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MI-DENGUE: AN INNOVATIVE TECHNOLOGY FOR GPS MONITORING *AEDES AEGYPTI* POPULATION ON WEBPAGE AT REAL TIME

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Abstract Dengue has been considered as the most important airborne disease in Brazil. Limitations in the laboratory identification of immature *Aedes aegypti* and processing of field data based on larval surveys led to the development of the "Intelligent Dengue Monitoring" technology (MI-Dengue) (www.midengue.com.br). MI-Dengue consists of a sticky trap that captures gravid female *Ae. aegypti*, coupled with a computerized system for field data collection and access to geo-referenced maps in real time with an online web interface. Weekly geo-referenced maps and an entomological indicator provide information to health authorities on infested areas and infestation levels, colour-coded according to the number of captured female *Ae. aegypti*, and indicated risk-free (green), dengue alert (yellow), and critical situations (red). These levels correlate with transmission thresholds, and are being used to prioritize areas and direct vector control resources. Preliminary analyses have also shown that vector control directed to hot spot areas have reduced the adult mosquito abundances as well as dengue cases. At the moment, over 40 Brazilian cities are currently using MI-Dengue Technology. The cost of such technology is less tha US$ 1 per person per year. More recently, the system has also been used to obtain data on the infection status of all mosquitoes routinely collected. Preliminary data are intriguing and have demonstrated spatial and temporal clustering by dengue serotype, evidence of infected mosquitoes in proximity to clinical cases, clinical cases in the absence of infected mosquitoes, and infected mosquitoes in the absence of cases. Molecular epidemiological studies are anticipated to provide higher resolution information regarding the most important locations of suspected transmission.
Key Words MosquiTRAP, vector, surveillance

INTRODUCTION

It is well known that the only measure currently available to prevent the dengue transmission is to control the *Aedes aegypti* vector. In Brazil, *Ae. aegypti* is monitored by larval surveys which provides unreliable dengue risk rates, since it utilizes entomological indices based on immature forms of the vector. Adult mosquitoes sampling methods is more adequate indices for dengue control programs, but some apparatus like aspirators have been used to capture resting adult, mainly outdoors, but with limitations, especially because the method is labor intensive and intrusive.

The stickytrap MosquiTRAP™ captures adult mosquitoes, especially gravid females due to the use of a synthetic oviposition attractant (AtrAedes™) developed from volatile grass infusions (WHO, 2006). The mosquitoes are captured by a sticky card, and are easily identified during field inspection of the trap. Usually the MosquiTRAP are placed in the outdoor environment (e.g., front or back yard) (Gama et al., 2007, Fávaro et al., 2006). Field studies have shown that the MosquiTRAP is more sensitive than larval surveys and it is capable of detecting and monitoring female *Ae. aegypti* even during the dry season, when larval surveys do not detect the presence of larvae. The sticky trap was also used to caught *Ae. aegypti* naturally infected in the field and it showed to be the useful role of virus investigations in adult mosquitoes for monitoring DENV circulation (Vilela et al., 2010).

Observation of the difficulties involved in these field procedures motivated the development of the Intelligent Dengue Monitoring system (MI-Dengue™, Ecovec Ltda., Belo Horizonte, Brazil), consisting of a set of tools that allow capturing and identifying the adult vector with the MosquiTRAP, recording and sending data on electronic spreadsheets, and providing entomological indices and georeferenced maps on infestations of female *Ae. aegypti*, on-line on the Internet, to orientate vector control activities by municipal health managers.

The present study aims to describe a novel real-time web-site system for monitoring and dengue (DENV) virus serotypes of adult *Ae. aegypti* and to show the MI-Dengue as a strategy to identify key areas and orient dengue vector control activities.

MATERIALS AND METHODS

MosquiTRAP

The sicky trap MosquiTRAP (Ecovec Ltda., Belo Horizonte, Brazil) consists of a matte black container and an inner sticky card that captures mosquitoes and a synthetic oviposition attractant (AtrAedes™). The traps were installed outdoors in a visible place, at a maximum height of 1.5 m above ground, sheltered from sun and rain, out of reach of domestic animals and children inspection. The captured mosquitoes were identified during trap recorded, and removed from the sticky card and placed in a code-bar Eppendorf tube for DENV-virus detection. The sticky card was changed every 30 days and the AtrAedes attractant every 45 days, whereas the water was changed weekly.

Intelligent Dengue Monitoring: MI-Dengue

The system consists of recording field data from the MosquiTRAP that are placed using a Global Position System (GPS), with an mobile phone loaded with the software (Geo-Dengue™, Ecovec Ltda, Belo Horizonte, Brazil). This system allows sending and making data available online in real-time on the Internet for municipal health managers to access and view information on the density of *Ae. aegypti* on georeferenced maps and in analytical tables of the sites monitored with MosquiTRAP. Implementation of MI-Dengue in the municipalities did not require any additional human resources, beyond the existing dengue control teams. The technical team in each municipality received training on MI-Dengue operations, identification of genus/species and sex of the captured mosquitoes, data acquisition on the electronic spreadsheet, data transmission, and access to the results. The Municipal Health Secretariats in each municipality received a password for Internet access to the tables, graphs, and geopro- cessed maps that were updated weekly with the trap inspection field data. The health managers were thus able to monitor the positive sites and *Ae. aegypti* infestation levels.

Entomological Indices. *Mean Female Aedes Index* (MFAI) was used for weekly monitoring of vector infestations in the urban areas. MFAI (MFAI = k/n) is the mean number (k) of female *Ae. aegypti* specimens captured by (n) traps installed per epidemiological week. *Temporal Mean Female Aedes Index* (MFAIt): This index averages the MFAI values for the three previous and consecutive weeks.

Geoprocessing of Infestations. Weekly monitoring in the blocks as a function of the number of female *Ae. aegypti* captured by the installed traps was used to establish color categories for classifying blocks as follows: green (absence of captures), yellow (one female *Ae. aegypti*/MosquiTRAP/week = low infestation), orange (two females/trap/week = medium infestation), and red (> three females/trap/ week = high infestation).

Vector Control Measures. The municipalities monitored by MI-Dengue adopted the weekly maps and tables on *Ae. aegypti* infestation to orient their vector control measures. The activities were those recommended by the National Dengue Control Program (e.g., elimination of breeding sites, tires, and disposables, covering water tanks with lids, use of larvicides, and occasionally adulticides). The field inspectors adopted control measures with house-to-house visits in a 200m radius, or 100 m on each side of the positive traps, i.e., approximately nine blocks.

DENV – Virus Detection. Pools of caught mosquitoes were submitted to PCR-Real time.

RESULTS AND DISCUSSION

The sticky trap allowed in detecting and monitoring the presence of female *Ae. aegypti* throughout the year. Every week, by epidemiological week, block-by-block georeferenced maps of infestations with female *Ae. aegypti* in the municipalities were made available to Municipal Health Secretariats on the Internet. The website provided a window allowing access to all the monitored epidemiological weeks, thus furnishing a spatial and temporal understanding of the infestations. The sticky trap has advantages over other methods for monitoring *Ae. aegypti* mosquitoes. Since the ideal place for setting the MosquiTRAP in households is outdoors (in the peridomicile) (Fávaro et al., 2008), the trap is a non-invasive method (Maciel-de-Freitas,et al., 2006), thus it does not require to enter in people houses.

The MI-Dengue technology (Figure 1) provides georeferenced maps by epidemiological week provided color-coded information on the sites (blocks) and infestation levels, based on the number of female *Ae. aegypti* captured

Figure 1. Escheme of computerized System “Intelligent Dengue Monitoring” (MI-Dengue) that is used for monitoring adult *Aedes aegypti* on real-time web-site.

in each block (Figure 2). Based on the observations, each week the infested sites were concentrated in given areas or neighborhoods of the municipalities, thus facilitating implementation of targeted control measures.

Since MosquiTRAP allows identifying the mosquito captured in the trap, without requiring additional procedures in the laboratory, the data collected in the field reaches the health system manager virtually in real time. MI-Dengue uses a mobile phone rather than paper spreadsheets, thus saving time and streamlining the processing of field results. Thus, by generating speedy, safe, weekly indices and maps that are absorbed into the municipal health service within 24 hours, furnishing seasonal vector data, MI-Dengue incorporates into the municipal dengue control programs the parameters that are needed to target and optimize *Ae. aegypti* control activities. The advantages of MI-Dengue over conventional field data acquisition systems are: (a) immediate access to field data; (b) production of automatic entomological indices; and (c) organization and control of field inspectors’ work (sites visited and scheduled for visits, visit times, trap locations, residents’ names, etc.).

Monitoring *Ae. aegypti* with MosquiTRAP and MI-Dengue allowed the Municipal Health Secretariats to conduct weekly follow-up of infestation trends in neighborhoods and municipalities. These weekly data on infested sites and vector infestation levels incorporated important information into the municipal dengue control programs

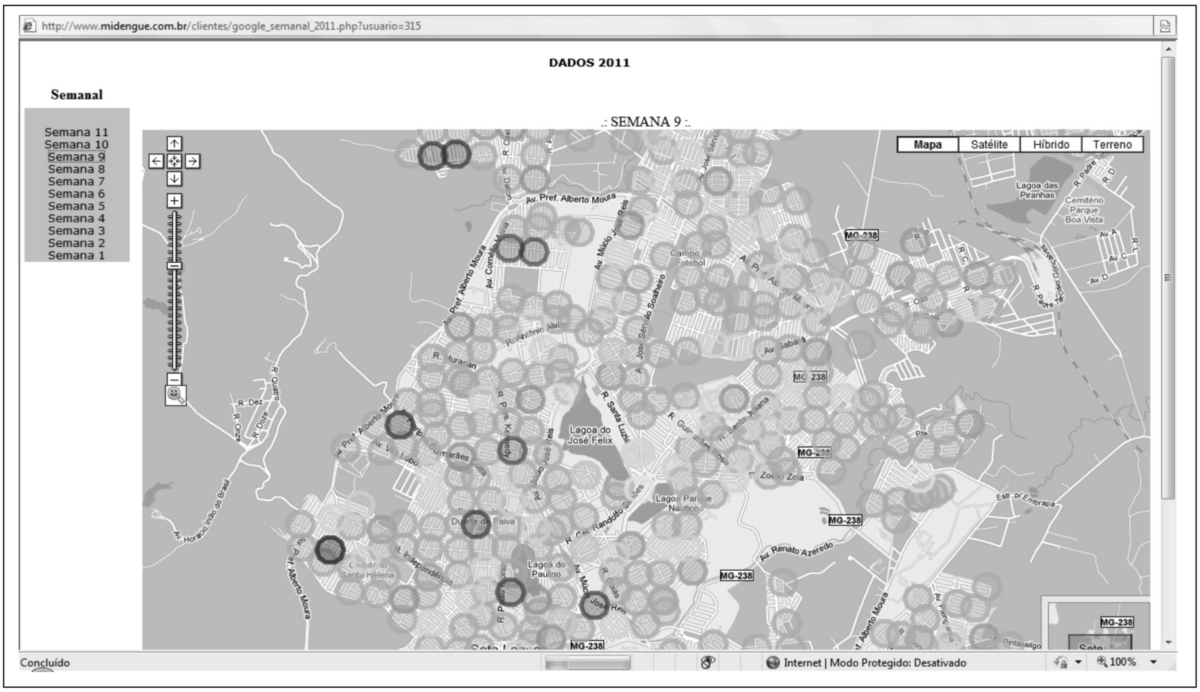

Figure 2. Example of MI-Dengueweb-site in real time of an urban area.

that assisted municipal health managers in targeting and optimizing their *Ae. aegypti* control activities. The current study demonstrated the feasibility of MosquiTRAP and MI-Dengue under operational conditions for weekly monitoring of female adult *Ae. aegypti* in real time, as compared to other geo-referenced studies that used sampling of immature forms of the mosquito (Chansang et al., 2007) (eggs and larvae), which demand time and infrastructure for identification, quantification, and data processing.

The geo-referenced maps produced by MI-Dengue and provided weekly on the Internet allowed municipal health managers to identify city blocks by colors (green, yellow, orange, and red) according to the number of female *Ae. aegypti* specimens captured. This information thus helped target activities to infested blocks in a 200-meter radius. This focal vector control strategy, supported by a weekly infestation monitoring system, allowed spatial localization of vector infestation and the evaluation of control measures within the radius represented by the trap. Weekly analysis of *Ae. aegypti* neighborhood reinfestation in the previous four weeks helped managers to monitor the weekly situation with *Ae. aegypti* reinfestation in the municipality and visualize the evolution in control activities.

Table 1. Dengue infection cases classified into INFAt categories and its respective frequencies in Vitoria city (ES, Brazil) during 15 epidemiological weeks of study in Vitoria city (ES, Brazil).

IMFAt	Frequency (Neighborhood/week)	No. of Dengue cases	Dengue casesdensity*	% ofall dengue cases
0.00 – 0.10	80	3	0.04	2.26
0.11 - 0.20	118	12	0.10	
0.21 - 0.30	134	17	0.13	21.80
0.31 - 0.40	130	20	0.15	
0.41 - 0.50	96	28	0.29	
0.51 - 0.60	57	13	0.23	75.04
0.61 - 0.70	46	14	0.30	
0.71 - 2.00	59	26	0.44	

A new procedure for interpreting the MFAIt by categories and for classifying neighborhoods as “non-critical”, “dengue alert”, and “critical” facilitates is shown in Table 1. This entomological index optimizes, and prioritizes the interventions recommended by the dengue control program in the municipality. Previous report (Eiras and Resende, 2009) suggested that the strategy that triggers interventions in cases of “dengue alert” and “critical” situations, with the adoption of control measures including house-to-house visits in a radius of 200m from the positive trap, indicating that the MI-Dengue system helped reduce dengue cases in the municipalities that adopted it. However, epidemiological data such as seroprevalence and seroincidence should be taken into consideration when evaluating the system.

The MosquiTRAP’s features are relevant for developing risk indices for dengue epidemics, based on the approach of capturing adult mosquitoes and furnishing entomological indices (Focks, 2003). In the current study, entomological indices were provided to municipal health managers to indicate the vector infestation sites and levels, thus prioritizing areas for vector control (Figure 3). However, we believe that an entomological index cannot be considered separately from other data to determine the risk of a dengue epidemic, which requires incorporating spatial and temporal data on the vector in the municipality, susceptibility of the human population to the virus, and mosquito infection rates. Combined with weekly entomological diagnosis of the traps, the computerization of these procedures introduced advantages into the overall process, and the experience showed that these new innovative technological tools do not pose difficulties for learning how to use them or including them in the existing dengue control program.

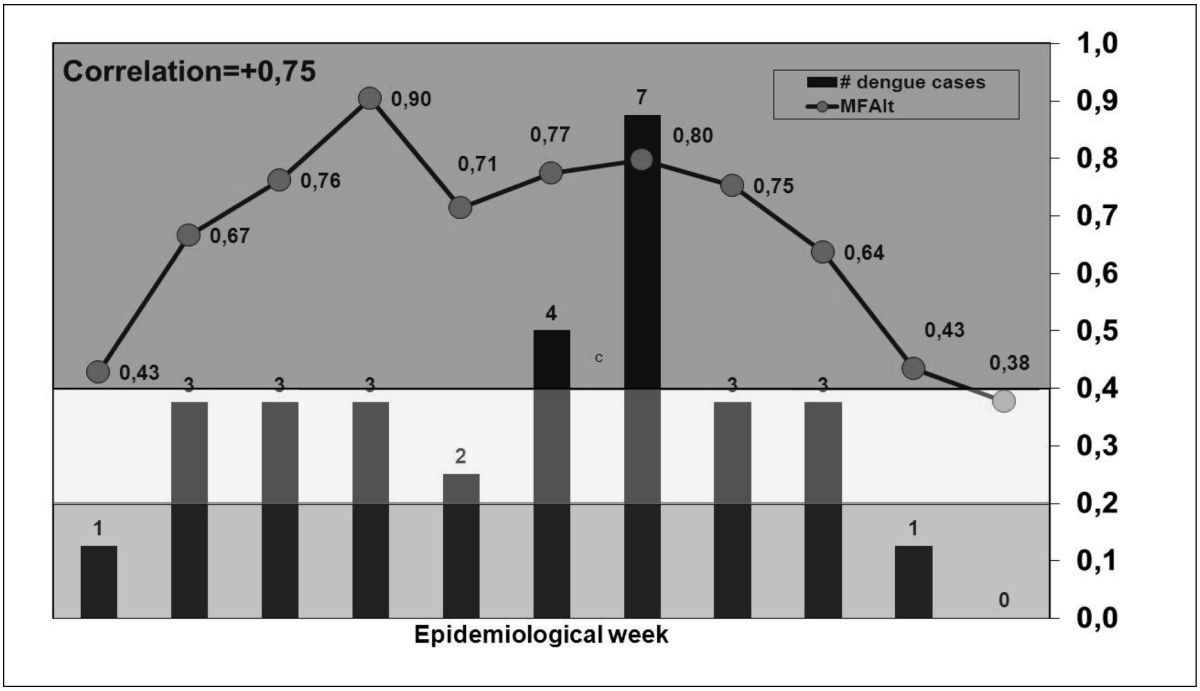

Figure 3. Threshold limit established for Dengue cases occurrence risk based on *A. aegypti* female mosquitoes captured by MosquiTRAP clusters and Dengue infection cases cluster in Jabour neighborhood, Vitoria (ES, Brazil) during epidemiological weeks 8 to 19, 2007.

CONCLUSIONS

The sticky trap MosquiTRAP allowed in detecting and monitoring the presence of female *Ae. aegypti* throughout the year. MI-Dengue technology indicated hot spot areas of dengue vector for directional control areas. Early detection of infected mosquito by DENV-virus caught in MosquiTRAP and web-site on real time MI-Dengue may avoid dengue outbreaks. New vector control strategies supported by the MosquiTRAP and the MI-dengue system represented important strides, and that the knowledge acquired from these experiences opens new channels for research on *Ae. aegypti* control.

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