EFFECTIVENESS OF THREE SYNTHETIC PYRETHROIDS AGAINST MOSQUITOES [1]

J. R. HASKINS,[2] R. H. GROTHAUS,[2] R. BATCHELOR,[2]
W. N. SULLIVAN [3] AND M. S. SCHECHTER [3]

ABSTRACT. Three new synthetic pyrethroids were evaluated for their effectiveness against mosquitoes. Resmethrin was found to be 100% effective against *A. quadrimaculatus* and *A. triseriatus* when used as a space spray in open tents at a dosage rate of 5 mg per cubic foot. Tent panels treated with resmethrin and then exposed to sunlight provided kills of 100% for *A. quadrimaculatus* for 3 days. The same panels controlled *A. triseriatus* for only 2 days. In comparative controlled environment studies, test fabric panels were treated with resmethrin, S-2539, and Plus S-2539. All of the compounds provided in excess of 95% control of *A. quadrimaculatus* for 7 days. The same compounds failed to provide 100% control of *A. triseriatus* after 4 days.

INTRODUCTION. In 1945 it was reported that residual applications of DDT to the inner surface of buildings provided effective control for certain groups of mosquitoes (Gahan and Lindquist, 1945; Gahan *et al.* 1945). Subsequently, military entomologists utilized residual applications of DDT, dieldrin, and malathion on tents, etc., to control *Anopheles* mosquitoes. Thus, residual interior treatments for the control of malaria vectors became an important tool in preventive medicine. However, Altman and Gahan (1969), Busvine (1957), Fox (1961), Fox and Garcia-Moll (1961), and others have shown that resistance has occurred to the extent that many insecticides are no longer effective against mosquitoes.

One group of chemicals that appears to hold promise is the synthetic pyrethroids. The first of these pyrethrin-like chemicals, allethrin, was synthesized by Schechter *et al.* (1949). Since 1949 these compounds have proved to be valuable because of their relatively low mammalian toxicity and short residual life. The lack of overseas product dependence is also a desirable attribute.

After the development of allethrin, several new promising synthetic pyrethroids became available. The first of these was resmethrin, a chrysanthemumic acid ester, synthesized by Elliot *et al.* (1945). This pyrethroid, presently labelled and produced in the United States, has been extensively studied for its insecticidal qualities. Elliot *et al.* (1967) reported that resmethrin was 55 times as toxic to adult female *Musca domestica* L. as the mixed esters of natural pyrethrins. It was also found to be effective in controlling German and American cockroaches (Grothaus *et al.* 1972). Brooks *et al.* (1969) found that resmethrin controlled 40 species of insects including several species of *Anopheles* and *Aedes* mosquitoes. *Culex* spp., *Anopheles* spp., and *Aedes aegypti* L. have been satisfactorily controlled with resmethrin aboard aircraft (Sullivan *et al.* 1972).

This paper compares the effectiveness of three of the following promising pyrethroids against *Anopheles quadrimaculatus* Say and *Aedes triseriatus* (Say): (5-benzyl-3-furyl)methyl *cis trans*-(±)-2,2-dimethyl-3-(2-methylpropenyl)cyclopropanecarboxylate, resmethrin;[4] *m*-phenoxybenzyl *cis, trans*-(±)-2,2-dimethyl-3-(2 methylpropenyl) chrysanthemate, Sumitomo S-

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[2] Entomology Division, Naval Medical Field Research Laboratory, Camp Lejeune, N.C. 28542.

[3] U.S.D.A., Agricultural Research Service, Beltsville, Md.

[4] S. B. Penick Corp.

2539;[5] and *m*-phenoxybenzyl *cis, trans*-(±)-2,2-dimethyl-3-(2-methylpropenyl) chrysanthemate, Sumitomo Plus S-2539.[5]

MATERIALS AND METHODS. Our first test was designed to study the effectiveness of resmethrin as a space spray in field-type enclosures. The test was conducted using a minimum of 20 DDT-susceptible adult female *Anopheles quadrimaculatus* and 20 DDT-susceptible adult female *Aedes triseriatus* held separately in 6 x 3 inch conical wire cages. The cages were suspended near the top of a 900 ft^3 tent. The tent was treated with an aerosol can at the rate of 5 gm aerosol per 1000 ft^3 of space, using 1.33% resmethrin formulated directly in freon 11 and 12 (50:50), without non-volatile carriers. Control cages were held outside of the tent. Four control cages of each species were also placed inside of the tent before the test to ensure that chemicals in the fabric did not contribute to the knockdown values obtained. After 15 minutes, exposed mosquitoes were transferred to clean wire cages containing a source of 50% sucrose solution. Knockdown counts were recorded at 15 minutes, 1 hour, and 24 hours. The test was replicated 10 times.

In addition, two residual tests were conducted using 929.03 cm^2 (1 ft^2) canvas tent panels. The panels were treated with insecticide at the rate of 1 g actual per m^2, using 12-oz aerosol cans fitted with valves. The test insecticides were formulated in freon 11 and 12 (50:50); no petroleum distillates were added.

In one test, the panels were treated with resmethrin and taken outdoors each test day. The panels were individually draped, treated side down, over wooden dowels placed vertically in the ground. The panels were exposed for 6 hours each day. Weather conditions varied from clear to partly cloudy. No rainfall was recorded during the test period. The mean exposure period temperature was 104° F; the mean relative humidity was 56%. In the other test, canvas panels were treated with compounds S-2539, Plus S-2539, and resmethrin. These panels were maintained in a controlled, dark environment with a temperature of 100° F and a relative humidity of 55%.

A minimum of 20 adult female *A. quadrimaculatus* and 20 adult female *A. triseriatus* were used on each panel assay. Each group of test mosquitoes was placed under separate petri dish tops on the treated panel surfaces for 1 hour. After the 1 hour, knockdown counts were conducted, pieces of paper were inserted between the mosquitoes and the treated canvas. Subsequently, a 5 x 5 inch piece of thin metal was inserted between the paper and canvas to facilitate removal. The mosquitoes were held in the petri dishes and provided with a solution of 50% sucrose in water. A temperature of 82° F and a relative humidity of 75% were maintained until the 24-hour knockdown counts were recorded.

The test was continued until the residuals failed. All daily assays contained three panel replications of each compound and one control (non-treated) panel.

RESULTS AND DISCUSSION. In the study to determine the effectiveness of a resmethrin aerosol against flying mosquitoes inside tents, the 24-hour knockdown value for every test was 100% (10 repetitions). The 24-hour knockdown values for the controls were: *A. quadrimaculatus*, 22%; *A. triseriatus*, 11%.

It was interesting to note that although the aerosol was never directed at the caged mosquitoes, the resmethrin was very effective. It was thought that the holding cages might reduce the percentage of kill by preventing the insecticide particles from impinging on the mosquitoes. However, a good kill was obtained against caged mosquitoes in a rather open-type shelter. This indicated that a non-distillate resmethrin formulation would provide excellent results when released from a standard aerosol can. There was no evidence to indicate that the finer particles inherent with this type of formulation were any

[5] Sumitomo Chemical Co.

TABLE 1. Comparative residual toxicity of three synthetic pyrethroids applied to test fabrics * against two species of mosquitoes.

Age of residual (days)	Control alive (%) (avg 2 reps)		Resmethrin Knockdown (%)		Plus S–2539 Knockdown (%)		S–2539 Knockdown (%)	
	1 hr	24 hr.	1 hr	24 hr	1 hr	24 hr	1 hr	24 hr
			Anopheles quadrimaculatus					
1	100	98	100	100	100	100	100	100
2	100	98	100	100	100	100	100	100
3	100	100	100	100	100	100	100	100
4	100	95	100	100	100	100	100	100
7	100	100	100	97	100	98	100	100
8	100	91	100	94	100	93	100	100
			Aedes triseriatus					
1	100	100	100	100	100	100	100	100
2	100	100	100	100	100	100	100	100
3	100	100	100	100	100	100	100	100
4	100	98	100	100	100	100	100	100
7	100	100	88	83	89	79	89	84
8	100	98	83	63	78	71	79	75

* Treated at the rate of 1 gm/m² fabric. Tent holding chamber temperature 100° F, RH 55%±5%. Mosquito exposure room temperature 83° F±1° F, RH 72%.

less effective than the larger particles obtained in a petroleum distillate and insecticide formulation (Schechter *et al.*, 1960).

In an effort to explore further the potential uses of the synthetic pyrethroids against mosquitoes, the comparative residual test was conducted. Results are presented in Table 1. All of the compounds tested provided in excess of 95% control of *A. quadrimaculatus* for 7 days. Both resmethrin and Plus S-2539 failed on the 8th day of testing. The compound S-2539 was still providing 100% effective residual protection 7 days after application. However, our observations indicated that although the test mosquitoes were not walking around, they were obviously in a less weakened condition than on previous days. Thus, there was little doubt that the S-2539 compound was also beginning to break down.

The three compounds were less effective against *A. triseriatus*. All were 100% effective through the 4th day of the test but less than 85% effective after the 6th day. It is of interest that 5–10% of the test specimens that definitely appeared morbid during the 1-hour reading recovered after 24 hours. This is not in agreement with reports that indicate that certain synthetic pyrethroids cause unrecoverable knockdown (Brooks *et al.*, 1969).

Table 2 shows the results of the resmethrin panels exposed to sunlight. The residual fell below accepted control levels on the 4th day against *A. quadrimacu-*

TABLE 2. Residual effectiveness of sun irradiated, resmethrin-treated tent fabric * against two species of mosquitoes.

Age of residual (days)	Control alive (%)		Knockdown (%)	
	1 hr	24 hr	1 hr	24 hr
	Anopheles quadrimaculatus			
1	96	92	100	100
2	100	100	100	100
3	100	96	100	100
4	100	95	66	66
	Aedes triseriatus			
1	100	100	100	100
2	100	100	100	99
3	100	100	55	45
4	100	100	5	3

* Treated at the rate of 1 gm/m² fabric. Average temperature 104° F, RH 55%.

latus, and failed to provide protection after the 2nd day against *A. triseriatus.*

The ambient temperature and relative humidity were compatible in both tests, indicating that heat and sunlight caused a pronounced increase in degradation of the resmethrin. The panels were exposed treated-side down, so it would appear that heat build-up was the principal factor involved. Pyrethroid compounds are degraded rapidly by excessive heat and light, but our tests indicate that resmethrin could be used for residual treatments of tentage if necessary.

Sudies to date indicate that the synthetic pyrethroids, now appearing in ever-increasing numbers, will prove to be excellent chemicals for use against many mosquitoes. Considering the elimination of the dependence on foreign production of natural pyrethrins and the environmental interest in the reduction of human exposure to hydrocarbons, the synthetic pyrethroids formulated directly in freon 11 and 12 appear to be advantageous over older aerosol formulations.

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Mr. Thomas D. Mulhern, Executive Director
American Mosquito Control Association
5545 East Shields Ave.
Fresno, CA 93727