes mosquito were detected and their stage vary localities wise in dengue affected areas. We also recorded the positivity rate of Aedes larvae irrespective of the number of dengue cases recorded in these localities.

The distribution of Aedes larvae and Breeding Preference Ratio (BPR) in different types of breeding habitats was also recorded, and their results are depicted in Table 3. Among all the Aedes mosquito breeding habitats, the highest positivity of Ae. aegypti larvae were found in junk materials (4.46) followed by cemented tanks, pots & seepage water tanks (3.96), mud pots (3.58), discarded tyres (3.72), tree holes (2.95), desert coolers (1.97), money plant pots (1.86), plastic containers (1.02), tray of the domestic refrigerator (0.72) and flower pots (0.22) (Table 3). During the entomological survey, few localities were found to be positive with the breeding of Ae. albopictus and Ae. vittatus breeding were also observed in outdoor open spaces of the houses in a few localities. Aedes mosquitoes breeding were also found in intra-domestic water storage containers from the same areas where dengue cases were also reported.

During indoor mosquito collections, only 3 Aedes mosquito species were collected and out of which Ae. aegypti and Ae. albopictus were found to be the most abundant species and other Ae. vittatus species was found in small numbers (Table 4&5). Average Man Hour Density (MHD) of dengue vector was calculated and found to vary locality to locality from the dengue-affected localities (Table 4&5).

Entomological surveys were carried out by NIMR Field team in both residential and commercial (office) premises of Haridwar city during the month of June 2021 to December 2021 to find out the breeding sites where mosquito breeds and infects the peoples. During the survey, a total of 1922 house premises were surveyed and out of which 1910 houses were screened from residential areas and 12 from commercial areas. In Residential areas out of 1910 houses, 237 houses were screened to be positive with Aedes breeding while out of 12 commercial areas, 7 were tagged positive with Aedes breeding. Inside the both premises, a total of 5081 water containers were screened for larval presence and found out that out of 5081 water containers, 4884 water containers from residential areas and 197 water containers from commercial area were found positive with Aedes breeding (Table 1 & 2).

In residential areas (4884 water containers), only 395 water containers were positive with Aedes breeding during survey. When we compute its overall House Index (HI), Container Index (CI), and Breteau Index (BI), it was observed that the HI (12.40), CI (8.08) and BI (20.68) of water containers were calculated (Table 1). While in commercial areas (197 water containers), only 66 water containers were witnessed with Aedes breeding and their CI (33.50) were calculated during the survey (Table 2). In study areas (Haridwar city and BHEL complex) during investigation, different stages of both larvae and adult of Aedes mosquito were detected and their stage vary localities wise in dengue affected areas. We also recorded the positivity rate of Aedes larvae irrespective of the number of dengue cases recorded in these localities.

The distribution and existence of Aedes larvae and Breeding Preference Ratio (BPR) in different types of breeding habitats was also examined, and their results are depicted in Table 3. Of all the Aedes mosquito breeding habitats, the highest positivity of Ae. aegypti larvae were found in junk materials (4.46) followed by cemented tanks, pots & seepage water tanks (3.96), mud pots (3.58), discarded tyres (3.72), tree holes (2.95), desert coolers (1.97), money plant pots (1.86), plastic containers (1.02), tray of the domestic refrigerator (0.72) and flower pots (0.22) (Table 3). At the time of entomological survey, Ae. albopictus and Ae. vittatus breeding was also observed in outdoor open spaces of the houses in a few localities. Aedes mosquitoes breeding were also found in intra-domestic water storage containers from the same areas where dengue cases were also reported.

During indoor mosquito collections, only 3 Aedes mosquito species were collected and out of which Ae. aegypti and Ae. albopictus were tagged to be the most abundant species and other Ae. vittatus species was found in small numbers (Table 4&5). Average Man Hour Density (MHD) of dengue vector was calculated and found to vary from locality to locality in dengue-affected areas (Table 4&5).

During the indoor adult mosquitoes' collections, area wise Aedes mosquitoes of Ae. aegypti, Ae. albopictus and Ae. vittatus were collected from different localities and no. of mosquitoes for each locality ranged between in residential area 18-86, 11-91 and 0-12 and 5-32, 22-44 and 0-14 in commercial/ official area respectively. The average MHD of Ae. aegypti, Ae. albopictus and Ae. vittatus were in residential area 10.77, 6.81 and 0.52 (Table 4) and in commercial/ official area 4.75, 7.95 and 1.68 (Table 5).

Percent species composition of Aedes mosquitos' larvae were isolated and collected from different localities of Haridwar City and BHEL complex (Table 6). A total of 637 larvae emerged into adults in the insectary/ laboratory condition and among all five species of Aedes mosquitoes i.e. Ae. aegypti, Ae. albopictus, Ae. vittatus, Ae. pseudotaeniatus and Ae. thomsoni were properly identified. In Haridwar city, Ae. aegypti was widespread mostly and % species composition was 89.1% while in BHEL complex Ae. albopictus was most prevalent and its % species composition was 73.3% and very low breeding of Ae. aegypti 23.9% was recorded. High prevalence Ae. aegypti was recorded in Haridwar city which was as dengue affected area. Overall, percent species composition of Ae. aegypti, Ae. albopictus, Ae. vittatus, Ae. pseudotaeniatus and Ae. thomsoni 56.5, 41.45, 1.05, 0.4 and 0.6 respectively.

Table 1: Prevalence of Aedes Mosquito Larvae in Different Localities of Residential Areas in Haridwar City during Dengue Transmission Season

Sr. No.	Name of the study area	No. of House surveyed	No. of House positive	No. of Water containers surveyed	No. of positive containers	H. I. (%)	C. I. (%)	B. I. (%)
1	Hajari Bagh, Kankhal	188	8	156	11	4.25	7.05	5.85
2	Bhagwant Vatika, Kankhal	91	5	76	6	5.49	7.89	6.59
3	Indira Basti, Kankhal	88	9	196	16	10.2	8.16	18.2
4	Phari Bazaar, Kankhal	229	7	526	9	3.05	1.71	3.93
5	Miyan Mohalla, Kankhal	114	6	241	11	5.26	4.56	9.64
6	Sector-1, 2, 3 & 5 BHEL	221	64	1144	116	29	10.1	52.5
7	Bairagi Camp Bajariwala, Kankhal	451	28	1044	62	6.2	5.93	13.7
8	Devpura, Project Bairaj Colony & Vichitra Vatika	188	39	398	59	20.7	14.8	31.4
9	Canal Colony Mayapur	74	27	360	46	36.5	12.8	62.2
10	Shiv Murti Chowak	133	10	469	15	7.51	3.19	11.3
11	Bairaj Colony	74	31	241	41	41.9	17	55.4
12	Kashipura, Mansa Devi Area	59	3	33	3	5.08	9.09	5.08
		1910	**237**	**4884**	**395**	**12.4**	**8.08**	**20.7**

*H.I.= House Index, C.I.= Container Index, B.I.= Breteau Index

Table 2: Prevalence of Aedes Mosquito Larvae in Different Localities of Commercial Areas in Haridwar City during Dengue Transmission Season

S r . No.	Name of the study area	No. of House surveyed	No. of House positive	No. of Water containers surveyed	No. of positive containers	C. I. (%)
1	Civil Maintenance Office, Sec-3, BHEL	1	1	23	13	56.52
2	Civil Maintenance Office Sec-5, BHEL	1	1	28	5	17.85
3	Civil Maintenance Office Sec-12, BHEL	1	1	23	5	21.73
4	CIVIL Maintenance Main Building, BHEL	1	0	9	0	0
5	Vidhut Sub Station Sec-3, BHEL	1	1	3	1	33.33
6	Vidhut Sub Station Sec-5, BHEL	1	0	3	0	0
7	Vidhut Sub Station Sec-1, BHEL	1	1	11	1	9.09
8	Jal Sansthan Sec-3, BHEL	1	0	19	0	0
9	Kotwali Police Station Ranipur Sec-5, BHEL	1	0	11	0	0
10	SOG, Office Police Station Sec-5, BHEL	1	0	4	0	0
11	State Office, BHEL	1	1	12	12	100
12	Trishul Guest House, BHEL	1	1	51	29	56.86
	Total	**12**	**7**	**197**	**66**	**33.5**

*C.I.= Container Index

Table 3: Breeding Preference Ratio (BPR) of Aedes Larvae in Haridwar City during Dengue Transmission Season

S r . No.	Type of breeding habitats	Number of containers with water				B P R (Y/X)
		Examined	(X %)	With larvae	(Y %)	
1	Flower Pots	2750	54.12	55	11.93	0.22
2	Desert Coolers	1155	22.73	207	44.9	1.97
3	Plastic Containers (Tubs, Bowls, Tanks, Buckets, Drums, Kens)	793	15.60.	74	16.05	1.02
4	Refrigerator Trays	15	0.29	1	0.21	0.72
5	Mud Pots /Pitchers	71	1.39	23	4.98	3.58
6	Discarded Tyres	55	1.08	15	3.25	3
7	Air Conditioner's Trays	11	0.21	0	0	0
8	Cemented Tanks, Pots & Seepage Water Tanks	67	1.31	24	5.2	3.96
9	Tree Holes	11	0.22	3	0.65	2.95
10	Mani Plants	12	0.23	2	0.43	1.86
11	Junk Materials (Iron Drum, Containers, Steel Pots, Steel Wastes, Lids, Drums, Aluminium Sodium Light Fitting Covers, Discarded Toilet Seat, Cistern Lid, Discarded Helmet, Waste Crocary)	141	2.77	57	12.36	4.46
	Total	**5081**		**461**		

*B.P.R= Breeding Preference Ratio

Table 4: Man, Hour Density (MHD) of Ae. aegypti, Ae. albopictus and Ae. vittatus Mosquito Species in Commercial Areas of Haridwar City during Dengue Transmission Season

S r . No.	Name of the study area	No. of Ae. aegypti	MHD of Ae. aegypti	No. of Ae. albopictus	MHD of Ae. albopictus	No. of Ae. vittatus	MHD of Ae. vittatus	Ratio of Ae. aegypti, Ae.albopictus and Ae. vittatus
1	Hajari Bagh, Kankhal	37	9.25	21	5.25	0	0	1.8:1
2	Bhagwant Vatika, Kankhal	21	5.25	11	2.75	0	0	1.9:1
3	Indira Basti, Kankhal	30	7.5	18	4.5	2	0.5	15:09:01
4	Phari Bazaar, Kankhal	34	8.5	26	6.5	0	0	1.4:1
5	Miyan Mohalla, Kankhal	18	4.5	10	2.5	0	0	1.8:1
6	Sector-1,2,3&5, BHEL	56	14	91	22.75	12	3	4.7:7.6:1
7	Bairagi Camp Bajariwala, Kankhal	35	8.75	40	10	8	2	4.4:5:1
8	Devpura, Project Bairaj Colony & Vichitra Vatika	86	21.5	18	4.5	0	0	4.8:1
9	Canal Colony Mayapur	44	11	23	5.75	0	0	1.9:1
10	Shiv Murti Chowak	31	7.75	13	3.25	0	0	2.4:1
11	Bairaj Colony	83	20.75	34	8.5	3	0.75	27.7:11.3:1
12	Kashipura, Mansa Devi Area	42	10.5	22	5.5	0	0	1.91:1
	Average MHD		**10.77**		**6.81**		**0.52**	

*MHD= Man Hour Density

Table 5: Man, Hour Density (MHD) of Ae. aegypti, Ae. albopictus and Ae. vittatus Mosquito Species in Residential Area of Haridwar City during Dengue Transmission Season

S r . No.	Name of the study area	No. of Ae. aegypti	MHD of Ae. aegypti	No. of Ae. albopictus	MHD of Ae. albopictus	No. of Ae. vittatus	MHD of Ae. vitta-tus	Ratio of Ae. aegypti, Ae. a l b o p i c t u s and Ae. vittatus
1	Civil Maintenance Office, Sec-3, BHEL	16	4	23	5.75	8	2	02:09.9
2	Civil Maintenance Office Sec-5, BHEL	12	3	22	5.5	4	1	06:05.5
3	Civil Maintenance Office Sec-12, BHEL	11	2.75	27	6.75	4	1	2.8:6.8:1
4	CIVIL Maintenance Main Building, BHEL	28	7	35	8.75	13	3.25	2.2:2.7:1
5	Vidhut Sub Station Sec-3, BHEL	32	8	44	11	9	2.25	3.6:4.9:1
6	Vidhut Sub Station Sec-5, BHEL	26	6.5	35	8.75	10	2.5	2.7:3.5:1
7	Vidhut Sub Station Sec-1, BHEL	20	5	29	7.25	6	1.5	3.3:4.8:1
8	Jal Sansthan Sec-3, BHEL	22	5.5	40	10	6	1.5	3.7:6.7:1
9	Kotwali Police Station Ranipur Sec-5, BHEL	5	1.25	24	6	0	0	01:04.8
10	SOG, Office Police Station Sec-5, BHEL	8	2	31	7.75	0	0	01:03.9
11	State Office, BHEL	28	7	33	8.25	7	1.75	05:11.7
12	Trishul Guest House, BHEL	20	5	39	9.75	14	3.5	1.4:2.8:1
	Average MHD		**4.75**		**7.95**		**1.68**	

*M.H. D= Man Hour Density

Table 6: Percent Species Composition of Aedes Mosquitoes from Haridwar City and BHEL Complex during Dengue Transmission Season

Sr. No.	Area	No. of emerged adults identified	Species composition				Ae. thomsoni
			Ae. aegypti	Ae. albopic-tus	Ae. vittatus	Ae. pseudo-taeniatus	
1	Haridwar City	380	89.1	9.6	0.5	0.8	0
2	BHEL complex	257	23.9	73.3	1.6	0	1.2
	Total	637	56.5	41.45	1.05	0.4	0.6

*Adults mosquitoes were identified from larvae emerged

Discussion

Since the MHD more than one depicts critical level, it necessitates the adequate vector control measures to eliminate mosquito breeding habitats in the houses and surroundings to avoid contamination of the disease in the localities. Vector Control (VC) is the only way to disease control and can be achieve by the enhance Integrated Vector Management (IVM) for early detection of mosquito breeding, so that, VC measures could be taken into action to eliminate mosquito breeding [40]. Environment Management Method (EMM) are used to control of Aedes mosquito larvae and adult also. In our study, overall percent species composition of Ae. aegypti, and their high entomological indices was recorded in Haridwar city; and water storing habits in the water holding containers were also observed in some of the localities due to scarcity of the tap water, and the house holders were not aware of the factors exacerbating breeding of mosquitogenic conditions, the larval indices have been also observed above the critical levels by the earlier workers from the state [28, 34]. Additional steps can be taken to eliminate the potential mosquito breeding habitats in the houses and in localities by

covering all water holding containers to prevent fresh egg laying by the dengue vector [40]. For control of Vector Borne Diseases (VBDs) and its prevention depends on reduction of mosquito density through breeding source and contact between mosquito and people, this ultimately enhanced the surveillance of Integrated Disease Surveillance Programme (IDSP) at the community level in dengue case detection and keeping a watch on people returning from dengue affected areas and suffering from febrile illness [22, 31].

To know the percentage of species composition of Aedes mosquitoes, larvae were collected from different localities of Haridwar City and BHEL complex (Table 4). After emergence of larvae into adults, they were properly examined and five species were recorded. Ae. aegypti, Ae. albopictus, Ae. vittatus, Ae. pseudotaeniatus and Ae. thomsoni mosquito species were recorded during the study. Aedes aegypti was found as dominant and most prevailing species in residential area, which were inhabitants of domestic and peri-domestic water holding containers and this data was recorded earlier also [2, 20, 22-24, 27]. Most of Ae. aegypti was found as dominant species inside the houses in dengue affected areas during dengue epidemic in the most of areas showing larval indices may be the most probable reason for the persistence of dengue. Ae. albopictus species was found in the wet containers, mostly outside the house which were left in the open space around the house premises [21, 34]. Similarly, previous researchers recorded these types of water holding containers, left outside the houses that were rarely cleaned, and mostly remain undisturbed for long time, which further became the site for Aedes mosquito breeding. Water storing habits determined as one of the reasons responsible for Aedes mosquito breeding [25]. Ae. albopictus and Ae. aegypti were also found to co-breed in the same type of mosquito breeding habitats in several localities. In addition, mixed breeding of Ae. aegypti, Ae. albopictus and Ae. vittatus were also recorded in some manmade breeding habitats [41]. This may be due to fast urbanization in the last three-four decades and destruction of natural breeding habitat conditions, these conditions forced to Ae. albopictus and Ae. vittatus to acquire and adapt to breed in manmade habitats besides restriction of natural habitats. Similar, observations were recorded by the previous researchers on the adaptation of both the mosquito species in Malaysia [42]. There may be intra-species competition for food and their existence, which increases its epidemiological potential and risk to the population. Pant et al. 1973 recorded that “Ae. albopictus mosquitoes are feed outdoor as compared with Ae. aegypti. Aedes albopictus mosquitoes may play the role in amplifying dengue transmission” [43]. Both the Aedes species should be checked before the transmission season in Haridwar City as observed by Joshi et al., 2003 which may play an important role in maintenance of urban cycle of dengue in Jodhpur and more attention should be paid in clarifying the involvement and transmission dynamics of dengue of Ae. albopictus in Haridwar City [44].

In earlier study, high entomological indices were observed in some of the villages of Haridwar due to water storing habits in the domestic containers. The highest positivity number of Ae. aegypti larvae was found in the domestic refrigerator tray (4.55), most of the people/ villagers were not aware of these factors exacerbating mosquito breeding conditions, suggesting its potential for future outbreaks (unpublished data) [45]. Similar observations were observed by the previous researchers on environment and highlight these factors [46]. The present situation of mosquito breeding indices might be attributed to changes in the ecology and social behaviour of resident's/ house holders, changes in the living lifestyle, and non-availability of tap water supply properly enforcing water storage practices [47]. Therefore, continuous entomological surveillance should be undertaken in Haridwar City area to control the repeated occurrence of dengue disease and the information should be utilized to forecast dengue future outbreak, so that necessary VC efforts could be taken before possible dengue outbreak by the DHA to cease the epidemic and stop resurgence in future.

Special efforts can be used to emptying, drying water holding containers, desert coolers, bird baths, flower pots etc. at least once a week. Gambusia larvivorous fishes can be introduce in ornamental water tanks, similarly, Bacillus thuringiensis (BTi) and Temephos larvicides can be applied in stagnant water more than one week. Temephos larvicides, which is not dangerous to humans and non-targeted organism, or environment when use as per the WHO/ National guidelines [30, 40]. Synthetic Pyrethroids (SP) insecticide can used for Indoor Residual Spray (IRS) in areas where dengue cases are reported [28]. Pyrethrum spray/ malathion fogging can be applied for the control of adult Aedes mosquitoes. Personal protective prevention (PPP) measures can be used as an insect repellent and wearing light-colored clothes for the more coverage of the body; closed the doors and windows properly, and should use mosquito bed nets/ insecticide-treated bed nets for sleeping to protection for mosquitoes biting [28]. Legislative measures and byelaws should be implemented for avoidance of situations which favor mosquito breeding. Health education for community mobilization and community participation to eliminate Aedes mosquitoes breeding with the involvement of other sectors/ departments should be encouraged as per National guidelines for dengue prevention (NCVBDC).

Conclusion

The field study showed that Aedes mosquito breeding were detected in all the dengue-affected areas during transmission season in Haridwar City. Most of the areas showing high larval indices may be the probable reason for the persistence of dengue in the City. Focal and small outbreak of dengue was reported in Hardwar district of Uttrakhand state during 2021. Dengue infection was also observed in the rural area of the district Haridwar but the infection was low. The vector control and all the preventive measures need to be directed to eliminate the Aedes mosquitoes breeding by adopting a bottom-up vector born disease control program, the water management practice by the house holders along with the implementation of IEC activities are suggested to contain dengue epidemics in the future, which was hitherto free, for further containment.

Conflict of Interest

The authors declare that they don’t have any conflict of interest

Acknowledgment

The authors are thankful to the technical staff of ICMR-NIMR Field Unit, Haridwar Mr. Mohan Dobhal, Mangat Ram, Rajesh Kumar Mittal, Rajesh Kumar Singh, Dayal Chandra, Bhagwan Das, Shiv Raj Singh, and Shri M. B. Sharma Driver, for their active involvement and assistance during the field survey.

Highlights

- Haridwar is an ancient city and important Hindu pilgrimage site in North India's Uttarakhand state, for outbreak of dengue disease
- Dengue virus transmitted by the biting of female Aedes mosquito and it is a day biter mosquito
- Aedes aegypti mosquito was found dominant species in domestic and peri-domestic breeding habitats, while Ae. albopictus and Ae. vittatus mosquitoes were also found in outdoor breeding habitats of the houses.
- Five species of Aedes mosquitoes i.e. Ae. aegypti, Ae. albopictus, Ae. vittatus, Ae. pseudotaeniatus and Ae. thomsoni were recorded

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