PERMETHRIN AS A RESIDUAL LAWN SPRAY FOR ADULT MOSQUITO CONTROL

B. V. HELSON[1] AND G. A. SURGEONER[2]

ABSTRACT. The synthetic pyrethroid, permethrin, was evaluated as a residual lawn spray for adult mosquito control. In small-plot trials, the residual toxicity of four permethrin formulations was similar. Effectiveness did improve with increasing dosage, particularly between 0.01 and 0.05 g AI/m^2. At 0.25 g AI/m^2 the residual activity of permethrin was much greater than chlorpyrifos, carbaryl, methoxychlor, iodofenphos and malathion, currently registered as lawn sprays. However, two other pyrethroids, fenvalerate and particularly cypermethrin were more effective than permethrin.

Backyards were also treated with EC formulations of permethrin at 0.007 g AI/m^2. In six trials, landing counts of *Aedes stimulans* group mosquitoes were reduced 72% the evening of application and 63% the following evening in four of the trials. Thereafter, the control obtained declined and became more variable. Foliage treatment with permethrin is a very promising method of adult mosquito control.

INTRODUCTION

Permethrin belongs to a new class of pyrethroids possessing increased photostability, high insecticidal activity and low mammalian toxicity (Elliott et al. 1978). It has proven to be very effective against adult mosquitoes in a variety of applications (Barlow et al. 1977, Thompson and Meisch 1977, 1978; Mount et al. 1978). Permethrin has also provided protection from biting flies as a clothing treatment (Lindsay and Mcandless 1978, Schreck et al. 1978). In residual hut treatments against malaria vectors, it has shown promise and interestingly, seems to irritate mosquitoes causing them to leave treated surfaces (Taylor et al. 1981).

Schoof (1968) has described the use of exterior residual insecticide treatments for the control of mosquitoes. Consequently, we tested permethrin as a residual lawn treatment to determine its effectiveness in reducing adult mosquito populations in small areas. Many homeowners are exposed to heavy mosquito populations on their property but although numerous devices and materials are available for "backyard mosquito control," few provide acceptable relief in such situations (Helson and Wright 1977, Surgeoner and Helson 1977).

MATERIALS AND METHODS

Two approaches were used to evaluate permethrin as a residual lawn treatment. The first consisted of small plot trials to determine the effectiveness and residual activity of permethrin in comparison with other insecticides registered for this purpose in Canada. Three replicate 2 × 2 m grassy plots were treated with each insecticide at 0.25 g AI/m^2 using a constant flow, battery operated, pump sprayer with a 6 liter capacity. Three plots were left untreated. Once the spray had dried, grass clippings were collected from at least three locations in each plot. Smooth brome grass, *Bromus inermis* Leyss, ca 10 cm in length was the primary vegetation in these plots. Two grams of clippings were placed in a 200 ml, Lab-Tek® plastic specimen container which was then covered with cloth screening. *Aedes* spp. females, mostly *Ae. stimulans* (Walker), *Ae. euedes* Howard, Dyar and Knab and *Ae. vexans* (Meigen) were collected by aspirator in a nearby woods earlier on the same or previous day. Fifteen to 20 females were placed in each cup and mortality recorded at one or 2-hr intervals until eight hr after exposure and also at 24 hr after exposure. The mosquitoes were held in an expanded polystyrene cooler lined with wet paper towelling during this period. This procedure was repeated with fresh clippings at periodic intervals after treatment until insecticidal activity had declined to low levels.

Mortalities from treated plots have been corrected for natural mortality by Abbott's method (Neal 1976). The mean mortality ± SE of the three plots receiving each treatment was calculated for all exposure periods, on each test day after treatment. Linear regression analysis of time (days after treatment) vs mortality was then performed for selected exposure periods. The number of days until mortality had declined to 50% was calculated from the resulting, least square's equations. The insecticides tested were methoxychlor 25% EC (Interprovincial Cooperators Ltd.), chlorpyrifos 10% EC (Wilsons Laboratories Ltd.), iodofenphos 20% EC (Green Cross), malathion 50% EC (Wilsons Laboratories Ltd.) and permethrin 1.25% EC (Chipman Chemicals Ltd.). All were applied as 0.5% aqueous solutions in a total of 200 ml per plot. Carbaryl 50% WP (Wilsons Laboratories

[1] Forest Pest Management Institute, Environment Canada, Sault Ste. Marie, Ontario P6A 5M7.

[2] Department of Environmental Biology, University of Guelph, Guelph, Ontario N1G 2W1.

Ltd.) was tested at the same dosage in a separate trial.

Different permethrin formulations (1.25% EC, 25% EC, 25% WP and 0.25% oil solution) at 0.00625 g AI/m² and different dosages (0.01, 0.05, 0.1, 0.15 and 0.2 g AI/m²) of permethrin 1.25% EC were compared in a similar fashion. Permethrin 1.25% EC was also compared with two other synthetic pyrethroids, fenvalerate 30% EC and cypermethrin 40% EC, both supplied by Shell Chemicals Ltd., at 0.00625 and 0.01 g AI/m².

The second approach consisted of an evaluation of permethrin as a residual lawn spray in several backyards with high mosquito populations near Guelph, Ontario. These yards, all located on the same street, abutted on a ca 4-ha deciduous woods which was an ideal breeding area for *Aedes stimulans* group mosquitoes. Large numbers of mosquitoes were observed flying up from the lawns and bordering vegetation when disturbed. This suggested they were resting in these areas.

In six separate trials permethrin was applied at 0.7 g AI/100 m² by a compressed air sprayer to the lawn and 10–15 m of the vegetation in the bordering woods between 1300 and 1600 hr. In 1979, four trials were performed with permethrin 25% EC between 28 June and 16 July, while in 1980, the 1.25% EC formulation was used for two trials on 12 June and 7 July.

Each year two female students made mosquito landing collections in these yards between 1930 and 2245 hr to evaluate the treatments. Mosquitoes were collected with aspirators for 15 min followed by a 15-min break during which the students left the yards, such that seven collections were made each evening. All mosquitoes landing were counted whether captured or not for each 15-min period. Representative samples of those captured were identified. The two students were dressed identically in brown coveralls and green headnets.

For each trial, one student made collections in the treated yard on the evening of application while the other student performed counts simultaneously in another untreated yard separated by at least two yards. Counts were also taken on some subsequent evenings in each trial depending on weather and other research commitments. Collections were also made from both yards within one week before treatment in five of the trials. In total, three different yards were treated with permethrin and four different students were used to evaluate the treatments. The formula:

$$\% \text{ control} = 1 - \left(\frac{\text{Ta} \times \text{Cb}}{\text{Tb} \times \text{Ca}}\right) \times 100$$

(Neal 1976) has been used to correct for natural temporal changes in populations. Logarithmic transformations of numbers caught per collection period and resulting geometric means have been used to compare populations in treated and untreated yards (Bidlingmayer 1969).

RESULTS AND DISCUSSION

SMALL PLOT TRIALS. The results of trials comparing permethrin with other insecticides registered as residual lawn sprays for mosquito control are presented in Table 1. All compounds provided 100% mortality on the day of treatment after 4-hr exposure except iodofenphos. In this and another trial using the same dosage, an 8-hr exposure was required to obtain high mortality with this organophosphorous insecticide. The residual effectiveness of permethrin was much greater than the other materials. Mortality after 6-hr exposure de-

Table 1. The percent corrected mortality (± SE) of adult female mosquitoes after 6-hr exposure to grass treated with different insecticides at 0.25 g AI/m².

Days after treatment	Insecticides					Days after treatment	Insecticide
	Malathion	Chlorpyrifos	Iodofenphos	Methoxychlor	Permethrin		Carbaryl[1]
0	100 ±0.0	100 ± 0.0	64.4±30.1	100 ± 0.0	100 ± 0.0	0	100 ± 0.0
6	2.8±2.8	11.1±11.1	0.0± 0.0	80.6±19.4	100 ± 0.0	2	53.5±9.7
12	6.3±3.3	10.3± 2.6	4.8± 4.8	37.1± 6.3	96.2± 3.9	5	60.4±0.6
15	8.9±6.9	18.2±18.2	2.0± 2.0	16.9± 8.6	97.1± 2.9	7	0.0±0.0
19	0.0±0.0	5.7± 3.9	0.5± 0.5	3.1± 3.1	72.6±10.5		
26			—		34.3±12.8		
33					7.3± 2.3		
Linear regression equation y = for indicated period (days)				$104.4-5.5\chi$ (0–19)	$169.1-5.0\chi$ (15–33)		$94.5-11.7\chi$ (0–7)
r				−0.99	−0.99		−0.89

[1] Tested in separate trial.

Table 2. The percent corrected mortality (± SE) of adult female mosquitoes after 3-hr exposure to grass treated with different permethrin formulations at 0.00625 g AI/m^2.

Days after treatment	Formulation			
	1.25% EC	25% EC	WP	Oil
1	80.9± 6.4	98.1± 1.9	98.2± 1.8	80.6±10.4
2	86.5±10.3	93.7± 4.2	83.4± 6.7	74.4±12.4
4	78.8±14.6	40.3±22.1	27.8±11.7	19.9±10.3
7	27.6±10.4	20.3±12.7	34.9±13.8	19.7± 8.4
9	0.0± 0.0	9.6± 9.6	0.6± 0.6	13.8± 3.7
Linear regression equation: y =	$105.-11.0\chi$	$106.3-11.7\chi$	$99.9-11.1\chi$	$81.1-8.6\chi$
r	−0.95	−0.96	−0.92	−0.88

clined to 50% by 23.8 days with permethrin, 10 days with methoxychlor and less than 6 days with the other insecticides. Regression equations could not be calculated for chlorpyrifos, malathion or iodofenphos because of insufficient data. In another trial with malathion at the same dosage, better residual activity was obtained, with mortality declining to 50% after 7.4 days with a 6-hr exposure ($y = 128.7 - 10.6x$, $r = -0.95$).

The results with different permethrin formulations are presented in Table 2. All formulations were similar in their initial effectiveness and residual activity. Mortality after 3-hr exposure declined to 50% by 5 days with the 1.25% EC, 4.8 days with the 25% EC, 4.5 days with the 25% WP and 3.6 days with the 0.25% oil. Although the oil formulation appeared to be slightly less effective and shorter lived, this may have been due to the method of application. A small quantity of undiluted material was applied by mist blower to the plots while all other formulations were diluted in water and applied by a pump sprayer. Consequently, poorer coverage may have been obtained with the oil formulation. Since there were no major differences in the effectiveness of these formulations, an EC formulation would be most appropriate for backyard mosquito control because of the convenience in handling, measuring, diluting and applying such a formulation.

The results of trials with different dosages of permethrin are presented in Table 3. Complete mortality was obtained within two hr with all dosages on the day of application. Thereafter, residual toxicity improved with increasing dosage. Mortality after 6-hr exposure declined to 50% by 3.5, 17.8, 21.4, 25.7 and 27.3 days at 0.01, 0.05, 0.10, 0.15 and 0.20 g AI/m^2 respectively. Significantly, a five-fold increase in residual effectiveness was realized with a five-fold increase in dosage from 0.01 to 0.05 g AI/m^2. Furthermore, on the day of treatment 100% mortality was obtained after only 0.5 hr exposure with the latter dosage while only 20% was observed with the former. These results suggest that a small increase in the dosage of 0.007 g AI/m^2 tested to date for backyard mosquito

Table 3. The percent corrected mortality (± SE) of adult female mosquitoes after 6-hr exposure to grass treated with different dosages of permethrin 1.25%EC.

Days after treatment	Dosage, g AI/m^2				
	0.01	0.05	0.10	0.15	0.20
0	100 ± 0.0	100 ± 0.0	100 ± 0.0	100 ± 0.0	100 ± 0.0
4	30.3± 8.7	100 ± 0.0	100 ± 0.0	100 ± 0.0	100 ± 0.0
7	11.3± 3.5	100 ± 0.0	100 ± 0.0	100 ± 0.0	100 ± 0.0
11	25.0± 0.0	89.5± 0.8	100 ± 0.0	100 ± 0.0	100 ± 0.0
15	10.3±10.3	83.4± 5.6	93.2± 6.8	100 ± 0.0	96.6± 3.4
19	18.0± 6.5	30.9±18.0	66.4± 4.9	89.0± 7.6	96.0± 4.0
22	0.0± 0.0	13.3± 6.9	26.4± 9.8	72.0±11.9	73.4±19.1
26		9.6± 4.2	47.3±26.8	50.1±21.7	59.7±23.3
29		0.0± 0.0	1.9± 1.9	39.1±17.4	28.5±11.9
33				4.2± 4.2	14.0± 3.3
40					4.7± 2.4
Linear regression equation: y =	$94.6-12.9\chi$	$141.6-5.2\chi$	$162.3-5.2\chi$	$185.1-5.3\chi$	$173.4-4.5\chi$
for indicated period (days)	(0–7)	(7–29)	(11–29)	(15–33)	(19–40)
r	−0.97	−0.96	−0.92	−0.99	−0.96

control might greatly improve the initial effectiveness and residual activity of permethrin treatments.

The results of trials comparing the three pyrethroids, permethrin, fenvalerate and cypermethrin are presented in Table 4. At dosages of 0.00625 and 0.01 g AI/m² all pyrethroids provided 100% mortality on the day of treatment after 2-hr exposure except fenvalerate which required 4 hr at the lower dosage. The order of residual toxicity for these compounds was permethrin < fenvalerate < cypermethrin. At 0.00625 g AI/m² mortality after 6-hr exposure declined to 50% by 3.7, 5.2 and 10.8 days respectively and 9.5, 12.5 and 14.9 days at 0.01 g AI/m².

BACKYARD TRIALS WITH PERMETHRIN. The results of the backyard treatments with permethrin are presented in Fig. 1 and Table 5. Trials with the two EC formulations have been combined as they produced similar results. The predominant species captured were *Aedes stimulans*, *Ae. fitchii* (Felt and Young), *Ae. euedes* and *Ae. canadensis* (Theobald). Before treatment, both total numbers (Table 5) and numbers in each 15-min collection (Fig. 1a) were very similar in the yards. The evening of application (Day 0) numbers were significantly lower in the treated backyards compared to the untreated ones. Using the above formula to correct for natural population changes, 66% control was obtained when the numbers from each trial were pooled before analysis. The mean control was 72% (range 41–94%) when each trial was analyzed separately with this formula. In four of the trials, 85% control or more was obtained on the evening of application. Numbers were suppressed in every collection period by 49–77% (excluding 2230 hr – 100%) (Fig. 1b).

One day after treatment the corrected population reductions were 58 or 63%, when the trials were pooled or analyzed separately respectively, and the difference was again significant (Table 5). Numbers in the treated yards

Table 4. The percent corrected mortality (± SE) of adult female mosquitoes after 6-hr exposure to grass treated with synthetic pyrethroids.

Days after treatment	Dosage of 0.00625 g AI/m²			Days after treatment	Dosage of 0.01 g AI/m²		
	Permethrin	Fenvalerate	Cypermethrin		Permethrin	Fenvalerate	Cypermethrin
0	100 ±0.0	100 ± 0.0	100 ± 0.0	0	100 ± 0.0	100 ± 0.0	100 ± 0.0
2	79.4±8.3	65.7± 8.7	100 ± 0.0	3	100 ± 0.0	100 ± 0.0	100 ± 0.0
5	26.8±9.0	33.0± 3.8	97.1± 2.9	6	85.4±14.6	100 ± 0.0	100 ± 0.0
7	3.6±3.6	23.1± 2.8	56.3±22.5	11	18.6±12.2	47.8±15.6	58.9± 7.0
9	1.8±1.8	47.8±27.3	75.3±12.4	14	8.6± 4.8	35.5± 5.4	57.1±24.7
13		0.0± 0.0	21.0± 2.4	18	3.9± 2.0	17.0±10.9	26.9± 9.6
16			13.7± 7.0	21		1.4± 1.4	15.3± 9.1
21			0	28			4.4± 4.4
Linear regression equation:							
y =	1.02−14.4χ	84.0−6.5χ	112.8−5.8χ		118.1−7.2χ	128.2−6.3χ	114.9−4.4χ
for indicated period (days)	(0–7)	(0–13)	(2–21)		(3–18)	(6–21)	(6–28)
r	−0.99	−0.88	−0.95		−0.95	−0.98	−0.96

Table 5. Comparative numbers of mosquitoes collected in treated and untreated backyards before and after treatment with permethrin at 0.7 g AI/100 m²

Days after treatment	No. trials	Mean number ± SD		T paired samples	Significance[1]
		Control	Treated		
Pretreatment	5	85.2± 34.4	80.8±36.2	0.275	NS
0	6	79.3± 65.5	25.5±37.0	4.020	≈0.005
1	4	114.3± 91.8	39.3±53.9	2.873	<0.05
2	3	110.0±137.8	54.7±56.9	1.148	NS
3	2	32.0± 29.7	13.5±13.4	1.609	NS
4	4	47.3± 22.9	34.0±28.0	0.724	NS
5	1	21	18	—	—
6	2	32.0± 19.8	23.0± 7.1	1.00	NS
7	1	34	33	—	—

[1] 1-tailed T-test.

were lower during every collection period by 43–82% (excluding 2230 hr) on this evening (Fig. 1c). On subsequent evenings, control declined and became more variable until by four or more days after treatment only small reductions were evident and similar or greater numbers were collected during some 15-min periods in the treated yard. Mean daily temperatures, rainfall and bright sunshine ranged from 13–23°C, 0.0–3.6 mm and 3.8–11.3 hr respectively during these trials. Control usually declined greatly following rains. No obvious trends with other meteorological factors were evident.

Consequently, these permethrin treatments provided good relief from biting mosquitoes for at least two evenings following treatment. Other insecticides registered for this purpose including malathion, methoxychlor, chlorpyrifos, iodofenphos and carbaryl were much less effective than permethrin under similar conditions (Helson and Surgeoner, unpublished data). These are registered at 3–36× the dosage of permethrin used in these trials. If costs would allow, a comparable 5–10× increase in the dosage of permethrin might further improve the residual activity and possibly the ini-

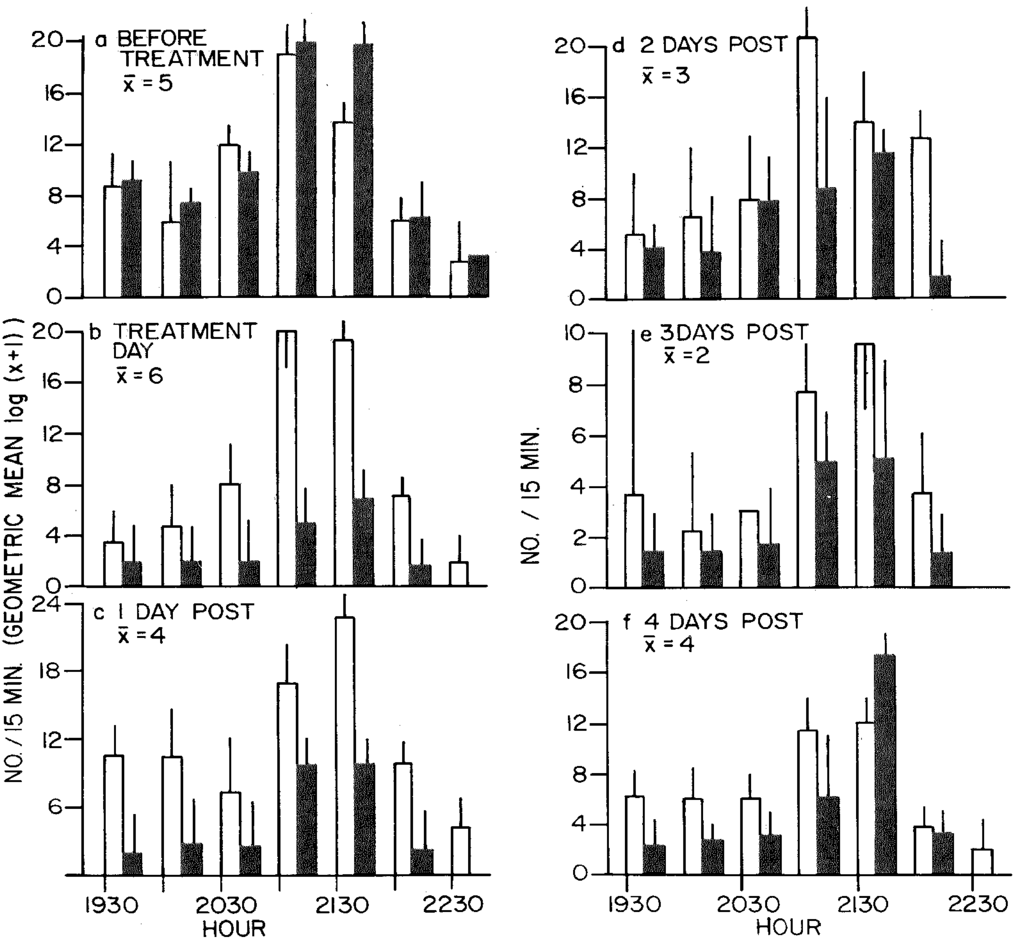

Fig. 1. The mean number (± SD) of adult female mosquitoes landing during each 15-minute collection period in treated (solid bars) and untreated (open bars) yards before and after treatment with permethrin at 0.7 g AI/100 m^2

tial effectiveness of permethrin in such situations based on the data from small plot trials. Other synthetic pyrethroids such as fenvalerate and cypermethrin might also be equally or more effective than permethrin at equivalent dosages.

It is perhaps surprising that permethrin was effective in substantially reducing the mosquito populations in these backyards considering the small areas treated and the large reservoir population of mosquitoes in the woodlot which could reinvade the yards. Either permethrin must kill mosquitoes very quickly after brief contact with treated surfaces or this insecticide has a repellent or irritant effect. In support of the first mechanism, Schreck et al. (1977) found that another synthetic pyrethroid, resmethrin, when impregnated in wide-mesh net clothing, showed no repellent activity but did produce very rapid intoxication and behavioral changes providing high level protection from *Aedes taeniorhynchus* (Wied.). Schreck et al. (1978) later demonstrated that permethrin as a clothing treatment could also provide rapid kill and had potential for personal protection from blood-feeding arthropods. Lindsay and Mcandless (1978) showed that significant protection from blackflies and mosquitoes could be obtained from permethrin-treated jackets and significantly, the protection increased with time suggesting that permethrin was killing or immobilizing an increasing proportion of the biting fly population in the vicinity of the wearer, rather than repelling them.

However in two of the small plot trials where counts were made every 0.5 hr, high mortality or knockdown was achieved only after 1.5–2.0 hr exposure to grass treated with permethrin at the dosage used in backyards. Furthermore, Taylor et al. (1981) present and cite data that permethrin sprayed on walls for malaria control irritates or repels *Anopheles* spp. mosquitoes, causing exodus from huts and actually reduces entry by *Mansonia* spp. It is not possible to conclude which mechanism was operating to reduce mosquito populations in these backyards and in fact both may have been operating. Such information would be useful for selecting other potential insecticides and for determining mosquito control.

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References Cited

Barlow, F., A. B. Hadaway, L. S. Flower, J. E. H. Grose and C. R. Turner. 1977. Some laboratory investigations relevant to the possible use of pyrethroids in mosquito and tsetse fly control. Pestic. Sci. 8: 291–300.

Bidlingmayer, W. L. 1969. The use of logarithms in analyzing trap collections. Mosq. News 29:635–640.

Elliott, M., N. F. Jones and C. Potter. 1978. The future of pyrethroids in insect control. Annu. Rev. Entomol. 23:443–469.

Helson, B. V. and R. E. Wright. 1977. Field evaluation of electronic mosquito repellers in Ontario. Proc. Entomol. Soc. Ont. 108:59–61.

Lindsay, J. G. and J. M. Mcandless. 1978. Permethrin-treated jackets versus repellent-treated jackets and hoods for personal protection against black flies and mosquitoes. Mosq. News 38:350–356.

Mount, G. A., D. G. Haile, N. W. Pierce and K. F. Baldwin. 1978. Aerosols of permethrin and propoxur for control of adult mosquitoes. Mosq. News 38:39–42.

Neal, J. W., Jr. 1976. A manual for determining small dosage calculations of pesticides and conversion tables. Entomol. Soc. Am. Publ., College Park, Maryland.

Schoof, H. F. 1968. Residual treatments. *In*: Ground equipment and insecticides for mosquito control. Am. Mosq. Control Assoc. Bull. No. 2.

Schreck, C. E., D. E., Weidhaas, N. Smith and K. H. Posey. 1977. Chemical treatment of wide-mesh net clothing for personal protection against blood-feeding arthropods. Mosq. News 37:455–462.

Schreck, C. E., K. Posey and D. Smith. 1978. Durability of permethrin as a potential clothing treatment to protect against blood-feeding arthropods. J. Econ. Entomol. 71:397–400.

Surgeoner, G. A. and B. V. Helson. 1977. A field evaluation of electrocutors for mosquito control in southern Ontario. Proc. Entomol. Soc. Ont. 108:53–58.

Taylor, R. N., M. H. Hill, D. C. Stewart and R. Slatter. 1981. A field evaluation of permethrin (OMS 1821) and NRDC 161 (OMS 1998) for residual control of mosquitoes. Mosq. News 41:423–433.

Thompson, G. D. and M. V. Meisch. 1977. Residual efficacy of permethrin as a larvicide and an adulticide against riceland mosquitoes in Arkansas. J. Econ. Entomol. 70:771–774.

Thompson, G. D. and M. V. Meisch. 1978. Residual efficacy of permethrin against adult ricefield mosquitoes contained on treated panels. Mosq. News 38:275–281.