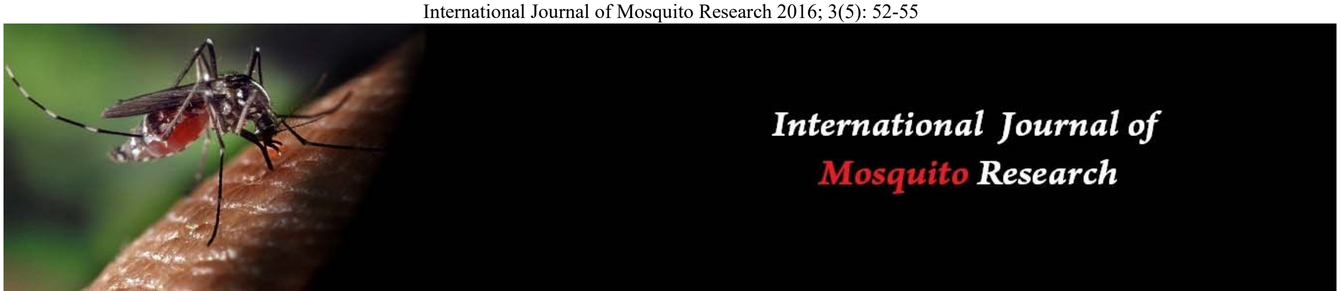

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A study on the seasonal prevalence of *Culex quinquefasciatus* larvae in Agra, Uttar Pradesh (India)

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Abstract
Seasonal abundance of the immature stages of the mosquito, *Culex quinquefasciatus,* the vector of *Japanese encephalitis* and other mosquito borne diseases were studied in Agra, Uttar Pradesh, India. Samples were collected from temporary, semi-permanent and permanent ground water pools and other mosquito breeding sites throughout the year.
In Agra, the larval index of *C. quinquefasciatus* was highest in rainy season, July to September and lowest in winters, from December till February. Larval development was remarkably slow during this season. The larval index starts increasing in April, 53.1, 37.3 and 47.3 for the first, second and third year respectively. The larval index again decreases in June due to extreme hot summers. The maximum larval index was noted in September (173.1, 136.2 and 124 for the first, second and third year respectively). The larval index showed an unusual rise in the month of July (134.7) for the first year and in February (32.1) during the third year of the study which shows its direct relation with the meteorological conditions prevailing in that area. The larval index shows two peak values first in the month of August and September and then in April and May during the study which coincides with the incidence of *Japanese encephalitis*, chikungunya, filariasis and other mosquito borne diseases. Systematic water management, usage of larvivorous predators and organizing literacy campaigns can be a remedy for the breeding of *C. quinquefasciatus* mosquito in the city.

Keywords: *C. quinquefasciatus, Japanese encephalitis*, larval index, Agra

1. Introduction
Of the many blood sucking and biting insect mosquitoes (*Culicidae*) pose the greatest threat to public health. They are at the centre of worldwide entomological research primarily because of their abilities to transmit pathogens causing some of the most life – threatening and debilitating diseases of man, like *Japanese encephalitis*, filariasis, dengue, chikungunya, malaria, yellow fever etc. [1, 4] *Japanese encephalitis* is endemic to large part of Asia and the pacific regions [1]. As estimated about 3 billion people are at the risk of *Japanese encephalitis* virus which is spreading to new territories globally. About 378 million individuals are exposed to the risk of *Japanese encephalitis* virus in India [2]. The state of Uttar Pradesh is highly endemic contributing 52.40 % of the total deaths due to *Japanese encephalitis* in the country [3]. Filariasis has been another major health problem worldwide. In India, filariasis ranks next to malaria in magnitude among mosquito borne diseases. Lymphatic filariasis is widespread throughout the tropical and subtropical areas of Asia, Africa, the Western Pacific and some parts of America. Approximately 20% of the world's population live in areas expose to the risk of filarial infection. In India, about 342 million people are exposed to the risk of *Bancroftian* infection, with largest incidence of 80.58 million people from Uttar Pradesh [4]. On the same way out of the total 17.56 million people in India with filarial manifestation, 6.35 million people were reported from Uttar Pradesh [4].
The mosquito, *Culex quinquefasciatus* Say is responsible for transmitting *Japanese encephalitis*, filariasis, chikungunya virus, rift valley fever virus and variety of other such arboviruses [5]. *C. quinquefasciatus* is strongly anthropophilic and the most predominant species in urban, semi urban and rural areas. *C. quinquefasciatus* shows wide spatial distribution during pre-monsoon, monsoon and post-monsoon. It usually breeds in organically rich and polluted surface waters collections, artificial containers, shallow ponds, drains, wells, septic tanks, rain water containers, tyres and even in leaf axils. In the absence of such type of water collections they are found to breed in comparatively clean water collections also.

Agra is a city situated on the bank of the river Yamuna in northern state of Uttar Pradesh, India between 27.11' degree Latitude North and 78.0' degree Longitude East. It is about 363 kilometres west of the state capital, Lucknow, and about 200 kilometres south of the national capital New Delhi. According to the 2011 census Agra district has a population of 43,80,739, approximately equal to the nation of Moldova or the US state of Kentucky [6]. Agra, being the city of the inimitable Taj Mahal, is famous for tourism worldwide. Agra has a continental sub-tropical climate, summers are extremely hot and the maximum temperature goes as high as 45º C, while the weather during winter remains cold and foggy. During the Monsoon season, from July to September, Agra city receives heavy rains and the weather becomes hot and humid. During rainy season the risk of virus transmission by the vector is very high. Incidences of mosquito borne disease occur in the recent past years in this region [9].

The study of the seasonal prevalence of vector population is absolutely essential to develop suitable vector control strategies [7]. Seasonal abundance study is also useful when there is a need to know the density of the species and its potential in transmitting any particular disease [8]. Hence, the present study was undertaken to describe the seasonal prevalence of *C. quinquefasciatus* larvae in different regions of Agra city.

2. Materials and Methods

2.1 Study area and duration: *Culex quinquefasciatus* larvae were collected from various mosquito breeding sites within the different regions of Agra (26° 44' N to 27° 25' N latitude; 77° 26' E to 78° 32' E longitude). Central region comprising of St. Johns College, Ghatia Azam Khan, Sanjay Place, Raja ki Mandi, SN Medical, etc. Eastern region comprising of Taj Mahal area, Freeganj, Bijali Ghar, Agra Fort, etc. Western Region comprising of Shahganj, Arjun nagar, Cantonment area, etc, Northern Region comprising of Dayal Bagh, Swami Bagh, Kamla Nagar, Transport Nagar, ISBT Agra, etc. And Southern region comprising of Saheed Nagar, Saufuta Road, Maruti Estate, Faith Church, TDI shopping complex etc, were surveyed and each mosquito breeding sites were periodically observed at least twice a month from February 2008 to December 2010.

2.2 Larval collection and Data analysis: The mosquito larvae were collected using a hand net (diameter of 4''). Incidences of larval collections were recorded and the larval density was calculated as the average number of immature per dip collected from each habitat. Samples of larvae were brought to the laboratory and reared. Identification of species was done following standard keys [9]. Fourth instar larvae were taken for categorization and reared until adult emergence for further confirmation of the species. Both the larvae and adults were identified and preserved. The larval index at various months of the year were recorded and analysed statistically.

3. Results

The month wise larval densities of *C. quinquefasciatus* from 2008 to 2010 along with the temperature, humidity and rainfall are presented in Table-1, 2 and 3. During the first year of survey (Table-1), the larval index remained high in July, August and September. The highest larval index was recorded in September (173.1) with temperature ranging from a minimum of 24 °C to the maximum of 33.4 °C. The minimum larval index was recorded in February (14) with temperature ranging from 10.7 °C to 25.8 °C. In the second year of survey (Table-2), the larval index remained high during August, September and October. The highest larval index was recorded in September (136.2) with temperature ranging from 24.6 °C to 33.4 °C. The lowest larval index was recorded in January (14) with temperature ranging from 7.4 °C to 22.2 °C. In the third year (Table-3), the larval index remained high during the month of August and September. Again the highest larval index was recorded in September (124) with temperature ranging from 24.3 °C to 34 °C. The minimum larval index was recorded in January (16.3) with average temperature ranging from 7.7 °C to 22.3 °C.

In Agra the larval density of *C. quinquefasciatus* varied from 12.1 to 173.1, highest in September and lowest in extreme winter (January and February). From December to February the larval index is considerably low (20, 12.1 and 14 during the first year, 22.5, 16.3 and 12.4 for second year and 22.5 10.3 and 32.1 for third year. Larval development was very slow during this season. The larval index starts increasing in April, 53.1, 37.3 and 47.3 for the first, second and third year respectively. The larval index again decreases in June. The larval index increased considerably during monsoon, July to September, (134.7, 158.2 and 173.1 during first year, 86.4, 124 and 136.2 for the second year and 61.2, 111.2 and 124 for the third year. The maximum larval index was noted in September (173.1, 136.2 and 124 for the first, second and third year respectively). The larval index then starts decreasing in October/November and a considerable decrease was observed from December to February. The larval index shows two peak values first in the month of August/ September and then in April/May during the study. The larval index showed an unusual rise in the month of July (134.7) for the first year and in February (32.1) during the third year.

Table 1: Larval index of *Culex quinquefasciatus* during first year

Months	Rainfall(Mm)	Humidity	Temp(Min)	Temp(Max)	Larval Index
January	--	--	--	--	--
February	0	48	10.7	25.8	14
March	0	28	15.9	32	33.6
April	14.1	17	21.7	37.8	53.1
May	22.2	20	27.1	41.8	40
June	116	39	29.7	40.6	92
July	173	66	27.1	35	134.7
August	162	78	25.8	32.9	158.2
September	56.6	69	24.6	33.4	173.1
October	0.3	45	19.3	33.6	91.3
November	0	22	12.2	29.2	39
December	0	57	8.4	24.4	20

Table 2: Larval index of *Culex quinquefasciatus* during second year

Months	Rainfall(Mm)	Humidity	Temp(Min)	Temp(Max)	Larval Index
January	0	55	7.4	22.2	12.1
February	0	49	10.3	25.7	12.4
March	0	29	15.7	31.8	21.2
April	1.6	28	21.6	37.7	37.3
May	38	22	27.2	41.8	56.4
June	16.8	41	29.5	40.5	37
July	74.1	72	27	34.8	86.4
August	76.7	79	25.8	32.8	124
September	84.4	71	24.6	33.2	136.2
October	62.6	58	19.1	33.3	121.9
November	14.8	32	12	29.2	93.9
December	2	59	8.2	24.1	22.5

Table 3: Larval index of *Culex quinquefasciatus* during third year

Months	Rainfall(Mm)	Humidity	Temp(Min)	Temp(Max)	Larval Index
January	0	58	7.7	22.3	16.3
February	8.6	52	10.3	25.5	32.1
March	0	27	15.5	31.9	20
April	0	19	21.5	37.9	47.3
May	0	21	26.5	41.7	38.8
June	13.5	40	28.9	40.7	27
July	98.2	67	26.8	35.3	61.2
August	119.7	76	25.7	33.2	111.2
September	146.7	75	24.3	34	124
October	1.5	49	19.1	34	93
November	27.8	29	12.5	29.2	71.4
December	1.7	52	8.2	23.9	22.5

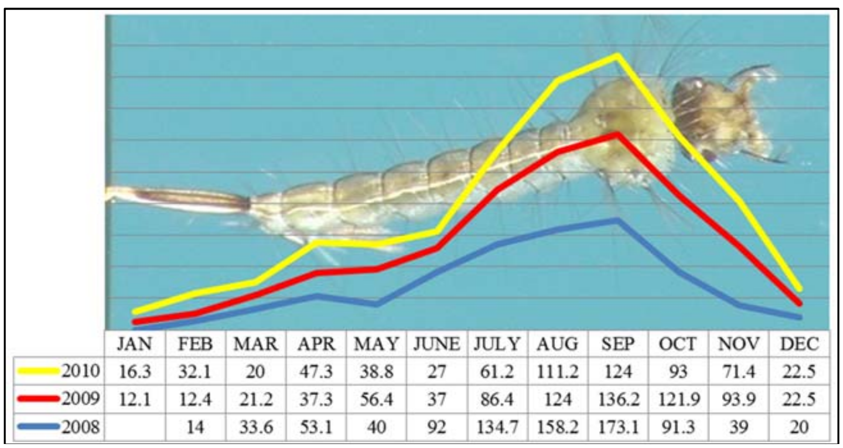

Fig 1: Larval index of *Culex quinquefasciatus from* 2008 - 2010

4. Discussion

In India, mosquito borne diseases generally occur during or after the monsoon due to vector abundance after the monsoon. In Agra *C. quinquefasciatus* density is high from July to September during first year, August to October in during the second year and August to September during third year. In the neighbouring city of Gurgaon larval index was high in August (5.3), while in Gorakhpur the density was high in March [3, 10]. In the neighbouring states, Rajasthan and Madhya Pradesh the larval density also maintained high during from July till October. The density of *C. quinquefasciatus* was high in Mysore, Karnataka in July, in Khurda, Orissa in January while in Rajmundhary, Andhra Pradesh in December [7, 11, 12].

In, Agra during winters (November to February) *C. quinquefasciatus* larval index was very low and it decreased considerably in January and February (12.1 and 14 during first year, 16.3 and 12.4 during second year and 10.3 and 32.1 during third year). The similar observation was reported from Gurgaon (Haryana) having lowest larval index during January and February and also from Delhi the lowest larval index was reported in January [10, 13]. In high altitude areas of Assam, Arunachal Pradesh, Meghalaya and Nagaland also, during severe winter the breeding of the mosquito ceases. In Mysore, the lowest index was reported from October to December, in Khurda district of Orissa it was lowest in May and June and in Rajahmundry of Andhra Pradesh it was lowest in January, February and June [7, 11, 12].The larval index further starts increasing in March reaching the second peak in April and May (53.1.1& 40, 37.3 & 56.4, 47.3 & 38.8 for the first, second and third year respectively) and shows a gradual decrease in larval index during June. The larval index in the present study shows two peaks first in the month of September and then the second peak in the month of April and May. In Gurgaon also, first peak value was reported in August and second in April and May. In Mysore, Karnataka first peak in larval density was reported in October and reached the second peak in May. In Mandya, first peak value was in July (100) and the second in February (54) [1, 10, 11].

Weather determines the favourable conditions that enable a vector population to increase or decrease rapidly or gradually [13]. Two main factors that regulate the mosquito larval growth are nutrition and the temperature of the water in the breeding places [15]. In Agra, the trend of the larval index shows that vector density is positively associated with monsoon months since the abundance was high and the previous studies in Andhra Pradesh and Orissa describe about it [7, 12]. The temperature and relative humidity with 25-35 °C and 65-75% respectively are most suitable to maintain the vector density at higher level. Above the temperature of 36 °C, the larvae generally fail to transform into pupae. Extreme hot and dry weather conditions makes the mosquito eggs inviable, kills the larvae and render adult mosquito inactive [15]. In the present investigation also the monthly variation in the density pattern and seasonality of the vector seems to be related to the meteorological conditions prevailing in the area. During the study the larval prevalence was more generally in August and September but in first year the larval index started increasing from June due to the early rainfall. A sudden increase in larval abundance was noticed in February (32.1) during 2010 due to the moderate rainfall and humidity. Pandya (1982) has stated that one of the possible reasons for the seasonal aberration could be the fluctuating breeding habitat of mosquitoes in different types of containers also [16].

The mean larval index was highest in first year (71.75) than that of the second year (63.79) and third year (55.4). The average rainfall and relative humidity were also high during the first year when compared with the second and third year of the study. The vector abundance in post monsoon months favoured the transmission of mosquito borne diseases [7]. The transmission of such infections in the post monsoon period were noticed in Goa from May to October, in Tamil Nadu from October to January, in Karnataka from August to September and in Andhra Pradesh from September till December [1].

5. Conclusion

Culex quinquefasciatus population density in Agra is considerably more in the collected mosquito larval samples. The present study reveals the presence of high vector density within the different regions in Agra throughout the year which may be because of water loggings due to the pressure of urbanization, improper management of domestic and other neglected water collections in the city. In Agra the larval density of *C. quinquefasciatus* varied from 12.1 to 173.1, highest in September and lowest in winter (January and February). The larval index shows two peak values, first during August and September and then during April and May in every year. The maximum larval index was noted in September (173.1, 136.2 and 124 for the first, second and third year respectively). During this time chikungunya, *Japanese encephalitis*, filariasis along with other mosquito borne diseases were also prevalent in Agra city. The present study alarms to the immediate need of vector control operations to reduce the man vector contact. Release of larvivorous predators in the water collections and organising literacy campaigns can be a useful remedy.

6. Acknowledgments

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