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WATER STOCKING HABITS AND SEASONAL VARIATIONS IN BITING RATES OF *AEDES* (*STEGOMYIA*) *AEGYPTI* LINNAEUS (DIPTERA: CULICIDAE) IN A SUB-SUDANIAN VILLAGE OF COTE D'IVOIRE

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ABSTRACT: Yellow fever is an arthropod-borne viral disease transmitted to man in Africa by mosquitoes of the genus *Aedes*. It is endemic in the sub-sudanian savannah of West Africa, where its general epidemiological scheme is well known. In spite of the availability of an efficient vaccine, this disease is re-emerging all over the afro-tropical geographical area. The permanent virus circulation in several regions of Côte d'Ivoire requires an accurate and regular entomological monitoring to determine the zones and/or the periods at risk. A survey was carried out in a village located 13 km east of the city of Katiola (8° 8' N - 5° 5' W) in the sub-sudanian savannah of Côte d'Ivoire. From December 1996 to November 1997, larval surveys and adult mosquito collections on human baits were performed. The results showed a great number (1176) of potential breeding sites which appeared to be of limited diversity. Earthen-ware jars and medical pots were the most common and most frequently infested breeding sites. The mean infestation rate (49,1 %) varied from 20% for basins to 54,2% for medical pots. Earthen-ware was significantly more infested than metallic containers. Four genera and 24 species of Culicidae were identified. *Aedes aegypti* represented 62,9% of the total collected mosquitoes. The monthly variations of its biting rates could not be directly correlated to the rainy season. A strengthened programme of information, education, and communication adapted to the local population must be implemented, while the possibility of an improved water supply should be considered and yellow fever immunization should be urgently developed to prevent any outbreak.

KEY WORDS: *Aedes aegypti*, Culicidae, vector of yellow fever, biting rates, water stocking habits, Côte d'Ivoire.

INTRODUCTION

Yellow fever is an arthropod-borne viral disease transmitted to man in Africa by mosquitoes of the genus *Aedes*. *Aedes (Stegomyia) aegypti* Linnaeus, 1762, the main interhuman vector, breeds in small natural or man made water collections: tree holes, rock holes, coconut shells, jars and discarded containers such as tins and automobile parts, specially tires (TRPIS *et al.*, 1971). Yellow fever is endemic in the northern part of the «virus emergence belt» of West Africa (GERMAIN *et al.*, 1982; CORDELLIER, 1991). From 1902 to 1985 yellow fever cases have been virologically confirmed in Côte d'Ivoire: Grand Bassam (1902 in KOFFI, 1995), Issia, Satama-Sokoura and Dabakala (CHIPPAUX *et al.*, 1981), Niakaramandougou, M'Bahiakro and Dabakala (LHUILLIER *et al.*, 1985). The 1982 yellow fever outbreak at M'Bahiakro lead to 600 cases and 35 deaths (LHUILLIER *et al.*, 1985). It has mobilized several specialists (virologists, entomologists, and biologists) and the different investigations allowed a better knowledge of the yellow fever epidemiology in this country (CORDELLIER, 1991). In 1983, an expanded programme of immunization, conducted by the National Institute of Public Hygiene of Côte d'Ivoire included yellow fever vaccine, which is given to babies from 9 to 11 months of age. The mean coverage was estimated at 57% in 1998 (BENIE, pers. comm.). Since 1985, no indigenous yellow fever case has been confirmed in Côte d'Ivoire. However, the recent re-emergency of this disease all over the afro-tropical geographical area (TOLOU, 1996), specially in a neighbouring country (Liberia) are of great concern. The permanent virus circulation in forest, pre-forest and sub-sudanian zones of this country (CORDELLIER, 1991), requires an accurate and regular entomological monitoring to determine the zones/periods at risk. Such information is of paramount importance to forecast outbreaks and take action before they could occur.

This paper presents observations of the seasonal variations in the biting rates of *Ae. aegypti* in a sub-sudanian savannah village with particular behaviour of the population in their water-stocking habits.

MATERIAL AND METHODS

Study area: The survey was carried out in Kabolo, a small village of 370 inhabitants living in roughly 200 compounds. It is located 13 km east of the city of Katiola (8° 8' N - 5° 5' W) in the sub-sudanian savannah of Côte d'Ivoire. This zone belongs to a tropical climate area characterized by two main seasons: a rainy season, from mid-April to October, and a dry season from November to mid-April. The 1997 rainfall (926,2 mm) was deficient as compared to the mean annual rainfall of 1200 mm observed over the last ten years. Instead of August, as usually observed, June was the rainiest month, with 306,5 mm in 1997 (AKODA, pers. comm.). Highest temperatures (28° C) are registered in March/April and the lowest (21° C) in December/January. Relative humidity is high (80 to 90%) in the rainy season and even relatively high in dry season (60 to 70%).

Human population: Local populations belong to the Tagwana

sub-group of the Sénoufo ethnic group in north-central Côte d'Ivoire: they are either Christians or animists. Agriculture is the most important economic activity. Maize, cotton, ground nuts, rice and yam are grown. The village is very clean, without any discarded industrial containers in the peri-domestic area. The habitations are so close that it is difficult to distinguish between different families. Houses are covered either with sheet-iron or thatch; they are usually large and some of them are used as kitchens and bedrooms for women. In the village there are three wells, one primary school but no dispensary. The closest medical point to Kabolo is located at Timbe, 4 km away. People usually go to hospital only after the failure of their traditionnal treatment.

Entomological methods: We developed two methods for collecting *Aedes* specimens: larval breeding site surveys and landing rate on human beings.

– *Larval surveys*: Sixty-nine compounds of the village were randomly selected and visited. The numbers of domestic and peri-domestic potential breeding sites were recorded. Those containing preimaginal stages of *Aedes aegypti* were noted as «positive», while the other ones were considered as «negative» at the time of the survey. Jars are of 30 to 60 liters of content. Most of them are buried (up to 10-15 cm in sand) to keep water cool; they were seldom empty. Medical pots are of varying dimensions, from half a liter to 15-20 liters, depending on their use. The density of larvae in positive breeding sites was estimated by the number of larvae by dipping. Three indexes have been established: the «Breteau index» (number of positive breeding sites in 100 visited houses), the «house index» (percentage of houses where at least one positive breeding site has been observed), and the «container index» (percentage of actual positive containers among those observed). The difficulty to assess the «Breteau index» and the «house index» is due to the absence of a clear definition of a house in the African context (PICHON, HAMON & MOUCHET, 1969). However, because of the importance of the epidemiological value of these indexes, the house has been defined as a traditional familial unit including a familial apartment and its annexes (HERVE *et al.*, 1978). The latter definition is quite applicable to the habitat structure of the study area. The epidemiological values of all these indexes are given by WHO's scale of density (ANONYMA, 1971).

– *Human bait collection of adult mosquitoes*: Entomological surveys were carried out during three consecutive days once a month, from December 1996 to November 1997. *Aedes aegypti* has a nocturnal activity and bites inside houses in this village (DIARRASSOUBA & DOSSOU-YOVO, 1997). It is thus possible to study the seasonal variation of its biting rates by night catches. Mosquito collections were executed from 6 p.m. to 6 a.m. during a malaria transmission study. Three teams, each composed of four men, collected mosquitoes at three catching points randomly selected in the village. The first group of fly catchers (one inside and the second outside the house) worked from 6 p.m. up to midnight; the second group worked from midnight to 6 a.m. Hourly collected mosquitoes were isolated in two lots (before and after midnight) and counted for each place (inside or outside house).

RESULTS

Potential larval breeding sites

A great number (1176) of containers were recorded and they appeared to be of limited diversity. Six different reservoirs were identified as potential breeding sites, and domestic containers constituted the majority (Table 1). The most important ones were earthen-ware jars and medical pots, which together represented 84,9% (999/1176) of the total recorded containers. Other potential breeding sites were basins (7,7%), barrels (3,9%) and kettles (3,3%). Only one tire (0,1%) and 20 barrels were found in the peri-domestic area.

Breeding sites	without water	with water	with larvae	% of positive breeding sites	Total
jars	356	203	107	52,7	559
medical pots	252	188	102	54,2	440
barrels	6	40	20	50,0	46
basins	41	50	10	20,0	91
kettles	21	18	6	33,0	39
tires	1	0	0	0,0	1
Total	677	499	245	49,1	1176

Table 1.– Breeding sites of *Aedes aegypti* at Kabolo, a sub-sudanian village of Côte d'Ivoire.

Of these containers 49,1% had preimaginal stages (larvae and/or pupae) of *Ae. aegypti*. The percentage of positive containers varied from 20% for basins to 54,2% for medical pots. Earthen-ware containers were significantly more often infested than metallic containers (χ^2 = 13,7 ; $p < 0,001$), while infestation rates of jars and medical pots did not significantly differ (χ^2 = 0,008 ; p = 0,9). Some drowned adult mosquitoes were observed under leaves of plants in medical pots.

The estimated «Breteau index» from observed positive containers in 69 houses was 355 at the time of the survey, while the «house index» was 100%. At least one or more positive breeding sites were observed in every visited house.

The mean number of larvae collected by dipping was 8, but in some jars more than 20 larvae could be counted. The other species present at larval stages were *Culex* gr. *decens* and *Culex tigripes*. The latter was always found in small numbers due to its cannibalism.

Relative importance of anthropophilic mosquitoes

Four thousand three hundred and fifty-four (4354) mosquitoes were collected during 162 man/nights in Kabolo. The mean biting rate was 26,9 bites per man and per night (b/m/n). Four genera (*Aedes, Anopheles, Culex* and *Mansonia*) and 24 species of Culicidae were caught in this village (Table 2). The percentage of the different species showed a tremendous abundance of *Ae. aegypti*, with 62,9% of the Culicidae and 96,9% (2738/2825) of Aedinae species collected. Aedes aegypti generally has a diurnal and/or crepuscular biting activity. However, in this village, because of a particular habit of water-stocking behaviour of the local population, this mosquito has a nocturnal biting activity (DIARRASSOUBA & DOSSOU-YOVO, 1997). Collections were performed on an annual basis, which allowed us to monitor the seasonal variation of the abundance of *Ae. aegypti*. The genera of *Anophe-*

Species	total number	bites/man/night	% of total catch
Ae. aegypti	2738	16,90	62,9
Ae. africanus	4	0,02	
Ae. furcifer	68	0,42	1,6
Ae. vittatus	1	0,00	
Ae. fowleri	1	0,00	
Ae. tarsalis	5	0,02	0,1
Ae. cumminsi	1	0,00	
Ae. ochraceus	1	0,00	
Ae. gr. *palpalis*	6	0,04	0,1
An. gambiae	324	2,00	7,5
An. funestus	328	2,02	7,5
An. nili	42	0,30	1,0
An. coustani	1	0,00	
An. broheri	1	0,00	
An. paludis	1	0,00	
An. pharoensis	9	0.05	0,2
An. welcomei	1	0,00	
An. ziemanni	2	0,01	
Cx. gr. *decens*	271	1,70	6,2
Cx. nebulosus	305	1,90	7,0
Cx. anulioris	3	0,02	
Cx. tigripes	11	0,07	0,3
Ma. africana	93	0,80	2,1
Ma. uniformis	137	0,84	3,1
Total	4354	26,90	100

Table 2.- Relative importance of the different species of mosquitoes at Kabolo, Côte d'Ivoire.

les, *Culex* and *Mansonia* represented 16,3%, 13,5% and 5,3% respectively of the total mosquitoes caught.

Anopheles gambiae s.s. Giles (DOSSOU-YOVO, unpubl. data) and *Anopheles funestus* Giles each represented 7,5% of Culicidae, but together they constituted 92,0% of Anophelinae. *Culex* (*Culex*) gr. *decens* Theobald and *Culex* (*Culiciomyia*) *nebulosus* Theobald were the most common species of the genus *Culex*, while *Mansonia uniformis* Theobald (3,1%) was slightly more frequent than *Mansonia africana* Neveu-Lemaire (2,1%).

Seasonal variations in biting rates of *Aedes aegypti*

At Kabolo the average biting rate of *Aedes aegypti* was 16,9 b/m/n but with important seasonal variations which are not directely dependent on rainfall (Fig. 1), most of the breeding sites being inside houses. The lowest densities were noticed in December and February (8,4 and 7,9 b/m/n, respectively) while the highest densities were observed in March and April (33,2 and 30,9 b/m/n). Then it regularly decreased till August (10,8 b/m/n) and remained at this level during the following months of the year.

Highest densities and highest temperatures occurred during the dry season and lowest biting rates were noticed during rainy season (August) as well as during the dry season (December-February) at lowest temperatures.

DISCUSSION

This village is worth studying from an entomological point of view and the reason for such diversity could be found at different levels. Several factors must be taken into consideration when analysing the great number of breeding sites suitable for *Ae. aegypti* in this village. It is

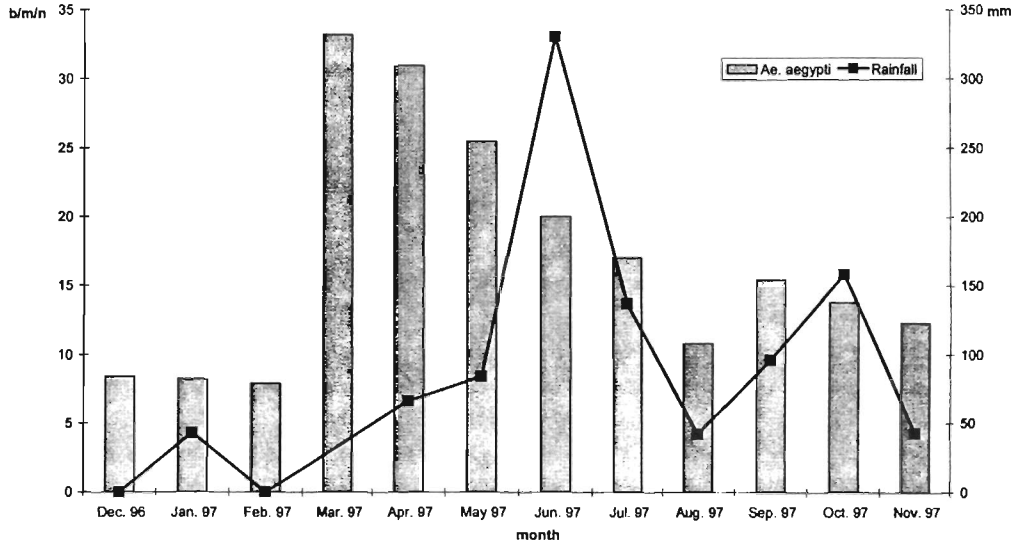

Fig. 1.- Seasonal variation of biting rate of *Aedes aegypti* at Kabolo, Côte d'Ivoire. b/m/n = bites per man per night; mm = height of rainfall in millimeters.

located just a few kilometers away from the city of Katiola, where many pottery factories are located and earthen-ware is offered at a very cheap price. The number of jars owned by inhabitants is a matter of pride for women. People are mainly animists and traditional medical pots are widely used, by both sexes, in all age groups; they believe that the longer plants macerate in water, the better the treatment should be. The great number of jars results in a low frequency of water renewal and this human behaviour gives a better chance for mosquito larvae to complete their larval development. Thus jars and medical pots were actually more often infested than metallic containers, where water is more frequently used. Indeed, water from barrels, kettles and basins is devoted to daily houschold work such as personal hygiene, washing linen, plates and dishes. The particularly great number of earthen-ware containers in this zone inhabited by the Tagwana has already been noticed by PICHON, HAMON & MOUCHET (1969).

The observed larval densities were important in the studied area. All the observed indexes («Breteau index»: 355; «house index»: 100%; «container index»: 49,1%) were very high and beyond the risk of epidemics as compared to the WHO thresholds of densities, which vary from 50 to 74 for the «Breteau index», from 35% to 44% for the «house index» and from 20% to 24% for the «container index» (ANONYMA, 1971). Furthermore, the high larval densities were confirmed by the important landing rate of *Ae. aegypti*, the populations of which are endophilic (DIARRASSOUBA & DOSSOU-YOVO, 1997). After their blood meal, female mosquitoes find resting places behind jars and clothes. The oviposition takes place in the same environment, thus the females do not need to disperse.

PICHON & GAYRAL (1970) partially explained the decrease in biting rates of *Ae. aegypti* in the rainy season by the pollution of the breeding sites, where this species could be displaced either by competition (*Culex* gr. *decens* and *Culex nebulosus*) or by predation (*Culex tigripes*). In the studied area this decrease is due to a sharp drop in the number of suitable breeding sites. In this village, rain is collected from conjugated sheet-iron covered roofs to several kinds of widely-opened containers. This water is pratically used on a daily basis, thus preventing the complete development of larval stages. Furthermore, larvae are driven out with the overflowing rainwater from full containers. The peak observed during the dry season could be explained by a great number of productive domestic containers holding water in the absence of rain collected from roofs. The seasonal variations could not be directly correlated with the rainy season (Fig. 1) because productive breeding sites are essentially inside houses.

Kabolo is situated in the same phytogeographical zone as the village of Petionara, located 20 km north of Katiola. In this village the biting rate of *Ae. aegypti* during the same period of observation never exceeded 1,3 b/m/n (DOSSOU-YOVO, pers. comm). Therefore, the multifold increase of the biting rate of *Ae. aegypti* and eventally of yellow fever transmission at Kabolo could be attributable to the local human behaviour. The risk of a yellow fever outbreak is thus more serious, as the Dabakala focus is located only a few kilometers away. In that area, the yellow fever virus is regularly isolated from vectors. Facing this situation, local authorities conducted mass immunization campaign against this virus in 1998.

A strengthened programme of information, education and communication should be implemented and adapted to the local population, who are conservative and refractory to any modification in their habits. The possibility of improving the water supply should be seriously considered, while yellow fever immunization should be urgently developed to prevent any outbreak.

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