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FIELD EVALUATION OF A SMOKE-GENERATING FORMULATION CONTAINING BETA-CYPERMETHRIN AGAINST THE DENGUE VECTOR IN ARGENTINA

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ABSTRACT. Previous results from laboratory and prefield assays obtained by our laboratory indicated that the fumigant canister CIPEIN PF-7 (Bolate®) a smoke-generating formulation containing 5% beta-cypermethrin, has excellent performance as an adulticide for *Aedes aegypti* control. A field trial was carried out to evaluate the effectiveness of CIPEIN PF-7 to control adult mosquitoes of *Ae. aegypti* inside houses. The trial was carried out in Colonia Delicia, a locality of 4,750 inhabitants, located in Misiones, a subtropical area in northeastern Argentina, an area highly infested with *Ae. aegypti* and at risk to dengue. One fumigant canister was applied in each house, which remained closed for 1 h and was then ventilated for 15 min by opening doors and windows. Taking into account the time spent in the fumigation activities, the rate of the treatment was around 20 houses per worker per day. Cages with adult mosquitoes and plastic cups with water containing mosquito larvae were put in various places of the houses. There was 100% initial mortality in each case after treatment with the fumigant canister. The residual effect showed 100% mortality of adults exposed 2 h for at least 3 days after treatment and 100% mortality of larvae 1 day after treatment. House and Breteau indices before the treatment were 51% and 106, respectively, falling to 23% and 44 after treatment. The potential for using this new tool in geographic areas very difficult to reach or as a quick alternative to control *Ae. aegypti* inside the houses, especially during dengue epidemics, is discussed.

KEY WORDS *Aedes aegypti,* dengue, fumigant canister, smoke-generating formulation, pyrethroids

INTRODUCTION

During the 1950s and 1960s, more than 20 countries in Latin America were able to eradicate *Aedes aegypti* (L.), the principal vector of the viruses causing dengue, but in the last decade, almost all of these countries, including Argentina, have become reinfested (Gubler 1997). Starting in 1997, the reinfestation with *Ae. aegypti* in the northern part of Argentina resulted in some sizable epidemics of dengue fever (Aviles et al. 1998, 1999). In the absence of a vaccine, control of the vector is regarded as essential to stop epidemics in tropical areas.

Different approaches to insecticide application are necessary in the control of *Ae. aegypti.* Unfortunately, many of the campaigns to reduce vector populations have not been successful due to the practical problems associated with treatment of urban areas and failure to sustain implementation of expensive control programs (Matthews 1996).

Emphasis is now given to community participation and intersectional collaboration in campaigns to eliminate larval habitats. However, in spite of extensive reduction of larval breeding, there are areas with adult *Ae. aegypti* infestations where dengue infections continue. For this reason, emergency measures for a rapid decrease in adult mosquito populations using space treatments must be available for use in areas of dengue transmission.

The principal treatment used currently for adult control is ground application of space sprays delivering a minimum volume of insecticide formulation per unit area (ultra-low volume, or ULV). This method requires little or no diluent, but does require equipment designed and constructed for the purpose of metering and atomizing the ULV flow rates. It has been noted that ULV applications have not been successful in some situations (Focks et al. 1987, Perich et al. 1990).

Pant and Yasuno (1970) demonstrated that 95% of *Ae. aegypti* mosquitoes rest indoors. Part of the adult population is found in wardrobes, under beds, behind furniture, and in other sequestered areas where it is difficult for aerosol droplets to reach. Failure of insecticide to reach *Ae. aegypti* in these protected resting sites may be a cause of many domestic spray treatment failures (Perich et al. 1990, 2000; Chadee 1985; Hudson 1986).

The fumigant canister is a smoke-generating device that releases pyrethroid formulations. It was developed as a result of previous work of our laboratory for the indoor control of Chagas disease vectors (Gonzalez Audino et al. 1999, Zerba 1999). The device consists of a disposable canister containing a solid fumigant mixture. Lighting a fuse on the top of the canister produces flameless combustion of the fumigant with the resulting release of insecticide (Zerba 1995).

The latest version of the fumigant canister (CIPEIN PF-7 [Bolate®]) contains beta-cypermethrin and was recently evaluated for mosquito control. Beta-cypermethrin delivery by this smoke-generating formula-

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tion was shown to be very effective against adult and larval stages of *Ae. aegypti* on the basis of laboratory and prefield bioassays (Zerba 2000).

The high penetration and mosquito adulticidal properties of the fumes delivered by the fumigant canister could provide a novel alternative for indoor control of dengue vectors. The present study was carried out in an area of Misiones, Argentina, which had a high incidence of *Ae. aegypti*. The purpose of the study was to evaluate the efficacy of the fumigant canister CIPEIN PF-7 for mosquito control under field conditions.

MATERIALS AND METHODS

Formulation

Fumigant canister CIPEIN PF-7 (Bolate®) containing 120 g of fumigant mixture (Gonzalez Audino et al. 1999) and 6 g beta-cypermethrin was supplied by Chemotecnica S.A. (Buenos Aires, Argentina).

Study site

Field tests were performed in Colonia Delicia, a small city located in Misiones, a northern subtropical province of Argentina, at 26°14′S and 54°37′W. In 1991, this city had 4,750 inhabitants. Almost all the houses of the urban area of Colonia Delicia were of either 2 types of construction: wooden walls and plane tree roofs or brick walls and tile roofs. The occurrence of larval and adult *Ae. aegypti* in most of these houses was established by the inspectors of the National Program of Vector Control of Argentina. The average temperature in the city during fumigation was 22 ± 3°C.

Entomological evaluation

Two indices are commonly used to record *Ae. aegypti* larval density (WHO 1995a):

a) the House index (HI) or *Aedes* index, the percentage of houses positive for *Aedes* larvae according to indoor and outdoor inspection, calculated as follows:

$$HI = \text{no. of houses positive for } \textit{Aedes} \text{ larvae} \times 100 \div \text{no. of houses inspected;}$$

b) the Breteau index (BI), the number of positive containers per 100 houses in a specific location, calculated as

$$BI = \text{no. of positive containers} \times 100 \div \text{no. of houses inspected.}$$

In the pre- and posttreatments, the HI and BI were calculated by sampling 1 of every 4 houses of the entire locality.

For identification, adult mosquitoes were collected in tubes upon landing on the body of a collector or when resting indoors in a building. After collection, mosquitoes were placed in netting-covered drinking cups and taken to the laboratory.

Fumigation treatment

After 1 wk of preintervention data collection, house fumigation using the fumigant canister CIPEIN PF-7 was undertaken by a team consisting of 6 local workers of the National Program of Vector Control of Argentina. Fumigation was done while residents were absent from their homes. Five hundred fifty-two houses were treated between April 30 and May 4, 2000. One fumigant canister was applied in the central part of each dwelling, keeping the rooms and closet doors open. After discharge of the fumigant, the dwellings were kept closed for 1 h and then ventilated not less than 15 min by the vector control workers wearing facemasks.

Fumigation effectiveness

Aedes aegypti adults that emerged from larvae collected in Colonia Delicia (Misiones) before the treatment and field-collected larvae were used to test fumigation effectiveness. Netting-covered plastic cups containing 10 adults and plastic cups containing 100 ml of water and 10 second- or third-stage larvae were located in 3 different positions in the houses: a) on the floor, 2 m from the canister, in the same room; b) at a height of 2 m in the same room where the canister was applied; and c) at a height of 2 m in a different room from the one where the canister was applied. Additional plastic cups containing adult mosquitoes were located outside the houses on a window frame. Mosquito adults and larvae were exposed for 1 h to the fumigant and observed 24 h posttreatment. Mosquitoes knocked down after treatment and ventilation of the houses were considered dead. Larvae that did not reach the pupal stage were considered dead. Mortality data obtained were an average from all houses treated.

Residual activity

Contact bioassay (cone) tests performed with adult and larvae collected as described above were performed at 6 h and then daily up to 4 days after treatment. Cones were placed over the wood or plastered walls and over the glass window of the room where the canisters were applied. The cone containing 10 adults was located 2 m above floor level, and the exposure time was 2 h. Mosquitoes knocked down at the end of the exposure time were considered dead. Mortality was recorded 24 h after exposure. Three independent replicates were performed for each residual time and each surface.

Plastic cups containing 100 ml of water were located beside a wall in the same room where treatments were performed. The cups with water were

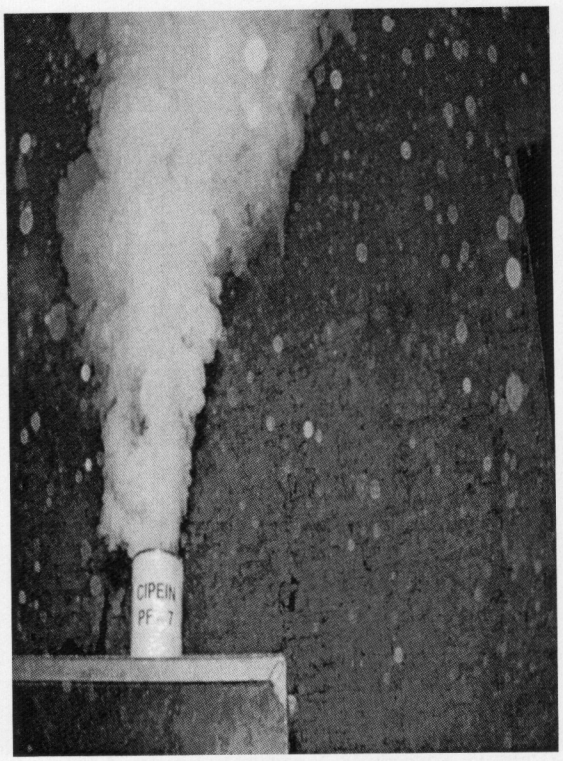

Fig. 1. Smoke generated by the fumigant canister CIPEIN PF-7.

withdrawn after the treatment and 10 second- or third-stage larvae were introduced in the water at 3, 6, 24, 48, and 72 h after the treatment. Mortality was recorded 24 h after exposure. Larvae that did not reach the pupal stage were considered dead. Three independent replicates were performed for each residual time period.

RESULTS

Entomological evaluation

During the week before the application of fumigant canisters, the HI and BI were established in Colonia Delicia. Values of 51% and 106, respectively, were found before treatment. After the treatment, they were considerably lower (23% and 44).

More than 90% of the mosquitoes collected near or inside the houses were identified as *Ae. aegypti* (WHO 1995a). No attempts were made to identify the remaining mosquitoes collected, although most of them were probably *Culex pipiens* L.

Fumigant treatment

The fumigant canister is shown in Fig. 1. A total of 552 houses were selected for treatment in the urban area of Colonia Delicia. About 20 houses per worker per day were treated.

Table 1. Mortality of caged adults and larvae in cups of *Aedes aegypti* exposed for 1 h in different locations to the fumes of fumigant canister CIPEIN PF-7 (1 canister per house); results are averages of all the houses treated.

Stage	Location	% mortality at 1 h
Adult	Indoors (2.0-m height)[1]	100
	Indoors (on the floor)[1]	100
	Indoors (far from the canister)[2]	100
	Outdoors (over the window frame)	100
	Control[3]	0
Larvae	Indoors (2.0-m height)[1]	100
	Indoors (on the floor)[1]	100
	Indoors (far from the canister)[2]	66[4]
	Control	0[3]

[1] Two meters from the canister, in the same room.
[2] In a different room than the canister at 2.0-m height.
[3] Adult and larvae in the control group were located on the floor of untreated houses.
[4] 100% mortality at 24 h.

Fumigant effectiveness

After 1 h of exposure to the smoke of one fumigant canister per house, 100% mortality was observed in adult *Ae. aegypti* (Table 1). In the same table, it can be seen that, for larvae located in the same room where the canister was applied, mortality was also 100%, but fumigation caused partial mortality in larvae located in places adjacent to the room where the canister was applied.

Residual activity

The evaluation performed on 3 different house surfaces showed a slight residual activity of beta-cypermethrin against *Ae. aegypti* adults (Tables 2 and 3). Insecticide deposited on glass showed the longest residual activity for adult mosquitoes (Table 2), with 100% mortality of adults exposed for 2 h up to 4 days after treatment. The minimal activity was observed on wood surfaces, where 100% mortality of exposed mosquitoes occurred up to 3 days

Table 2. Residual activity against adult mosquitoes on indoor surfaces after fumigant canister treatment.[1]

Time after the treatment (h)	% adult mortality			
	Wood	Plastering	Glass	Control[2]
6	100	100	100	0
24	100	100	100	0
48	100	100	100	0
72	100	100	100	0
96	47		100	0

[1] Results are the mean of 3 independent determinations. Mosquitoes were exposed during 2 h on a wall of the same room where the canister was applied.
[2] Adult and larvae of the control group were located in untreated houses.

Table 3. Residual activity in indoor water-holding containers after fumigant canister treatment.

Time after the treatment (h)	% larval mortality[1]	
	Treated containers	Control
3	100	0
6	100	0
24	100	0
48	57	0
72	37	0

[1] Results are the mean of 3 independent determinations.

after fumigation. The absorption by porous surfaces is probably the cause of the shorter residual activity observed on wood surfaces.

The mortality of larvae introduced in the water reservoirs exposed to fumigation was 100% up to 24 h after the treatment. Partial larval mortality was observed in the bioassay performed 2 or 3 days after fumigation (Table 3).

DISCUSSION

Dengue is now the most important arboviral disease in Argentina, and its incidence is increasing rapidly in the northern part of the country. Vector control is an essential component of dengue control programs. However, its value and relevance has been under discussion in recent years. One of the most important reasons of criticism for mosquito control campaigns is the poor use of alternative control tools (WHO 1995c). In an epidemic situation, spraying with adulticides is still essential in stopping dengue transmission. The space sprays can be applied as either thermal fogs or as ULV applications of organophosphorus or pyrethroid insecticides (WHO 1995b). These treatments have been shown repeatedly to yield poor control of indoor adult populations. This may be due to the resting behavior of *Ae. aegypti* (Perich et al. 1990, 2000). Ground ULV spray application may result in sublethal amounts of insecticide reaching the sequestered areas inside the houses where mosquitoes rest (Perich et al. 2000).

The results of canister fumigation tests in the urban area of Colonia Delicia demonstrated excellent adulticide effectiveness, as shown by the total mortality of caged adult *Ae. aegypti* exposed to the smoke. Assays of residual activity showing 100% mortality up to 4 days after treatment provide evidence of further value of this method for indoor treatment. Further, the significant larvicidal effect in water reservoirs exposed to the smoke and the slight residual activity after treatments on the walls and in water reservoirs suggest a further benefit. It is well recognized that pyrethroid compounds have high larvicidal effect against *Ae. aegypti* (Chavasse and Yap 1997).

A further demonstration of the effectiveness of treatments with the fumigant canister was the decrease of almost 50% of the HI and BI.

Previous studies of the control of Chagas disease vectors in Argentina demonstrated that the fumigant canisters are a useful tool not only for decentralized operations involving community participation but for governmental campaigns as well (Zerba 1988, 1995, 1999). According to the results of mosquito control in Colonia Delicia and the enthusiastic response to the fumigation from the local residents, the fumigant canister may be an effective new tool for *Aedes* control, especially in situations where there is dengue transmission. We consider this study to be an initial contribution to indoor *Aedes* control. Further field studies are underway to determine the effective of this treatment against wild mosquito adults.

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