ARTICLES

PERMETHRIN AND DIMETHYL PHTHALATE AS TENT FABRIC TREATMENTS AGAINST *AEDES AEGYPTI*[1]

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ABSTRACT. Tests were conducted to determine the persistence of compounds applied to tents to protect against mosquitoes. Interiors of 2 camping tents were treated by the manufacturer—one with the repellent dimethyl phthalate (DMP) and one with the insecticide permethrin. A third tent was untreated. Tents were set up outdoors and exposed to weathering for one year. Weekly tests were conducted by releasing *Aedes aegypti* into the tents, then recording knockdown (KD) and biting behavior during a 3-h period. Weather data were collected 24 h/day during the study. Year-long mean KD of mosquitoes exposed in the tent to permethrin was 58.6%, to DMP 2.7% and the control 0.9%. Mean biting was 11.9, 43.8 and 58%, respectively. Under constant exposure to weathering, the permethrin-treated tent gave best results with average protection from bites >96% for 9 months (DMP was <31%). Although preliminary, the data suggest permethrin would be effective as a tent treatment to reduce annoyance of mosquitoes.

INTRODUCTION

Modern camping tents not only provide shelter but have an attached floor and screened openings to help keep out biting arthropods. Chemical repellents may be applied to skin and clothing to provide protection from bites. However, neither of these defenses will prevent some pests from entering a tent. Screens may get torn or may be left open. Often, biting flies, ticks and other pests enter when people go into or leave the tent. This is particularly true with mosquitoes in the evening hours. These and other crepuscular or nocturnal pests also may use the tent as a daytime resting site, particularly if it is erected in a cool shady place. Repellents protect the person close up but do not provide ample spatial action. Thus, when a repellent loses effectiveness, biting may quickly ensue, often occurring when one is asleep and unaware of diminished protection.

Treatment of tent fabric with insecticides or repellents represents a potential method for reducing human-arthropod pest interaction. Preliminary tests with a mosquito repellent, dimethyl phthalate (DMP), and an insecticide, permethrin, were conducted to determine efficacy and duration of persistence when applied to the inner walls of tents. Dimethyl phthalate was chosen as a candidate because it is compatible with proprietary tent coatings used as protectants against weather and other hazards (R. D. Samson of the Graniteville Company, unpublished data). The widely used repellent, deet, apparently does not have this characteristic. Deet is too volatile and would make the finished coating sticky according to R. D. Samson.

Permethrin was selected because of its contact toxicity to a wide spectrum of pests, including mosquitoes. It is safe, nearly odorless and resistant to washing, heat and photo-degradation. Moreover, it has proven to be an effective fabric treatment on clothing, bed nets and other materials to protect against mosquito bites (Schreck et al. 1978, Anonymous 1989). In this study, biological activity of the treatments was assessed for insecticidal rather than repellent effect.

MATERIALS AND METHODS

Three family camping-type tents for this study were provided by the Graniteville Co., Graniteville, SC. The tents were constructed from 24.4 m^2 of Tex-Tex® fabric with a nylon screen-zippered door opening. Tex-Tex fabric is composed of 100% textured polyester with a weather resistant vinyl coating. Treatments were by the manufacturer at the rate of 2.58 g active ingredient (AI)/m^2. The fabric was impregnated using an industrial coating machine in a proprietary process which assures even dis-

[1] Mention of a commercial or proprietary product in this paper does not constitute an endorsement of this product by the United States Department of Agriculture.

tribution of the ingredients. After curing, the fabric was made into a tent. One tent was treated with permethrin (inside only, including floor), the second was treated with DMP (inside and outside because it was an ingredient in the fabric coating) and the third was an untreated control.

The 3 tents were erected October 30, 1989, at the USDA Medical and Veterinary Entomology Research Laboratory, Gainesville, FL, in an open grassy field, 2 m apart in a north-south row, each with its doorway facing east. They remained for one year, unshaded and fully exposed to the effects of weathering. Concurrently, within 30 m of the site, a weather station (Omnidata® Logan, UT) recorded wind speed and direction, precipitation, temperature, percent relative humidity, barometric pressure and solar radiation 24 h/day.

Efficacy assessments were made with weekly bioassays. Through the screen door zipper opening of each tent were released 75 to 80 seven-day-old laboratory reared susceptible strain female *Aedes aegypti* (Linn.). Upon release, the screen was closed, and the tent flaps and rear screen-covered window were left open for ventilation (tent flaps were kept closed at all other times). Mosquitoes were free to land or fly about inside the tent for 3 hours. Each hour after release, mosquito knockdown (KD), i.e., mosquitoes dead or moving but unable to fly, and bite counts were recorded. Bites were observed and recorded after a 1-min exposure of a volunteer's arm in the tent through a small opening unzipped in the screen door.

Hourly data indicated the rapidity of treatment effect on the mosquitoes during a 3-h exposure—i.e., whether treatment effect was rapid (during the first hour) or additive (after 2–3 h). The data also helped show when treatments began to lose potency because of exposure to weathering.

After 3 h, mosquitoes were removed from each tent with a battery powered aspirator and counted. Care was taken to avoid contamination between treatments by entering the untreated, repellent-treated and permethrin-treated tents in that order. Test data were recorded in terms of percent effect—i.e., number KD/biting ÷ total number in the tent = % KD/biting.

An attempt was made to keep the tests on a same-day schedule each week. Inclement weather at times made this difficult; however, 48 of 52 wk of tests were completed. During cooler months, tests were scheduled in the warmer afternoons, whereas during very warm months, tests were done in the cooler early morning hours.

The 3-h means of KD and bite data for weekly tests were computed but not analyzed, because only one replicate test of each treatment was made each week. Means of these weekly data were computed to provide a monthly view of treatment effect. Weekly bite data were calculated to percent protection by the following formula: % protection = % biting in control − % biting in treatment ÷ % biting in control. Monthly data for both KD and biting were analyzed using the analysis of variance procedure (ANOVA). Differences were determined using Duncan's multiple range test.

RESULTS

Presented in Table 1 are means of the monthly data shown as percent KD or biting during weekly exposures of *Ae. aegypti* to treated tents. Mean KD (58.6%) in the permethrin-treated tent for the year was significantly greater ($P = 0.05$) than DMP (2.7%) and the untreated control (0.9%) which were not significantly different from each other. Mean monthly KD in the control tent was rather consistent (0.87 ± 0.78%) for the year. This was also true for the DMP tent, except for the first 12 wk when KD averaged 8.5 ± 10.4%.

Mean biting in the permethrin-treated tent for the year was significantly less (11.9%, $P = 0.05$) than in the DMP-treated tent at 43.8%, which was significantly less ($P = 0.05$) than the control at 57.9%. With permethrin, biting averaged <1% for the first 6 months, 8.5% for the next 3 months and 33.8% for the last 3 months. Biting in the DMP-treated tent rose from 21.3 to >40% after the 11th wk and continued at this or a somewhat higher level for the duration of the study.

Mean air temperature for the year was 19.7°C, total rainfall 113.3 cm and mean solar radiation 194 watts/m^2. It was not within the scope of this investigation to analyze the effects of weathering on the treated tents. Rather, it was to record the observed conditions during the study. Any comparisons made with the bioassay results would be speculative. However, after 9 months, KD in the permethrin-treated tent dropped nearly 60%, and biting increased by 74%. By this time, the tents had been subjected to 87.6 cm of rainfall, the highest temperature reading of the year (36.4°C) and 4 months of the highest levels of solar radiation.

DISCUSSION

From November to July, mean numbers of mosquitoes biting in the permethrin-treated tent were <4% of those released. High levels (>96%) of overall protection from bites of *Ae. aegypti* (Fig. 1) existed for up to 9 months.

Table 1. Monthly mean percentage of *Aedes aegypti* mosquitoes biting or knocked down after weekly 3-h exposures to treatments* of permethrin, dimethyl phthalate (DMP) or no treatment in each of 3 camping tents.

	% knockdown			% biting		
Month no.	Permethrin	DMP	Control	Permethrin	DMP	Control
1 and 2**	81.9	2.5	0.8	0.4	24.2	47.6
3	99.0	14.4	0.3	0.0	26.1	52.3
4	96.8	2.1	2.6	0.5	43.6	67.4
5	94.4	1.1	0.5	1.5	46.9	66.2
6	71.3	1.4	0.5	2.1	50.5	61.5
7	48.6	1.7	0.6	13.4	57.3	75.9
8	56.9	1.5	0.9	4.9	49.6	56.6
9	58.9	1.1	0.2	7.1	42.8	58.8
10	24.3	1.4	0.9	27.2	48.4	51.7
11	7.2	1.5	2.1	34.9	46.9	54.3
12	5.0	0.7	0.2	39.3	45.4	45.5
Year mean***	58.6^{A}	2.7^{B}	0.9^{B}	11.9^{A}	43.8^{B}	57.9^{C}

* Treatments were 2.58 g active ingredient/m^2.

** Data for weeks 1, 2, 3 and 8 are absent because no tests were run. Thus, data for weeks 4, 5, 6 and 7 were combined and analyzed for this 2-month period.

*** Year means followed by the same letter are not significantly different ($P = 0.05$).

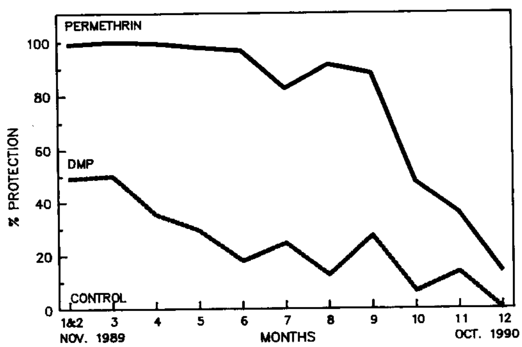

Fig. 1. Effects of aging and weathering on tent treatments of dimethyl phthalate (DMP) or permethrin as indicated by protection from bites of *Aedes aegypti*.

Protection may be longer with intermittent rather than constant exposure to weather. Average KD was ca. 88% for 6 months (November through April). Thus, even when the permethrin treatment produced less KD as the treatment aged and weathered, there was sufficient residual toxicity to effectively reduce biting for up to 9 months. Variables such as temperature, humidity, solar radiation, precipitation and wind may account for some weekly differences in test data. For example, with permethrin there was a 14% drop in protection from bites the 7th month (Fig. 1), a time when solar radiation was the highest recorded. The KD and reduced biting observed with the DMP treatment indicates it had insecticidal activity. However, it is clear that permethrin is superior to DMP in KD, protection from bites and duration of persistence.

Though preliminary, these data suggest permethrin is effective as a treatment for the inner walls of tents to reduce the nuisance of mosquitoes and probably other invasive pests. Pretreatment by the manufacturer could assure uniform application and dosage for new tents. Spray-on technology might be used for retreatment or to treat older equipment, as recommended by Qureshi et al. (1990). These proposals apply to military, recreational and other uses, but further study to identify the most appropriate technologies for specific needs is required.

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