THE EFFECTIVENESS OF PYRETHRIN AND PYRETHROID AEROSOLS AGAINST MOSQUITOES ENDEMIC TO PANAMA [1]

W. N. SULLIVAN,[2] W. A. GEBHART,[3] B. N. CHANIOTIS[4] AND J. T. WHITLAW [4]

ABSTRACT. *Anopheles, Aedes, Mansonia,* and *Culex* mosquitoes endemic to Panama were killed when they were exposed to synergized pyrethrin, resmethrin, or *d*-phenothrin formulated as aerosols applied to rooms. The avidity of the mosquitoes was much reduced after treatment. The pyrethroid formulations had no odor and did not irritate skin or eyes; the synergized pyrethrin containing kerosene had an odor and was irritating.

Since World II, the Department of Defense and others have used insecticidal aerosols as an aid in the prevention of malaria, yellow fever, dengue, filariasis, and other mosquito-borne diseases. Formulations have been altered as more effective insecticides have become available, and the present standard General Services Administration, U.S. Government aerosol contains pyrethrins synergized with piperonyl butoxide (Fales et al. 1970). However, 2 recently synthesized pyrethroids, resmethrin and *d*-phenothrin (Schechter et al. 1974), now appear to be promising for control of mosquitoes endemic to Panama. They were therefore compared with the standard in a study sponsored by the Armed Forces Pest Control Board and conducted by representatives from the Health and Environment Activity, USA MEDDAC, Canal Zone; the U.S. Navy Facilities Engineering Command; and the Agricultural Environmental Quality Institute, Agric. Res. Serv., USDA.

MATERIALS AND METHODS. The experiments were performed in 842-1428 ft^3 (23.84-40.29 m^3) rooms in unoccupied living quarters at Fort Clayton, C. Z. during daylight hours in November 1975. The formulations evaluated were:

(1) 0.6% pyrethrins, 1.4% piperonyl butoxide, 13% deordorized kerosene in propellants 11+12 (50:50).
(2) 1.2% resmethrin, premium grade in propellants 11+12 (50:50).
(3) 2.0% resmethrin in propellants 11+12 (50:50).
(4) 1.2% *d*-phenothrin in propellants 11+12 (50:50).
(5) 2.0% *d*-phenothrin in propellants 11+12 (50:50).

The *d*-phenothrin was supplied as S-2539 Forte by the Sumitomo Chemical Co., Ltd., Osaka, Japan.

The first 3 formulations were packaged by commercial fillers for the U.S. General Services Administration; formulations 4 and 5 were packaged at the Beltsville Agricultural Research Center in 340.2-g cans equipped with 0.018 in. (0.45 mm) valves. The flow rate for all formulations was approximately 1 g/sec.

In each trial approximately 100 mosquitoes (males and females) were used. Male insects were included in the tests to avoid injury on separation. Also, males contribute to the multiplication of the species. Most of the *Anopheles albimanus* used in the tests were supplied by the Gorgas Memorial Laboratory (GML), Panama, from a laboratory-reared strain established in 1934 by L. E. Rozeboom; in 1974, this strain had lost none of its ability to transmit malaria. Other test mosquitoes were native insects obtained at Albrook and Howard Air Force Bases (AH) in the Canal Zone, or from a horse trap (HT) located in the jungle on the Atlantic side of the C. Z. They included

[1] Mention of a pesticide or proprietary product in this paper does not constitute a recommendation or an endorsement of this product by the U.S. Department of Agriculture or the U.S. Department of Defense.

[2] Chemical and Biophysical Control Laboratory, Agricultural Environmental Quality Institute, Agricultural Research Service, USDA, Beltsville, Maryland 20705.

[3] Naval Facilities Engineering Command, 200 Stoval St., Alexandria, Virginia 22314.

[4] Health and Environment Activity, USA MEDDAC, Canal Zone, Fort Clayton, Canal Zone 09827.

An. albimanus Wiedemann, *An. triannulatus* (Neiva and Pinto) *Aedes taeniorhynchus* (Wiedemann), *Ae. angustivittatus* (Dyar and Knab), *Culex nigripalpus* (Theobald), *Cx. quinquefasciatus* (Say), *Mansonia venezuelensis* (Theobald) and *Ma. titillans* (Walker).

The particular genera and the number of each sex used in each test are given in Table 1. In one series of tests, 100 mosquitoes aspirated from stock cages, and placed in 1-qt ice cream cartons supplied with a sugar solution, were released in the test room 5 min before treatment. The target doses (synergized pyrethrum, 7 g/1000 ft^3; pyrethroids, 5 g/1000 ft^3) were selected for the trial after extensive testing in the laboratory and in operational aircraft (Fales et al. 1970, 1972; Sullivan et al. 1972; Cawley et al. 1974). The aerosol was directed towards the junction of the walls and ceiling in a circular motion from the center of the room. The aerosol cans were weighed before and after application to determine the actual dose used. At 5 min post-application, 2 or 4 subjects (exposed from the waist up) entered the room and remained for 15 min to determine the avidity (biting rate) of mosquitoes exposed to the treatment. Percentage knockdown was determined at 10 and 20 min after application, then the mosquitoes were collected by aspiration (25 min after application), placed in holding cages containing sugar-water on cotton, and held in the outdoor laboratory for 24 hr when mortality counts were made.

Since there was a 100% knockdown and 100% mortality in the first series of tests, mortality counts were made at 4 hr post-treatment in the second series of tests. Also, all mosquitoes in the second series were released directly from the holding cages into the room to avoid possible injury by aspiration.

Each series included a control, uncaged mosquitoes released in a similar but untreated room. Also, in the second series, caged *An. albimanus* (GML and HT), *An. triannulatus*, and *Cx.* spp. were in the untreated room.

The uncontrolled temperature (27-28.5° C) and the relative humidity (80%) were remarkably constant during the test period.

RESULTS AND DISCUSSION. The biting rate, knockdown, and mortality of mosquitoes exposed to synergized pyrethrins and the pyrethroids are given in Table 1.

All materials killed 100% of the test insects in all instances.

Knockdown was similar for all formulations, possibly because of the high concentrations. Also, when mosquitoes were released in a room treated 4 days earlier with an aerosol containing 2% *d*-phenothrin, there was 100% knockdown, indicating some residual activity. This finding is in accord with unpublished results of residue studies conducted at Beltsville.

The uncaged control mosquitoes settled on the ceiling of the test room; mosquitoes in the treated rooms were located on the walls 5 min after treatment and remained there until they dropped to the floor.

The avidity of mosquitoes after treatment with an insecticide was of particular interest since there is a paucity of information in this area. Subjects exposed from the waist up starting 5 min after application of the aerosol and ending 15 min later were bitten by 0.2-1.8% of the female mosquitoes, except in 1 of 4 trials with 6 g of 1.2% resmethrin (7.8%). Biting rates of the uncaged controls were 16.7 (second series) to 15.4% (first series). All bites occurred during the first 2 min of the exposure.

Since mortality was always 100%, and biting frequency was zero by 7 min after treatment, knockdown appears to be of negligible importance.

The subjects noted a definite odor and experienced irritation of the eyes during exposure to the pyrethrum/piperonyl butoxide formulations; no odor or irritation was reported for the resmethrin or S-2539 Forte. This result is in accordance with the findings of the U.S. Army Environmental Health Agency, Department of Defense (Steinberg, 1973).

ACKNOWLEDGMENTS. Appreciation is expressed to A. Dutary nd J. Gaona,

Table 1. The biting rate, knockdown, and mortality of mosquitoes exposed to synergized pyrethrins and pyrethroid aerosols. Room tests in military quarters (842–1323 ft³ rooms) in Panama.

Test no.	Species, source,[a] no.	Treatment: Material	Treatment: Avg dose g/100 m³	% biting in 15 min[b] (females)	% knockdown (females and males): 10 min	% knockdown (females and males): 20 min	Insect mortality (females and males) %
			Series 1				24 hr mortality
1	*Anopheles* (GML) 44 ♀ 41 ♂	Control	–	16.7	0	0	4
	Culex spp. (AH) 34 ♀ 20 ♂						11
2	*Anopheles* (GML) 81 ♀ 53 ♂	0.6% pyrethrins + 1.4% piperonyl butoxide (GSA Stock No. 6840-823-7849)	9.4	0.38	22	96	100
	Culex spp. (AH) 48 ♀ 35 ♂						100
3	*Anopheles* (GML, AH, HT) 389 ♀ 61 ♂	1.2% resmethrin (6840-149-0106)	5.5	0.20	55	100	100[c]
	Aedes spp. (HT) 36 ♀ 0 ♂						100[c]
	Culex spp. (AH) 70 ♀ 37 ♂						100
4	*Anopheles* (GML) 36 ♀ 28 ♂	2.0% resmethrin (6840-140-7930)	6.3	1.67	20	99	100
	Culex spp. (AH) 24 ♀ 10 ♂						100
5	*Anopheles* (GML) 65 ♀ 53 ♂	1.2% *d*-phenothrin	7.4	0.86	61	84	100
	Culex spp. (AH) 51 ♀ 19 ♂						100
6	*Anopheles* (GML) 103 ♀ 98 ♂	2.0% *d*-phenothrin	7.2	1.79	78	92	100
	Culex spp. (AH) 65 ♀ 21 ♂						100

Table 1. Continued

Test no.	Species, source,[a] no.	Treatment: Material	Treatment: Avg dose g/100 m³	% biting in 15 min[b] (females)	% knockdown (females and males): 10 min	% knockdown (females and males): 20 min	Insect mortality (females and males) %
		Series 2					4 hr mortality
1, 2[d]	*Anopheles* (GML) 36 ♀ 33 ♂ (averages)	Control	–	15.4	0	0	26
	Aedes spp. (HT) 2 ♀ 1 ♂ (averages)						0
	Culex spp. (AH) 38 ♀ 22 ♂ (averages)						5
3, 4, 5, 6	*Anopheles* (GML) 33 ♀ 24 ♂ (averages)	1.2% resmethrin	6.2	3.90	–	98	100
	Aedes spp. (HT) 3 ♀ p ♂ (averages)						100
	Culex spp. (AH) 24 ♀ 11 ♂						100
7, 8	*Anopheles* (GML) 38 ♀ 23 ♂ (averages)	0.6% pyrethrins + 1.4% piperonyl butoxide	7.6	0.00	–	95	100
	Aedes spp. (HT)[c] 2 ♀ 1 ♂ (averages)						100
	Culex spp. (AH) 24 ♀ 15 ♂ (averages)						100

[a] GML = Gorgas Memorial Laboratory; AH = Albrook and Howard Air Force Bases, C.Z.; HT = horse trap located in the jungle on the Atlantic side of the C.Z.

[b] All biting occurred within 2 min after entering the room, which was 5 min after applying insecticide.

[c] The horse trap mosquitoes in these tests were collected in nature. The percent kill (all females) was: *Anopheles albimanus* 100, *Mansonia venezuelensis* 100, *Ma. titillans* 100, and *Aedes angustivittatus,* 100.

[d] There was no mortality in the caged controls in Test 1, Series 2, (*An. albimanus* GML and HT, *An. triannulatus,* and *Culex* spp.)

MEDDAC, for their kind assistance during the course of this experiment. Appreciation is also expressed to Rolland Waters and Earl Fields, Agricultural Environmental Quality Institute, Agric. Res. Serv., USDA, for preparing the S-2539 Forte aerosols used in these tests.

Literature Cited

Cawley, B. M., W. N. Sullivan, M. S. Schechter and J. U. McGuire. 1974. Desirability of three synthetic pyrethroid aerosols for aircraft disinsection. WHO Bul. 51:537–540.

Fales. J. H., O. F. Bodenstein, R. M. Waters, and E. S. Fields. 1970. Development of synergized pyrethrin aerosols for use against public health insects on aircraft and ships. Aerosol Age, 15: 41, 44, 46, 48, 50, 52, 54, 56, 58, 60.

Fales, J. H., O. F. Bodenstein, R. M. Waters, E. S. Fields and R. P. Hall. 1972. Relative effectiveness of pyrethroid insecticides. Soap/Cosmetics/Chemical Spec. 48: 60, 62, 66, 68, 90, 92.

Schechter, M. S., W. N. Sullivan, H. F. Schoof and D. R. Maddock. 1974. *d*-phenothrin, a promising new pyrethroid for disinsecting aircraft. J. Med. Entomol. 11:231–233.

Steinberg, M., A. H. McCreesh, C. R. Pope, R. E. Bolt and M. Weeks. 1973. Hazard evaluation of aerosol formulations containing the synthetic pyrethroid insecticide (5-benzyl-3-furyl) methyl-2,2-dimethyl-3-(2-methylpropenyl) cyclopropanecarboxylate (SBP-1382®). Special Study No. 51–136–71/74. U.S. Army Environmental Hygiene Agency, Aberdeen Proving Ground, Md. 21010.

Sullivan, W. N., R. Pal, J. W. Wright, J. C. Azurin, R. Okamoto, J. U. McGuire and R. M. Waters. 1972. Worldwide studies on aircraft disinsection. WHO Bul. 46:485–491.