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Efficacy of Aerial ULV Application of Dibrom 14 Against *Aedes aegypti* in San Juan, Puerto Rico

As reported in Dengue Surveillance Summary No. 44, neither ground applied "Ultra-Low Volume" (ULV) nor thermal fog fumigation at maximum label dosage, was effective in controlling natural urban populations of *Aedes aegypti*. Because of our continuing interest in identifying control methods that might be used to intervene during an impending dengue epidemic, we evaluated the aerial ULV application of Dibrom 14 in the San Juan Metropolitan area.

Surveillance data collected early in the year suggested that Puerto Rico was at high risk for a dengue epidemic in 1987. The Director, Centers for Disease Control, requested and received approval from the Secretary of the Air Force, for assistance from the 907 Tactical Airlift Group/Aerial Spray Unit, U. S. Air Force Reserve, Rickenbacker Air National Guard Base, Ohio. The aircraft used by the aerial spray unit was a C-130 A (Hercules) equipped with IPSS Spray System, long stainless steel wing booms, and 8005 (July 28) or 8003 (August 5-8) nozzle tips oriented straight down. The aircraft was flown at 230 miles per hour at an altitude of 150 feet. The application rate for Dibrom 14 (Naled, 85%) was 1 ounce per acre. Swaths were approximately 1,000 feet wide. Spraying commenced at 0600 hours daily and lasted 3 to 3.5 hours per day, depending on the number of swaths and area to be covered.

Metropolitan San Juan was divided into two zones (A and B) so that approximately equal-sized areas would be treated on any given day (Figure 1). Orientation of the spray boundaries and swaths were based on prevailing morning wind direction (east-southeast). To optimize insecticide dispersal, and for safety, the entire spray operation was flown perpendicular to the prevailing wind direction (cross-wind), and swaths followed a racetrack flight pattern. Area A was sprayed on July 28 and August 5 and Area B was sprayed on August 6, 7 and 8. During the operation, a total of 177,009 acres were covered with 1,382 gallons of insecticide.

Eight study areas were selected (triangles, Figure 1) to include a cross-section of geographically dispersed, residential housing types with substantial *Ae. aegypti* populations. During each spray day four evaluation areas were treated and one served as an untreated "control". Commencing on July 20, the natural *Ae. aegypti* female population was monitored by standard

CDC ovitraps placed in 15 preselected houses in each area. A pair of ovitraps was placed in sites protected from direct sunlight and rainfall in the front and rear of each house. Seven-day-old hay infusion was used as the medium to enhance oviposition. The ovitrap pair consisted of one with a 100% infusion and another with a 10% dilution of the same, and clean, labelled masonite (5/8" x 5") oviposition paddles. Ovitraps were washed after each use and replaced prior to 11 a.m. daily through September 4.

To insure proper insecticide delivery, the spray system was calibrated prior to take off each day. Insecticide dispersal was monitored in several ways. First, a swath offset test was conducted before treatment with volunteers stationed at 100-foot intervals to determine the distance the insecticide was carried downwind. Second, the swath width was determined by spraying over a designated point and assessing mortality in bioassay cages positioned at specified intervals along a street perpendicular to the swath pattern. Third, three insecticide sensitive dye cards attached to small wooden cylinders, positioned vertically, were placed outside of five houses (usually in front, at the side, and to the rear) in each evaluation area to be sprayed. Fourth, spinning, teflon-coated slides were situated at 0.3 and 2.0 meters at two of these houses to collect insecticide droplets. Fifth, bioassay cages containing approximately 25 three- to six-day-old susceptible female Ae. aegypti, were placed at the front, side, rear and inside of each of the five houses. A similar bioassay cage scheme was followed in the untreated area. Following completion of the spray mission, bioassay cages were returned to the laboratory where mosquitoes were lightly anesthetized with CO_2 gas and transferred to clean one pint cartons, provided with a moist cotton pledget, and examined at 24 hours for mortality.

Additionally, bioassay cages were placed on the grounds of San Juan Laboratories. During the first two spray days, six strains of Ae. aegypti were used. Two of these were susceptible laboratory strains (REX and RUT) and the other four (VIR, IPK, CAS & PNU) were F_2 generation local strains collected from four of our evaluation areas, which exhibited low-grade tolerance to organophosphate insecticides.

One of the most important factors influencing insecticide dispersion through an area is wind. To monitor local meteorologic conditions, a continuously recording weather station was established on the roof of a house near the center of the spray area in Puerto Nuevo. In addition, data on wind conditions during the trial were obtained from 33- and 200-foot towers at Palo Seco in the northwest corner of Area A near the Atlantic Ocean and from the International Airport near the northern boundary of the eastern portion of Area B. In general, morning winds were strongest on August 5 and 6 and the average number of insecticide droplets counted on the dye cards was greatest on those days.

Mortality in bioassay cages placed in outdoor locations exceeded 96% on all days except July 28 (Figure 2). Mortality in bioassay cages placed indoors was also high except on July 28 and August 5. The lower rates on those days may have been a reflection of wind conditions, location of the evaluation area relative to the swath pattern, and/or perhaps a difference of insecticide penetration into different housing types. Nevertheless, bioassay cage mortality reflected better penetration of insecticide than previously observed in ground ULV trials.

Considerable variation in bioassay cage mortality was observed among mosquito strains with differing tolerance to Dibrom 14 that were placed at San Juan Laboratories on July 28 (Figure 3). All mosquito strains had relatively high mortality when placed in the open. When placed under an overhanging roof or in a covered passageway between two buildings, however, there was a marked difference in mortality rates between the susceptible strains (REX and RUT) and the local strains (VIR, OPK, CAS, PNU). This experiment was repeated on August 5 when wind velocity was higher, however, and mortality exceeded 75% in all strains at all locations.

While bioassay results are of some value, their direct relationship to the impact of insecticide treatment on the wild population of Ae. aegypti is not known. Therefore, the enhanced CDC ovitrap was used to measure changes in the relative abundance of the natural ovipositing female population. As reported earlier (Dengue Surveillance Summary, No. 44), no change in the number of eggs laid was discernible following ground ULV application of insecticides. Following multiple aerial applications, however, a substantial decrease in the mean number of eggs per trap occurred in two of our evaluation areas compared to the untreated Carolina area (Figure 4). These were Barrio Obrero (area 4, Figure 1), which was sprayed on all five days, and Reparto Metropolitano (area 2), which was sprayed on two days, but received drift during the last three days of spray. The arrows indicate spray days. The data presented have been "smoothed" using a data analysis method which plots medians of adjacent values. This technique reveals trends in the data which may be obscured by erratic daily fluctuations and gives less importance to outlying values.

Results from three evaluation areas showed little or no decrease in egg collections, as depicted in results from Las Virtudes (area 5, Figure 5). Two other evaluation areas showed a marginal decrease in egg counts. When data were analyzed by plotting the percent ovitrap pairs positive, similar curves were observed during the period of study.

The San Juan Metropolitan Area is heterogeneous in meteorologic as well as physical characteristics. Our results have demonstrated that repeated aerial application of insecticide can have a substantial impact on the natural adult female population. Since Dibrom 14 has no residual properties, however, larval development, pupation, and adult emergence should continue unaffected. The extended depression of oviposition for several weeks after the spray, therefore, is somewhat puzzling. Rainfall was only about 40% of normal during August, and this probably contributed to the continued low population of Ae. aegypti.

Dengue transmission in Puerto Rico was increasing during the weeks prior to the spray operation, but leveled off and even decreased a little in the metropolitan area immediately following insecticide treatment (Figures 6 and 7). A similar pattern was observed in other cities of the island that were not sprayed, but the decrease did not occur until two weeks after the spray operation (Figure 6). We do not know whether an explosive epidemic would have occurred in San Juan in 1987 if we had not sprayed, but surveillance data suggested a high risk situation. Whether the lack of epidemic transmission was due to the spray operation, the dry weather, the strain of virus, or more likely a combination of these factors, is not known.

We are encouraged by the positive results obtained from this trial and believe that this method, when applied under optimal conditions, may serve to suppress urban Ae. aegypti populations when an outbreak appears imminent. The questions that have arisen from this effort have convinced us that carefully designed and monitored replicate trials are necessary to further define optimal conditions under which large-scale, emergency aerial application measures should be implemented for maximum efficacy. This approach, however, is very expensive and is not a panacea for the control of Ae. aegypti. It should only be used when an epidemic is imminent.

Figure 1

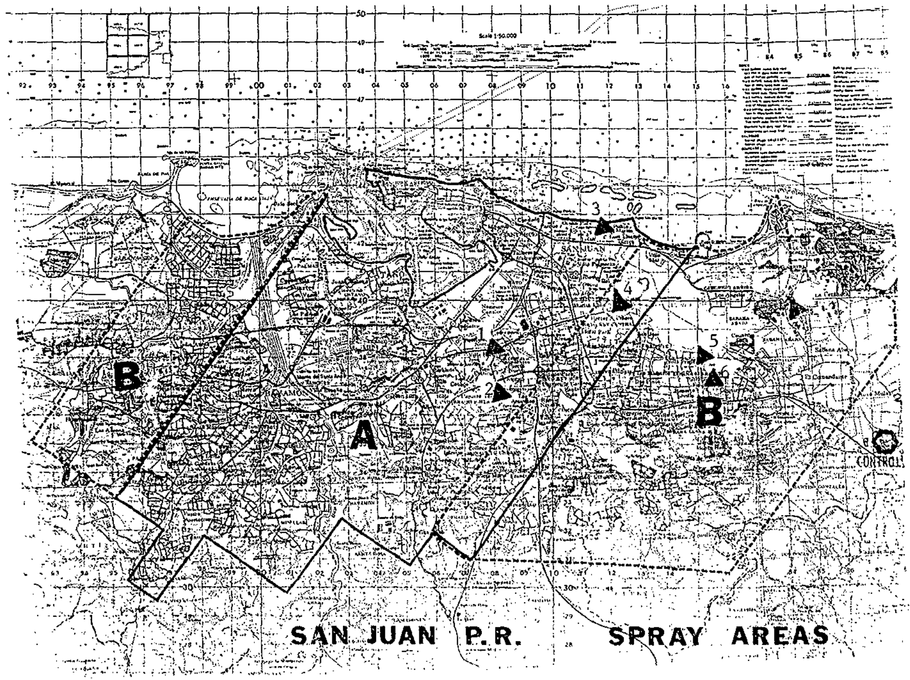

Figure 2
Bioassay Cage Mortality in Treated and Untreated Control Areas Following Aerial ULV Application of Dibrom 14, San Juan, Puerto Rico, 1987

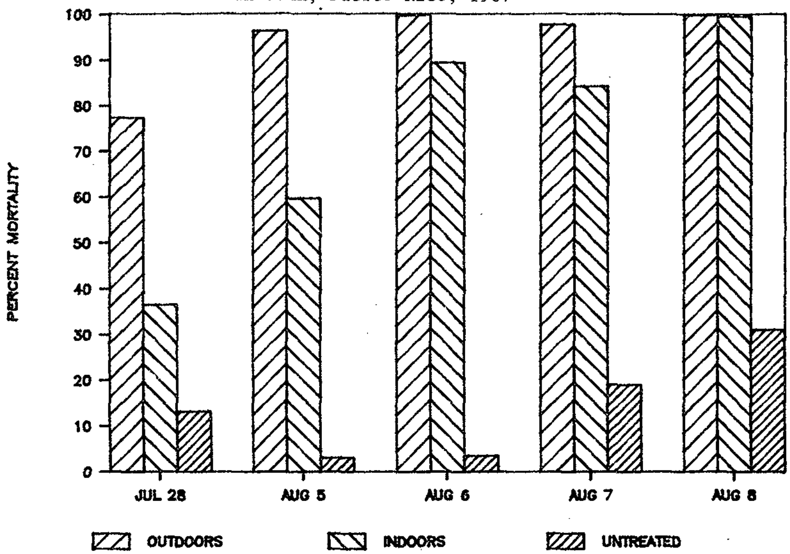

Figure 3
Bioassay Cage Mortality Among Mosquito Strains with Variable Tolerance to Dibrom 14, San Juan, Puerto Rico, July 28, 1987

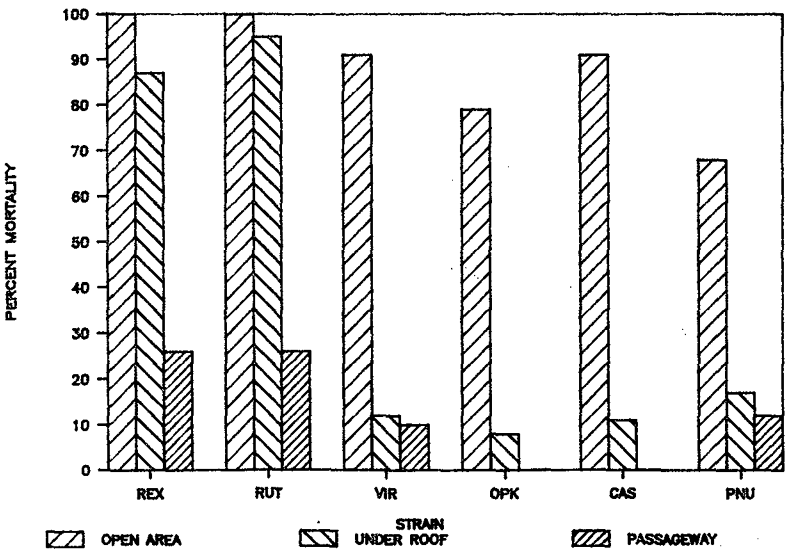

Figure 4

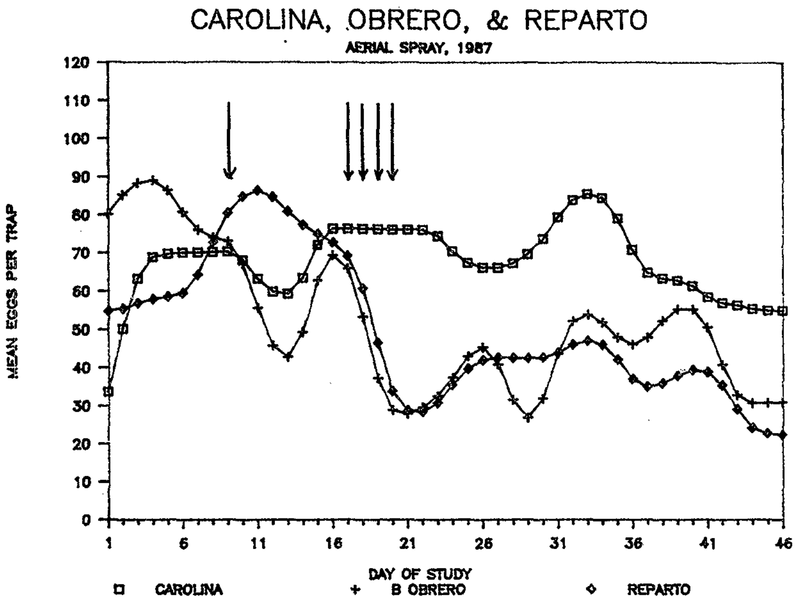

Figure 5

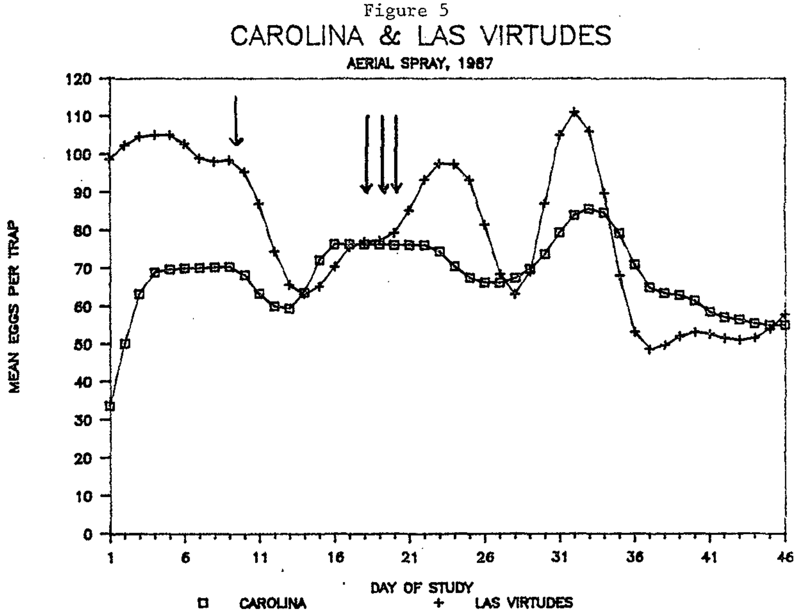

Figure 6

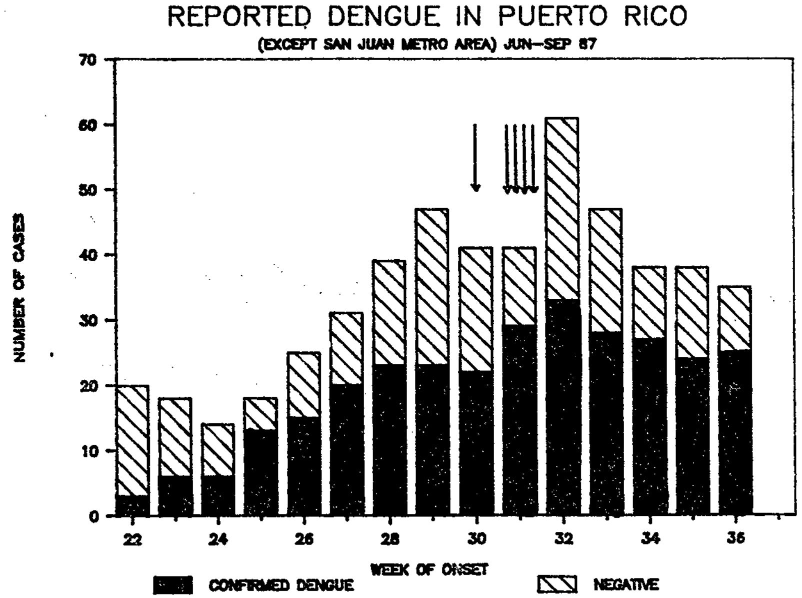

Figure 7