EFFECTIVENESS AND COST OF NONTHERMAL RESMETHRIN AEROSOLS FOR CONTROL OF *AEDES* MOSQUITOES IN WOODED AREAS[1]

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ABSTRACT. Tests were conducted by the Metropolitan Mosquito Control District to determine the operational effectiveness of SBP-1382 resmethrin nonthermal aerosols delivered by ground equipment in densely wooded areas. Percent control is reported for a dosage range of 0.0007 lb AI/acre to 0.007 lb AI/acre. Treatment rates higher than those used in open areas were found necessary to achieve adequate control of *Aedes* mosquitoes. A discussion of the cost of treatment required to achieve specified control levels is included.

INTRODUCTION

In the Minneapolis-St. Paul area, mosquito populations are suppressed by the Metropolitan Mosquito Control District (MMCD) larval and adult control program enabling daytime outdoor activities to occur with little annoyance. However, mosquito activity increases during evening hours, and greater annoyance is then encountered. Its severity varies with the size of *Aedes vexans* (Meigen) broods and the distance from the perimeter of the larval control area. Because of the greater effectiveness of larval control measures and the temporary nature and high cost of adult control measures, nonthermal aerosol applications are limited to large group gatherings, community events, daycamps, parks, and recreation areas. In addition, adult harborage areas, principally natural wooded areas in residential settings, are treated during early evening hours in lieu of blanket residential neighborhood treatments.

In 1974, field evaluations were conducted by the District to determine the efficacy of resmethrin applied as a nonthermal aerosol. Tests were run in sparsely wooded areas during early evening hours. Application rates as low as 0.0016 lb AI in 3 fl oz total volume per acre with wind speeds of less than 4 mph achieved 98% control. The high biological activity (Sjogren et al. 1973, Rathburn and Boike 1974, Mosely et al. 1977 and Womeldorf and Mount 1977) and favorable environmental attributes of resmethrin (Ridsdale 1975; Hausen and Schulz 1973. Miyamota 1976) and its relationship to natural pyrethrins which are recognized by the general public (Sjogren et al. 1978) led to resmethrin's extensive use by the District in 1975. Operational use of resmethrin at 0.0035 lb AI/acre in 1.5 total fl oz/min established its effectiveness on relatively level ground in semi-wooded areas at distances of 300 to 500 feet. The principal exceptions have involved rolling terrain where cold air draining down slopes has prevented uniform downwind particle cloud movement.

While aerosol particles produced by nonthermal aerosol machines penetrate foliage more effectively than those produced by other application equipment, reports by Alvarez (1974) and the operational experience of the MMCD left some question as to the level of control achieved in wooded areas at the 0.0035 lb AI/acre rate. It was the purpose of this study to determine the minimum dosage of resmethrin which could be used to obtain adult mosquito control in densely wooded areas.

MATERIALS AND METHODS

All treatments were made with SBP-1382-40 MF® diluted to the proper dosage with Klearol® white mineral oil.

[1] The use of brand names does not constitute endorsement by the authors or the MMCD.

Stainless steel canisters containing the treatment material were coded for each dosage by the authors and given to the field supervisors who were responsible for tests in their counties. The canisters were rotated among the 6 counties within the District so that all dosage rates could be tested in each county. Thus, field personnel did not know what resmethrin concentrations were used in their tests.

The tests were made in 2 series and combined for analysis. The 1st series, run between June 20 and July 24, included 5 concentrations of resmethrin and a check treatment of pure Klearol. Resmethrin concentrations were equally spaced from 0.0007 to 0.0035 lb AI/ acre. The 2nd series of tests, run between August 7 and August 24, included 4 resmethrin concentrations equally spaced from 0.0028 to 0.007 lb AI/acre. This series was added when it became apparent that the maximum dosage used in the first series was too low.

Treatment areas were chosen by the field supervisors. All of the areas chosen for use in testing were densely wooded known adult resting areas which conformed to set dimensions (Figure 1). Two field employees were used for each test.

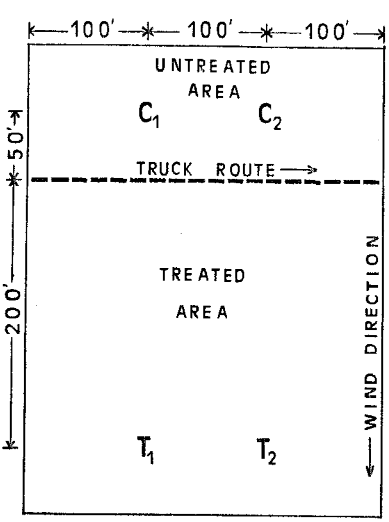

Fig. 1. Layout of treatment areas.

Each made 2 landing counts before and 2 landing counts after treatment. During the tests approximately 200 adult mosquitoes were collected and identified to determine the species composition. The dominant species collected, *Aedes vexans*, accounted for approximately 75% of the samples; *Ae. stimulans, ae. cinereus, Ae. trivittatus*, and *Ae. excrucians*, were among other species also collected. Pretreatment landing counts were made and recorded at all locations within the test areas (see Figure 1). Thus 4 landing counts were made pre-treatment. An average of at least 5 mosquitoes/5 minutes landing count was required for the test to continue. The mean pre-treatment count was 22.8 (S.D. 14.46).

The nonthermal aerosol machines were calibrated prior to making the tests and checked periodically throughout the study to insure proper delivery. The machines were run for 3 min. at least 0.5 mi. from the treatment area to purge the machine and to insure that the proper dosage rate was delivered. The application was then made using a flow rate of 9 fl oz per minute at 4 psi using a truck mounted modified Butte County (California) MAD design nonthermal aerosol machine (Hazeltine, personal communication 1974). Truck speed was 10 mph.

In ideal tests, the wind direction was perpendicular to the truck path. If the wind blew the insecticide fog over the check area or away from the treatment area the test results were disregarded.

All treatments were made 15–90 min. after sunset. Air temperature at the beginning of all tests was above 65°F (18°C) and wind speed was between 3 and 8 mph. When these environmental factors were not met, or if rain occurred during a test, the results were disregarded. If conditions invalidated the test, the application was repeated on another night when possible.

One hr. post treatment (½ hr. post treatment for the second series of tests) landing counts were made and recorded at all locations. Landing counts in the treated area were taken at only one distance, 200 ft. downwind from the point of discharge. If there was a 50% or greater decrease in the landing count at both check locations, the test was disregarded. If, however, there was a 50% or greater drop at only one check station, only that operator's observations were disregarded.

Percent control was defined as follows:

$$\% \text{ Control} = \left(1 - \frac{T_a}{T_b} \Big/ \frac{C_a}{C_b}\right) \text{X } 100$$

where: T_a = landing count in treatment area after treatment
T_b = landing count in treatment area before treatment
C_a = landing count in check area after treatment
C_b = landing count in check area before treatment

This measure of control was used to help remove the influence of time lag from before to after treatment since it was expected that even without treatment there would be less mosquito activity at the later time (Knight and Henderson 1967, MMCD unpublished data). Thus the change in landing count in the treatment area T_a/T_b, must be corrected for the change in landing count in the untreated area, C_a/C_b.

RESULTS

The only difference in procedure between the 1st and 2nd test series was a decrease in the time between treatment and landing counts from 1 hr to ½ hr. This change was made due to the shorter mosquito flight activity period caused by lower daytime temperatures and the more rapid drop in the air temperature after sunset.

Multiple regression techniques were used to determine that series I and series II tests fit a common regression line and that the county in which a test was made had no influence on percent control ($p = .74$).

In the second series, results from the .0056 lb AI/ acre (Table 1) treatments were consistently low. The cause could not be determined, thus this treatment was removed from further analysis. Subsequent analysis showed that the results obtained could have been expected from a treatment of .0016 lb AI/acre.

The remaining data (39 tests) were analyzed using linear regression (see figure 2). An excellent fit was obtained for the equation ($p < .00001$):

$$Y = 24.81 + 16.04 X$$

where Y = % control
X = $\log(\text{dose} \times 10^4 + 1)$

The value of r^2 for this equation is 0.73. It is interesting to note that the intercept is significantly different from 0 ($p = .00002$) indicating that some control was achieved with pure Klearol. The 95% confidence limits for mean % control for

Table 1. Observed and estimated control of adult *Aedes* mosquitoes in wooded areas with resmethrin aerosols.

Lbs AI/ Acre	Number of trials	Observed Mean % Control	S.D.	Regression Estimated % Control	95% Confidence Interval	
0.0000	5	20.84	14.99	24.81	14.45	35.18
.0007	4	61.56	14.79	58.17	53.27	63.07
.0014	4	63.91	15.66	68.25	64.10	72.14
.0021	3	74.82	21.83	74.39	70.23	78.56
.0028	9	79.09	7.554	78.83	74.42	83.23
.0035	4	85.58	17.78	82.29	77.59	87.00
.0042	6	86.59	15.57	85.14	80.13	90.16
*.0056	7	70.36	4.447	89.67	84.07	95.27
.0070	4	94.99	5.126	93.19	87.07	99.30

* Observations deleted before regression analysis.

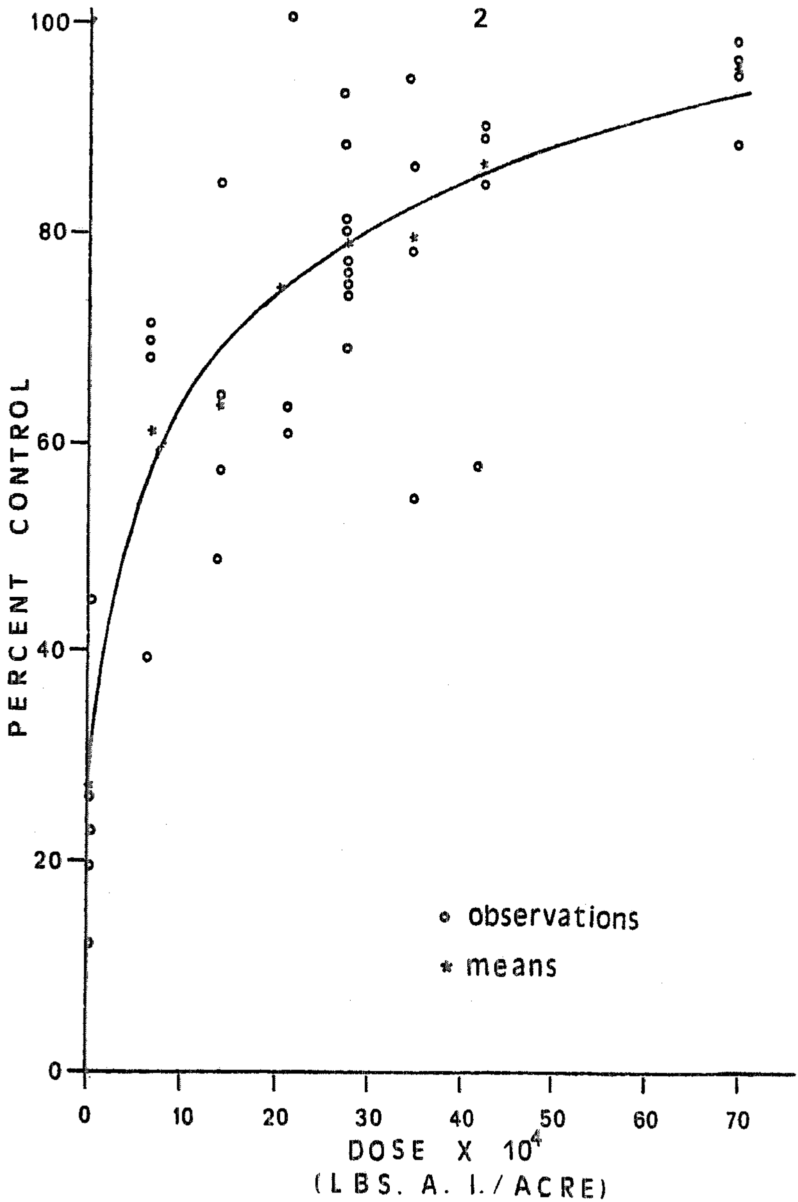

Fig. 2. Response of adult *Aedes* mosquitoes to resmethrin in densely wooded areas. The graph is back-transformed from the linear regression.

each test are given (Table 1), including the Klearol treatment.

There was some question after this analysis was completed whether or not air temperature during treatment which ranged from 67°F to 85°F affected percent control. However, a plot of the residuals from the regression analysis versus the average temperature during treatment (the mean of pretreatment and post-treatment temperatures) indicated that no such relationship existed for these data.

DISCUSSION

The approximate cost of labor and vehicle operation in the MMCD is $6.00 per

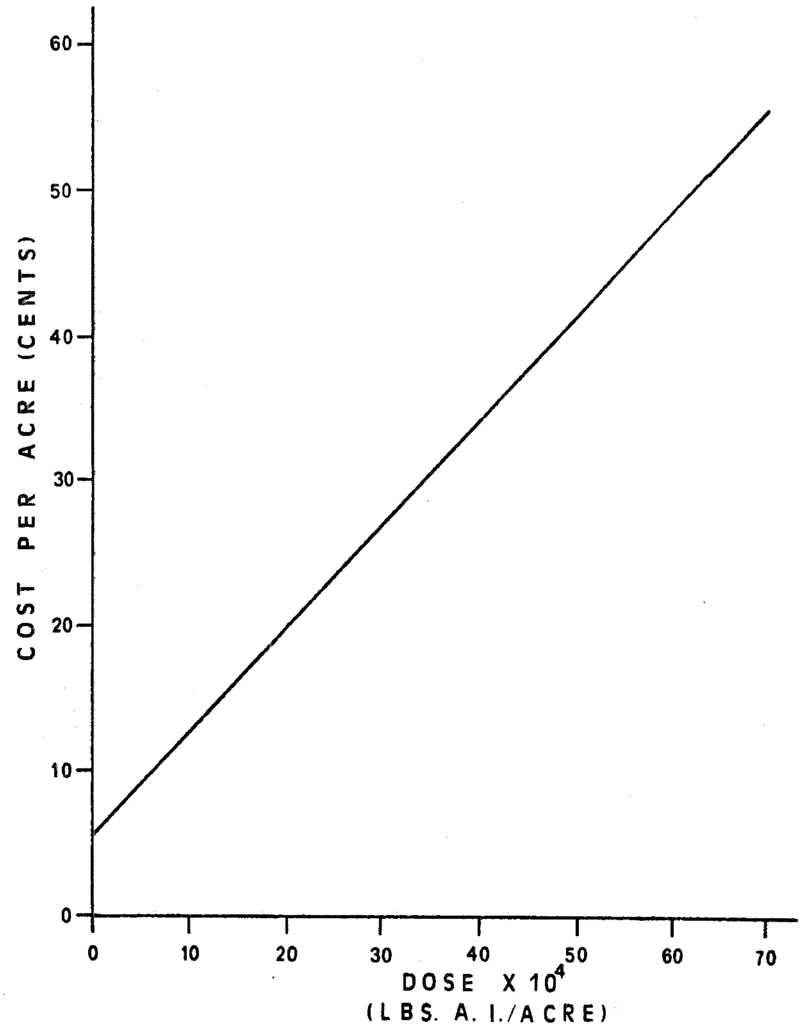

Fig. 3. Estimated 1978 cost of ground based resmethrin aerosol treatment in densely wooded areas.

hour. Assuming a vehicle treats 200 acres per hour, labor and vehicle operation costs approximate 3 cents per acre. Further, assuming a flow rate of 1.5 fl. oz. of finished material per acre, and December 1978 prices, the total cost of treatment with resmethrin in Klearol carrier can be graphically presented (Figure 3).

Since total cost is linearly related to dosage, a unit change in dosage will result in the same change in cost regardless of the dosage levels considered. For example, an increase in dosage from .007 to .0017 lb AI/acre will cost the same as an increase in dosage from .0060 to .007 lb AI/acre.

Changes in cost are not so simply related to changes in control levels. An increase in control from 70% to 80% will cost much less than an increase from 80% to 90% (Figure 4). The lowest rate tested, .0007 lb AI/acre, achieved 58% control while a 10-fold increase in dosage increased control only 1.6 times to 93%. The relatively high level of control achieved under the dense vegetation conditions over the entire dosage range provides the option of selecting an intermediate or low dosage for use during the peak mosquito populations when adult mosquitoes disperse nightly and rapidly re-invade controlled areas. Under these conditions a control program can suppress adult mosquito populations in a more cost effective manner by repeated treatments of a low dosage rate.

For example, to achieve 90% control in heavily wooded areas, it would be necessary to treat at a rate of .0057 lb AI/acre at a total cost of 46.1 cents per acre. Similarily, to achieve 75% control a treatment rate of .0022 lb AI/acre would be necessary. This would cost 21 cents per acre; thus 2 treatments at the lower rate would cost 42 cents per acre, a savings of 4 cents per acre.

This example can be taken one step further. In areas of constantly high mosquito density, i.e., adult mosquito resting areas, it is often necessary to retreat due to reinfiltration. Assuming on a given night the mosquito density is 10,000 mosquitoes per acre, treating at .0057 lb AI/acre would control 9,000 mosquitoes. Treating at .0022 lb AI/ acre would control 7,500 mosquitoes. If due to subsequent infiltration the density rose to 5,000, retreatment at .0022 lb AI/ acre would control an additional 3,750 mosquitoes. Thus two applications at .0022 lb AI/acre would achieve an increased control of 25% at less cost than the single treatment at the high rate.

If an assumption is made for a maximum adult mosquito summer lifespan of 4½ weeks, natural mortality accounts for an approximate 60% decline in the population within the 1st week after emergence. Thus, if higher control levels are desired the most logical time to raise the dosage rate would be after the adult dispersal phase has passed, when the population has stabilized and approximately 40% of the initial population remains.

With regard to operational use of nonthermal aerosol machines to control woodland mosquitoes, since satisfactory control of adult mosquitoes can be achieved in non-wooded areas at less than the maximum label rate applied at 10 mph, an appropriate decrease in truck speed along the leading edge of wooded areas can be used to increase the dosage rate and thus achieve the desired control level. It should be noted, however, that as wind speeds increase within the 3–8 mph treatment range, back pressure develops on the upwind face of wooded areas resulting in a portion of the aerosol cloud rising up the face and being carried over the top of the vegetation canopy rather than penetrating into the woods (Latta 1945).

Although no temperature related mortality was observed in these tests under relatively cool temperatures, Harris and Konoshita (1977) evaluating the direct toxicity of resmethrin on 1st instars of the cricket *Gryllus pennsylvanicus* (Burmeister) found the toxicity of resmethrin increased with decreasing temperatures. A 3.2 fold increase in toxicity was noted as

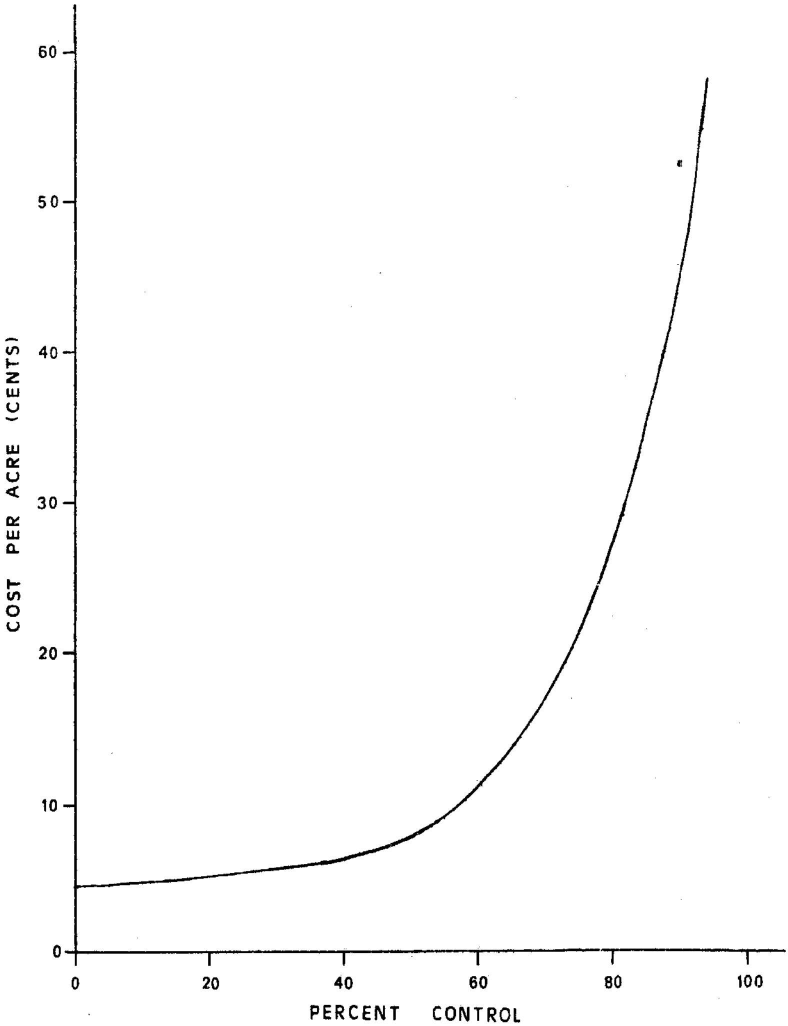

Fig. 4. Estimated cost of adult mosquito control in densely wooded areas of the MMCD using ground based resmethrin aerosols.

the temperature declined from 32°C to 15°C. This may have some important implications for resmethrin use in mosquito control under high temperatures.

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