STUDY TITLE:
Mosquito, Black Fly, and Biting Midges:
NALED Product Performance

DATA REQUIREMENT:
OPPTS Guideline 810.3400

AUTHOR:
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STUDY COMPLETED ON:
October 27, 2003

SPONSOR:
AMVAC Chemical Corporation
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PERFORMING LABORATORY:
Not Applicable

REPORT ID:
200-EFF-024

STATEMENT OF NO DATA CONFIDENTIALITY CLAIMS

No claim of confidentiality is made for any information contained in this study on the basis of its falling within the scope of FIFRA section 10(d)(1)(A), (B), or (C).

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Company Agent: Jon C. Wood Date: October 27, 2003

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GOOD LABORATORY PRACTICE COMPLIANCE STATEMENT

The information presented herein is not subject to the principles of 40 C.F.R. 160, GOOD LABORATORY PRACTICE STANDARDS (FIFRA), as promulgated in *Federal Register*, 54, No. 158, 34067-34704, 17 August 1989.

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TABLE OF CONTENTS

Summary

The performance of the organophosphate Naled (1,2-dibromo-2, 2-dichloroethyl dimethyl phosphate) as an insecticide for use in the control of mosquitoes, black flies, and biting midges, is demonstrated in this presentation of 100 peer-reviewed scientific publications representing 39 years of laboratory and field research performed under a variety of conditions.

Introduction

First registered in the United States in 1959, Naled (a.k.a. DIBROM®) has proven to be an effective adulticide for the control of mosquitoes/blackflies. Applied primarily as an Ultra-Low-Volume (ULV) aerial spray, Naled's usage has grown to the point that millions of acres are routinely treated for adult mosquito control in the U.S. each year.

It is difficult to find any source that disputes Naled's efficacy against the adult mosquito. This can best be demonstrated through the use of peer-reviewed scientific publications representing years of testing conducted by independent researchers that present un-biased results.

Procedures

No new testing was performed for this study. A search for peer-reviewed scientific publications on the efficacy of Naled (DIBROM®) was conducted by the following:

C. Roxanne Rutledge, Ph.D.
Assistant Professor, Extension Specialist
Florida Medical Entomology Laboratory
Institute of Food and Agricultural Sciences
200 9th Street SE
Vero Beach, Fl 32962
772-778-7200
crr@mail.ifas.ufl.edu

Dr. Rutledge used the following databases:

- AGRICOLA database search engine
- Cambridge Scientific Abstracts Internet Database Service (>60 databases)
- ISI Web of Knowledge Current Contents search engine
- ProQuest (5 databases)
- SilverPlatter WebSpirs (9 databases)

Additionally, the literature cited section of each reviewed article was crosschecked for additional references.

Acceptance criteria were defined based upon required elements of the U.S. EPA Pesticide Assessment Guideline (OPPTS 810.3400). One hundred of the two hundred fifteen articles reviewed met the criteria for the literature review. The review covered publications from 1960 – 1999. A search of the current contents (2001 – 2003) revealed no relevant publications on the efficacy of Naled/DIBROM for use against mosquitoes or other biting flies.

Table 1 lists the genus and species for all mosquitoes and biting flies that were included in these studies. There are two taxonomic name changes that occurred since the time of the publications reviewed. In many references, the name *Psorophora confinnis* appears. This species is currently known as *Psorophora columbiae*. Additionally, all references to *Aedes*, excluding *aegypti, albopictus, vexans, and cinereus*, is now known as *Ochlerotatus*. For examples, for every occurrence of *Aedes taeniorhynchus*, it is now known as *Ochlerotatus taeniorhynchus*.

Summary of Literature Reviewed

The following required information, extracted from each article by Dr. Rutledge, is presented in Appendix A to facilitate a summary review of the literature:

- SPECIES
- STAGE
- AGE
- SEX
- PLOT SIZE
- NUMBER TRIALS
- APPLICATION TECHNIQUE / EQUIPMENT
- EVALUATION PROCEDURES
- SAMPLING TECHNIQUE
- PERFORMANCE

However, the reviewer is encouraged to examine the entire article reproduced in Appendix B for complete details.

Conclusions

Research of peer-reviewed scientific publications has been conducted to demonstrate the performance of Naled in the control of mosquitoes, black flies, and biting midges. Any published articles found to meet the acceptance criteria established by the U.S. EPA Guideline (OPPTS 810.3400) were included in the review to present un-biased results, regardless of the level of product performance.

Overall, the literature indicates Naled's ability, regardless of formulation, to consistently control a variety of adult mosquito/blackfly species when used under proper conditions. Further, this report clearly demonstrates the magnitude and diversity of the laboratory and field research conducted over the past forty years with Naled, with consideration given to the performance of evolving field application technologies.

TABLE 1
Mosquitoes and biting flies used in naled (Dibrom) efficacy studies published from 1960-1999

Genus	species
Aedes	*aegypti, albopictus, atlanticus, canadensis, cantator, communis, fitchii, intrudens, nigromaculis, punctor, sollicitans, taeniorhynchus, triseriatus trivittatus, vexans*
Anopheles	*albimanus* *crucians/bradelyi* *punctipennis* *quadrimaculatus*
Coquillettidia	*perturbans*
Culex	*nigripalpus* *pipiens* *quinquefasciatus* *salanarius* *tarsalis* *tritaeniorhynchus*
Culiseta	*melanura*
Psorophora	*ciliata* *confinnis/columbiae* *cyanescens* *ferox*
Toxorhynchites	*rutilus rutilus* *splendens*
Wyeomyia	*vanduzeei* *mitchellii*
Culicoides	*furens* *hollensis* *mississippiensis* *mellus*
Chrysops	*atlanticus* *fuliginosus*
Tabanus	*nigrivittatus*
Stomoxys	*calcitrans*

APPENDIX A

Summary of Literature Reviewed

The following summarizes information from reviewed literature, with criteria selected in accordance with the EPA Product Performance Test Guidelines: OPPTS 810.3400, Mosquito, Black Fly, and Biting Midge (Sand Fly) Treatments (EPA 712-C-98-419, March 1998). Referenced literature is presented in the order of most recent publication first, in descending chronological order. Refer to reproduced article in Appendix B for complete details.

1999 Ham, C. M., M. V. Meisch, and C. L. Meek
Efficacy of Dibrom®, Trumpet®, and Scourge® Against Four Mosquito Species in Louisiana
J. American Mosquito Control Association 15: 433-436 (Amvac Ref. #1003)

SPECIES: *Anopheles quadrimaculatus*
STAGE: Adult
AGE: Unknown/Wild
SEX: Not reported
PLOT SIZE: 61m x 61m
NUMBER TRIALS: 3
APPLICATION TECHNIQUE/EQUIPMENT: Aerial ULV; Six 80015 tee-jet nozzles
EVALUATION PROCEDURES: Mortality of caged mosquitoes
SAMPLING TECHNIQUE: No population assessment conducted
PERFORMANCE: (Dibrom) 69% mortality; (Trumpet) 64% mortality

SPECIES: *Culex quinquefasciatus*
STAGE: Adult
AGE: Unknown/Wild
SEX: Not reported
PLOT SIZE: 61m x 61m
NUMBER TRIALS: 3
APPLICATION TECHNIQUE/EQUIPMENT: Aerial ULV; Six 80015 tee-jet nozzles
EVALUATION PROCEDURES: Mortality of caged mosquitoes
SAMPLING TECHNIQUE: No population assessment
PERFORMANCE: (Dibrom) 63.2% mortality; (Trumpet) 65.0% mortality

SPECIES: *Aedes sollicitans/taeniorhynchus*
STAGE: Adult
AGE: 3 days old (wild from larvae)
SEX: Not reported
PLOT SIZE: 61m x 61m
NUMBER TRIALS: 3
APPLICATION TECHNIQUE/EQUIPMENT: Aerial ULV; Six 80015 tee-jet nozzles
EVALUATION PROCEDURES: Mortality of caged mosquitoes
SAMPLING TECHNIQUE: No population assessment
PERFORMANCE: (Dibrom) 99.7% mortality; (Trumpet) 99.8% mortality

SPECIES: *Culex quinquefasciatus*
STAGE: Adult
AGE: Unknown/Wild
SEX: Not reported
PLOT SIZE: 61m x 61m
NUMBER TRIALS: 3
APPLICATION TECHNIQUE/EQUIPMENT: Ground ULV; Leco HD ULV and Londonaire 1820 sprayers
EVALUATION PROCEDURES: Mortality of caged mosquitoes
SAMPLING TECHNIQUE: No population assessment
PERFORMANCE: (Dibrom) 20.7% mortality; (Trumpet) 15.6% mortality

SPECIES: *Aedes sollicitans/taeniorhynchus*
STAGE: Adult
AGE: 3 days old (wild from larvae)
SEX: Not reported
PLOT SIZE: 61m x 61m
NUMBER TRIALS: 3
APPLICATION TECHNIQUE/EQUIPMENT: Ground ULV; Leco HD ULV and Londonaire 1820 sprayers
EVALUATION PROCEDURES: Mortality of caged mosquitoes
SAMPLING TECHNIQUE: No population assessment
PERFORMANCE: (Dibrom) 96% mortality; (Trumpet) 99.2% mortality

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1998 Sukontason, K., J. K. Olson, W. K. Hartberg, and R. E. Duhrkopf
Organophosphate and Pyrethroid Susceptibilities of *Culex salinarius* Adults from Texas and New Jersey
J. American Mosquito Control Association 14: 477-480 (Amvac Ref. #927)

SPECIES: *Culex salinarius*
STAGE: Adult
AGE: 3 – 4 days old (lab – NJ))
SEX: Female
PLOT SIZE: N/A
NUMBER TRIALS: 5
APPLICATION TECHNIQUE/EQUIPMENT: Scintillation vial assay
EVALUATION PROCEDURES: 24-hour mortality; LC50 and LC95
SAMPLING TECHNIQUE: No population assessment
PERFORMANCE: LC50 = 0.076 ug/vial; LC95 = 0.162 ug/vial; Resistance ratio <1 (no resistance)

SPECIES: *Culex salinarius*
STAGE: Adult
AGE: 3 – 4 days old (lab – TX))
SEX: Female
PLOT SIZE: N/A
NUMBER TRIALS: 5
APPLICATION TECHNIQUE/EQUIPMENT: Scintillation vial assay
EVALUATION PROCEDURES: 24-hour mortality; LC50 and LC95
SAMPLING TECHNIQUE: No population assessment
PERFORMANCE: LC50 = 0.043 ug/vial; LC95 = 0.106 ug/vial; Resistance ratio <1 (no resistance)

1998 Moore, C.G.
Letter to Editor RE: Impact of Naled (Dibrom 14) on the Mosquito Vectors of Eastern Equine Encephalitis Virus
J. American Mosquito Control Association 14: 482-484 (Amvac Ref. #1424)

SPECIES: N/A
STAGE: N/A
AGE: N/A
SEX: N/A
PLOT SIZE: N/A
NUMBER TRIALS: N/A
APPLICATION TECHNIQUE/EQUIPMENT: N/A
EVALUATION PROCEDURES: N/A
SAMPLING TECHNIQUE: N/A
PERFORMANCE: Comments on the appropriateness of methodology used in: 1997 Howard, J.J., and J. Oliver Impact of Naled (Dibrom 14) on the Mosquito Vectors of Eastern Equine Encephalitis Virus J. American Mosquito Control Association 13: 315-325 (Amvac Ref. #1416)

1997 Howard, J.J., and J. Oliver
Impact of Naled (Dibrom 14) on the Mosquito Vectors of Eastern Equine Encephalitis Virus
J. American Mosquito Control Association 13: 315-325 (Amvac Ref. #1416)

SPECIES: *Culiseta spp. & Aedes spp.*
STAGE: Adult
AGE: Unknown (wild)
SEX: Not given
PLOT SIZE: Swamp area total approx. 1600 ha (Cicero)
NUMBER TRIALS: 15
APPLICATION TECHNIQUE/EQUIPMENT: Aerial ULV; Piper Aztecs equipped with Micromist 900 spray systems
EVALUATION PROCEDURES: Mortality of trap-collected mosquitoes
SAMPLING TECHNIQUE: Yearly trap collections at 2-week post-treatment
PERFORMANCE: For 13 of 15 applications mortality ranged from 81% to 99%with an average of 96%; 2 applications showed no reduction

SPECIES: *Culiseta spp. & Aedes spp.*
STAGE: Adult
AGE: Unknown (wild)
SEX: Not given
PLOT SIZE: Swamp area total approx. 2000 ha (Toad Harbor)
NUMBER TRIALS: 7
APPLICATION TECHNIQUE/EQUIPMENT: Aerial ULV; Piper Aztecs equipped with Micromist 900 spray systems
EVALUATION PROCEDURES: Mortality of trap-collected mosquitoes
SAMPLING TECHNIQUE: Annual trap collections at 2-week post-treatment
PERFORMANCE: Mortality ranged from 32% to 98% with an average of 81%

1996 Burkett, D. A., T. L. Biery and D. G. Haile
An Operational Perspective on Measuring Aerosol Cloud Dynamics
J. American Mosquito Control Association 12: 380-383 (Amvac Ref. #1415)

SPECIES: *Aedes taeniorhynchus*
STAGE: Adult
AGE: 3 – 5 days old (lab)
SEX: Female
PLOT SIZE: Distance: 0.5 – 2.1 miles
NUMBER TRIALS: 3
APPLICATION TECHNIQUE/EQUIPMENT: Aerial ULV; TeeJet 8005 nozzles
EVALUATION PROCEDURES: Mortality of caged mosquitoes
SAMPLING TECHNIQUE: No population assessment
PERFORMANCE: >90% mortality (or better): no data given

1996 Mount, G.A., Biery, T.L., and D.G. Hailey
A Review of Ultralow-Volume Aerial Sprays of Insecticide for Mosquito Control
J. American Mosquito Control Association 12: 601-618 (Amvac Ref. #1210)

SPECIES: *Aedes spp., Culex spp., Psorophora spp.*
STAGE: Adult
AGE: unknown (wild)
SEX: Not given
PLOT SIZE: Various, ranging from 3 to 2112 square miles
NUMBER TRIALS: 24
APPLICATION TECHNIQUE/EQUIPMENT: Aerial ULV, large and small target areas
EVALUATION PROCEDURES: Various, not given – review of several articles
SAMPLING TECHNIQUE: Various, not given – review of several articles
PERFORMANCE: Mortality range from 14% to 100%; Average mortality >80%

1993 Tietze, N. S., E. T. Schreiber, P. G. Hester, C. F. Hallmon, M. A. Olson, and K. R. Shaffer
Susceptibility of First Instar *Toxorhynchites splendens* to Malathion, Naled and Resmethrin
J. American Mosquito Control Association 9: 97-99 (Amvac Ref. #1414)

SPECIES: *Toxorhynchites splendens*
STAGE: Larvae
AGE: 1^{st} instar: <24 hours old (lab)
SEX: Not reported
PLOT SIZE: 50-ml Pyrex beakers (40 ml water)
NUMBER TRIALS: 3 reported
APPLICATION TECHNIQUE/EQUIPMENT:
EVALUATION PROCEDURES: Lethal concentration (LC50)
SAMPLING TECHNIQUE: No population assessment
PERFORMANCE: 24hours: LC50 = 623ng AI/ml; 48 hours: C50 = 488ng AI/ml; Relative to Malathion and Resmethrin, Naled was least toxic.*

*This study was to determine the susceptibility of a predacious mosquito used for biological control. Naled was least toxic to this species, which in this case, is better. The goal is NOT mortality for this mosquito species.

1992 Linley, J. R. and S. Jordan
Effects of Ultra-Low Volume and Thermal Fog Malathion, Scourge® and Naled Applied Against Caged Adult *Culicoides Furens* and *Culex QuinqueFasciatus* in Open and Vegetated Terrain
J. American Mosquito Control Association 8: 69-76 (Amvac Ref. #1413)

SPECIES: *Culex quinquefasciatus*
STAGE: Adult
AGE: Not reported (lab)
SEX: Female
PLOT SIZE: Out to 500' from line of spray
NUMBER TRIALS: 12
APPLICATION TECHNIQUE/EQUIPMENT: Aerial ULV, Curtis Dynafog ULV machine; Thermal fog, Leco HD 120
EVALUATION PROCEDURES: Mortality of caged mosquitoes
SAMPLING TECHNIQUE: No population assessment
PERFORMANCE: Open terrain: 90% control out to 35'; Vegetated terrain: did not achieve 90% control
As effective as Scourge®; ULV provided greater mortality

SPECIES: *Culicoides furens*
STAGE: Adult
AGE: Not reported (wild)
SEX: Female
PLOT SIZE: Out to 500' from line of spray
NUMBER TRIALS: 12
APPLICATION TECHNIQUE/EQUIPMENT: Aerial ULV, Curtis Dynafog ULV machine; Thermal fog, Leco HD 120
EVALUATION PROCEDURES: Mortality of caged biting midges
SAMPLING TECHNIQUE: No population assessment
PERFORMANCE: Open terrain: Strikingly more effective than malathion and Scourge® against biting midges; 90% control to 117'; 86% mortality at 500'; 75% kill sustained out to 928'
Vegetated terrain: poor level of control. ULV was most effective method of application of naled against the biting midges

1990 Curtis, G. A., and D. B. Carlson
Evaluation of Hand Applied Naled Thermal Fog for Wyeomyia Control
J. American Mosquito Control Association 6: 421-424 (Amvac Ref. 1412)

SPECIES: *Wyeomyia vanduzeei; Wyeomyia mitchellii*
STAGE: Adult
AGE: Unknown; natural field population
SEX: Female
PLOT SIZE: 0.3 acres
NUMBER TRIALS: 11 (one day); 6 (3 consecutive days)
APPLICATION TECHNIQUE/EQUIPMENT: Thermal fog; London Turbo Hand Fogger; One day application and 3 consecutive days application
EVALUATION PROCEDURES: Landing rate
SAMPLING TECHNIQUE: 5 minute landing rates daily for 30 days prior to test and 24 hours post treatment
PERFORMANCE: One day: mean decrease of biting population by 13%; 3-day: mean decrease of biting population of 14.3%

1989 Boike, Jr., A. H., C. B. Rathburn, Jr., T. G. Floore, H. M. Rodriguez, and J. S. Coughlin
Insecticide Tolerance of *Culex Nigripalpus* in Florida
J. American Mosquito Control Association 5: 522-528 (Amvac Ref. #1410)

SPECIES: *Culex nigripalpus*
STAGE: Larvae (from wild adults)
AGE: 3rd instar
SEX: Not reported
PLOT SIZE: N/A
NUMBER TRIALS: 12
APPLICATION TECHNIQUE/EQUIPMENT: Beaker tests in laboratory
EVALUATION PROCEDURES: Mortality in beaker at 24 hours; LC 50 and LC 90 compared to susceptible strain
SAMPLING TECHNIQUE: Larvae were reared from natural adult populations at various locations
PERFORMANCE: Resistance ratios ranged from 0.9 to 7.2; Increase in tolerance from 2.8X – 4.9X from different areas of the state; no resistance detected

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1989 Brown, J. R., R. O. Melson, and G. E. Tetreault. United States Navy Pesticide Aerial Unit
J. Florida Anti-Mosquito Association 4-6 (Amvac Ref. #1411)

SPECIES: *Aedes aegypti*
STAGE: Adult
AGE: 3 – 6 days old (lab)
SEX: Not reported
PLOT SIZE: Distances of 15.2m – 91.4m perpendicular to flight path
NUMBER TRIALS: 6
APPLICATION TECHNIQUE/EQUIPMENT: Aerial; Beecomist rotary nozzle Model 360
EVALUATION PROCEDURES: Mortality of caged mosquitoes
SAMPLING TECHNIQUE: No population assessment
PERFORMANCE: (Dibrom 14) 100%

1989 Robert, L. L. and J. K. Olson
Susceptibility of Female *Aedes Albopictus* from Texas to Commonly Used Adulticides
J. American Mosquito Control Association 5: 251-253 (Amvac Ref. #1409)

SPECIES: *Aedes albopictus*
STAGE: Adult
AGE: 3 – 4 day old (reared from wild eggs: Houston, Liberty)
SEX: Female
PLOT SIZE: 20-ml glass vials
NUMBER TRIALS:
APPLICATION TECHNIQUE/EQUIPMENT: Plapp bioassay; mosquitoes exposed to vials coated with insecticide.
EVALUATION PROCEDURES: LC50 and LC95 per vial compared to susceptible strain of *Aedes aegypti*
SAMPLING TECHNIQUE: No population assessment
PERFORMANCE: Houston LC50 = 0.07 ug/vial, LC95 = 0.35 ug/vial. Liberty LC50 = 0.05 ug.vial, LC95 = 0.13 ug/vial. Different from control at LC95; no resistance reported.

1988 Curtis, G. A., and J. Mason
Evaluation of Equipment Modifications and Dosage Rates of Ground ULV Applications of Naled Against *Aedes Taehniorhynchus* in a Florida Citrus Grove
J. American Mosquito Control Association 4: 345-350 (Amvac Ref. #1407)

SPECIES: *Aedes taehniorhynchus*
STAGE: Adult
AGE: 3 – 6 day old (lab)
SEX: Female
PLOT SIZE: 120 acres
NUMBER TRIALS: 110 total
APPLICATION TECHNIQUE/EQUIPMENT: Ground ULV; Curtis-Dyna, Leco, London Aire
EVALUATION PROCEDURES: Mortality of caged mosquitoes
SAMPLING TECHNIQUE: No population assessment
PERFORMANCE: Dibrom 14 (3.6 fl oz/min) = 56.5%, 39.6%, 32.8% (respectively)
Dibrom 14 (10.8 fl oz/min) = >95%

1988 Linley, J. R., R. E. Parsons, and R. A. Winner
Evaluation of ULV Naled Applied Simultaneously Against Caged Adult Aedes Taeniorhynchus and Culicoides Furens
J. American Mosquito Control Association 4: 326-332 (Amvac Ref. #1406)

SPECIES: *Aedes taeniorhynchus*
STAGE: Adult
AGE: Not reported (lab colony)
SEX: Not reported
PLOT SIZE: Open field, not reported
NUMBER TRIALS: 2
APPLICATION TECHNIQUE/EQUIPMENT: Ground, vehicle mounted ULV Leco Model HD
EVALUATION PROCEDURES: Mortality of caged mosquitoes
SAMPLING TECHNIQUE: No population assessment
PERFORMANCE: 90% mortality extended only to 5 meters; 70% mortality out to 23 meters
SPECIES: *Culicoides furens*

STAGE: Adult
AGE: Unknown, wild
SEX: Female
PLOT SIZE: Open field, not reported
NUMBER TRIALS: 2
APPLICATION TECHNIQUE/EQUIPMENT: Ground, vehicle mounted ULV Leco Model HD
EVALUATION PROCEDURES: Mortality of caged biting flies
SAMPLING TECHNIQUE: Wild populations were used for the test
PERFORMANCE: 90% mortality not attained; 70% mortality out to 18 meters

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1987 Linley, J. R., R. E. Parsons, and R. A. Winner
Evaluation of Naled Applied as a Thermal Fog Against *Culicoides Furens (Diptera: Ceratopogonidae)*
J. American Mosquito Control Association 3: 387-391 (Amvac Ref. #1408)

SPECIES: *Culicoides furens*
STAGE: Adult
AGE: Not reported (wild)
SEX: Female
PLOT SIZE: Distance 50m from application site to test cages
NUMBER TRIALS: 1
APPLICATION TECHNIQUE/EQUIPMENT: Ground thermal fog, London Turbo Hand Fogger
EVALUATION PROCEDURES: Mortality of caged midges
SAMPLING TECHNIQUE: No population assessment
PERFORMANCE: 24 hours: 14.8% mortality

1986 Rathburn, Jr., C. B., J. C. Dukes, A. H. Boike, Jr., T. G. Floore and C. F. Hallmon
The Efficacy of Formulations of Dibrom 14 in Citrus Oil For The Control of Mosquitoes and Stable Flies
J. Florida Anti-Mosquito Association 4-8 (Amvac Ref. #1404)

SPECIES: *Aedes taeniorhynchus*
STAGE: Adult
AGE: Not reported (lab)
SEX: Not reported
PLOT SIZE:
NUMBER TRIALS: 8
APPLICATION TECHNIQUE/EQUIPMENT: Wind tunnel
EVALUATION PROCEDURES: LC50 and LC90
SAMPLING TECHNIQUE: No population assessment
PERFORMANCE: Dibrom LC50 = 0.033 mg/ml, LC90 = 0.104 mg/ml; Dibrom in citrus oil LC50 – 0.025 mg/ml, LC90 = 0.092 mg/ml

SPECIES: *Culex quinquefasciatus*
STAGE: Adult
AGE: Not reported (lab)
SEX: Not reported
PLOT SIZE:
NUMBER TRIALS: 8
APPLICATION TECHNIQUE/EQUIPMENT: Wind tunnel
EVALUATION PROCEDURES: LC50 and LC90
SAMPLING TECHNIQUE: No population assessment
PERFORMANCE: Dibrom LC50 = 0.067 mg/ml, LC90 = 0.161 mg/ml; Dibrom in citrus oil LC50 – 0.074 mg/ml, LC90 = 0.148 mg/ml

SPECIES: *Aedes taeniorhynchus*
STAGE: Adult
AGE: Not reported (lab)
SEX: Female
PLOT SIZE: Distance – up to 600 feet downwind of application
NUMBER TRIALS: 1
APPLICATION TECHNIQUE/EQUIPMENT: Ground ULV; Leco HD ULV generator.
EVALUATION PROCEDURES: Mortality of caged mosquitoes
SAMPLING TECHNIQUE: No population assessment
PERFORMANCE: Dibrom in citrus oil: 98.2 – 98.5% mortality; Dibrom in soybean oil: 100% mortality

SPECIES: *Culex quinquefasciatus*
STAGE: Adult
AGE: Not reported (lab)
SEX: Female
PLOT SIZE: Distance – up to 600 feet downwind of application
NUMBER TRIALS: 1
APPLICATION TECHNIQUE/EQUIPMENT: Ground ULV; Leco HD ULV generator
EVALUATION PROCEDURES: Mortality of caged mosquitoes
SAMPLING TECHNIQUE: No population assessment
PERFORMANCE: Dibrom in citrus oil: 53.6 – 79.9 % mortality; Dibrom in soybean oil: 89.6 – 94.3% mortality

SPECIES: *Culex nigripalpus*
STAGE: Adult
AGE: Not reported (lab)
SEX: Female
PLOT SIZE: Distance – up to 600 feet downwind from application
NUMBER TRIALS: 1
APPLICATION TECHNIQUE/EQUIPMENT: Ground ULV; Leco HD ULV generator
EVALUATION PROCEDURES: Mortality of caged mosquitoes
SAMPLING TECHNIQUE: No population assessment
PERFORMANCE: Dibrom in citrus oil: 93.3 - 100 % mortality; Dibrom in soybean oil: 100% mortality

SPECIES: *Stomoxys calcitrans*
STAGE: Adult
AGE: 3 days old (lab)
SEX: Female
PLOT SIZE: Distance – up to 600 feet downwind from application
NUMBER TRIALS: 1
APPLICATION TECHNIQUE/EQUIPMENT: Ground ULV; Leco HD ULV generator
EVALUATION PROCEDURES: Mortality of caged stable flies
SAMPLING TECHNIQUE: No population assessment
PERFORMANCE: 0.5 hour: Dibrom in citrus oil: 52 - 78 % mortality; Dibrom in soybean oil: 98-99% mortality; 12 hour: Dibrom in citrus oil: 78 - 96% mortality; Dibrom in soybean oil: 100% mortality

1986 Weathersbee, A. A., III, M. V. Meisch, C. A. Sandoski, M. F. Finch, D. A. Dame, J. K. Olson, and A. Inman
Combination Ground and Aerial Adulticide Applications Against Mosquitoes in an Arkansas Riceland Community
Journal of the American Mosquito Control Association 2: 456-460 (Amvac Ref. #1405)

SPECIES: *Anopheles quadrimaculatus, Psorophora columbiae*
STAGE: Adult
AGE: Unknown (wild populations)
SEX: Mixed
PLOT SIZE: 10.4 km^2
NUMBER TRIALS:
APPLICATION TECHNIQUE/EQUIPMENT: Aerial; 5 Teejet 8535 nozzles with D_2 orifices
EVALUATION PROCEDURES: Change in landing rates (2 days pre-treat and 2 days post-treat); change in density of females collected in resting stations (3 days pre-treat and 2 days post-treat); Mortality of caged mosquitoes
SAMPLING TECHNIQUE: Landing rates; resting collections of natural populations
PERFORMANCE: *Anopheles* resting collections: 90% and 77% reduction at 12 hours; 81% and 84% reduction at 36 hours; Landing rates: Initial reduction at 24 hours for both species; increase in both species at 48 hours; Caged mosquito mortality: 4 – 52.8%

1985 Floore, T. G.
Laboratory Wind Tunnel Tests of Nine Insecticides Against Adult Culicoides Species (Diptera: Ceratopogonidae)
Florida Entomologist 68: 678-682 (Amvac Ref. #1403)

SPECIES: *Culicoides mississippiensis, C. furens, C. mellus* (not separated in results)
STAGE: Adult
AGE: Unknown (wild)
SEX: Not reported
PLOT SIZE: N/A
NUMBER TRIALS: 1
APPLICATION TECHNIQUE/EQUIPMENT: Wind tunnel
EVALUATION PROCEDURES: LC50 and LC 90
SAMPLING TECHNIQUE: No population assessment
PERFORMANCE: 24 hour LC50 = 0.0586 mg AI/ml, LC90 = 0.1530 mg AI/ml
Compared to 8 other insecticides, naled was least effective

1985 Boike, Jr., A. H., C. B. Rathburn, Jr., K. L. Lang, H. M. Masters and T. G. Floore
Current Status on the Florida Abate Monitoring Program - Susceptibility Levels of Three Species of Mosquitoes During 1984
J. American Mosquito Control Association 1: 498-501 (Amvac Ref. #1402)

SPECIES: *Culex nigripalpus*
STAGE: larvae (reared from wild)
AGE: 3rd instar
SEX: Not reported
PLOT SIZE: 250 ml solution in beakers
NUMBER TRIALS: 12
APPLICATION TECHNIQUE/EQUIPMENT: Laboratory bioassay in beakers
EVALUATION PROCEDURES: LC50 and LC90
SAMPLING TECHNIQUE: No population assessment
PERFORMANCE: 1981: LC50 = 0.0528 ug AI/ml, LC90 = 0.0895 ug AI/ml; 1984: LC50 = 0.0722 ug AI/ml, LC90 = 0.1822 ug AI/ml: (Slight increase in tolerance to naled)

SPECIES: *Culex quinquefasciatus*
STAGE: larvae (reared from wild)
AGE: 3rd instar
SEX: Not reported
PLOT SIZE: 250 ml solution in beakers
NUMBER TRIALS: 12
APPLICATION TECHNIQUE/EQUIPMENT: Laboratory bioassay in beakers
EVALUATION PROCEDURES: LC50 and LC90
SAMPLING TECHNIQUE: No population assessment
PERFORMANCE:

Collier	1982: LC50 = 0.356 ug AI/ml, LC90 = 0.644 ug AI/ml
Collier	1984: LC50 = 0.399 ug AI/ml, LC90 = 0.759 ug AI/ml
Collier	1984: LC50 = 0.147 ug AI/ml, LC90 = 0.215 ug AI/ml
Lee	1981: LC50 = 0.142 ug AI/ml, LC90 = 0.240 ug AI/ml
Lee	1984: LC50 = 0.334 ug AI/ml, LC90 = 0.655 ug AI/ml
Manatee	1984: LC50 = 0.338 ug AI/ml, LC90 = 0.777 ug AI/ml
Polk	1980: LC50 = 0.646 ug AI/ml, LC90 = 1.140 ug AI/ml
Polk	1984: LC50 = 0.249 ug AI/ml, LC90 = 0.521 ug AI/ml

Less resistant to naled than the other AI's tested

1985 Dukes, J. C., C. F. Hallmon, J. P. Ruff, and J. C. Moore
Downwind Drift and Droplet Distribution of Naled Aerial Sprays Applied for Stable Fly Control Over Gulf Beaches
J. Florida Anti-Mosquito Association 86-90 (Amvac Ref. #950)

SPECIES: Stable flies (no scientific name given)
STAGE: Adult
AGE: Not reported. Lab reared
SEX: Not reported
PLOT SIZE: 3000 linear feet
NUMBER TRIALS: 4
APPLICATION TECHNIQUE/EQUIPMENT: Aerial application; DC3; 36 flat fan nozzles
EVALUATION PROCEDURES: Mortality of caged stable flies
SAMPLING TECHNIQUE: No population assessment
PERFORMANCE: 92 – 100% mortality

1984 Boike, Jr., A. H., C. B. Rathburn, Jr., L. A. Sizemore, and M. W. Peters
Susceptibility of Eighteen Strains of Culex quinquefasciatus Say from Florida to Five Organophosphate Insecticides
J. Florida Anti-Mosquito Association 55: 1-5 (Amvac Ref. #1400)

SPECIES: *Culex quinquefasciatus*
STAGE: Larvae
AGE: Not reported
SEX: Not reported
PLOT SIZE: N/A
NUMBER TRIALS:
APPLICATION TECHNIQUE/EQUIPMENT: Beaker bioassays in the laboratory
EVALUATION PROCEDURES: LC 50 and LC 90 established and compared to populations in various areas of the state
SAMPLING TECHNIQUE: Larvae tested were from eggs of wild populations
PERFORMANCE: Polk County – Least susceptible to naled at LC 50 = 0646 ug AI/ml; Most susceptible from Cottondale – LC 50 = 0.070 ug AI/ml; 5 strains had LC 50 ranging from 0.356 to 0.210 ug AI/ml; 8 strains had LC 50 ranging from 0.179 to 0.112 ug AI/ml.

1984 Haile, D. G., D. L. Kline, J. F. Reinert, and T. L. Biery
Effects of Aerial Applications of Naled on *Culicoides* Biting Midges, Mosquitoes, and Tabanids on Parris Island, South Carolina
Mosquito News 44: 178-183 (Amvac Ref. #1401)

SPECIES: *Culicoides hollensis, C. mellus, C. furens*
STAGE: Adult
AGE: Unknown, wild
SEX: Female
PLOT SIZE: 8047 acres
NUMBER TRIALS: 4
APPLICATION TECHNIQUE/EQUIPMENT: Aerial application; TeeJet nozzles
EVALUATION PROCEDURES: Mortality of caged biting midges, landing rates, trap collections
SAMPLING TECHNIQUE: Landing rates
PERFORMANCE: 1981: 24% control based on landing rates, 58% mortality in caged biting midges; 1982: 99% reduction in trap collections; 95% mortality in caged biting midges

SPECIES: *Aedes taeniorhynchus, Culex quinquefasciatus*
STAGE: Adult
AGE: Lab reared *Aedes; Culex* unknown, wild
SEX: Female
PLOT SIZE: 8047 acres
NUMBER TRIALS: 4
APPLICATION TECHNIQUE/EQUIPMENT: Aerial application; TeeJet nozzles
EVALUATION PROCEDURES: Mortality of caged biting midges, trap collections
SAMPLING TECHNIQUE: Trapping of natural populations
PERFORMANCE: 1981: 67% mortality in caged mosquitoes
1982: 96% mortality in caged mosquitoes; 63% reduction in trap collections

SPECIES: *Tabanus spp*
STAGE: Adult
AGE: Unknown, wild
SEX: Female
PLOT SIZE: 8047 acres
NUMBER TRIALS: 4
APPLICATION TECHNIQUE/EQUIPMENT: Aerial application; TeeJet nozzles
EVALUATION PROCEDURES: Trap counts
SAMPLING TECHNIQUE: Trap counts of natural population
PERFORMANCE: 69% reduction in trap counts

1982 Boike, A. H., Jr., C. B. Rathburn, Jr., L. A. Sizemore, and M. W. Peters
Results of the Florida Program for Monitoring Mosquito Susceptibility to Temephos, 1980-82
Journal of the Florida Anti-Mosquito Association 84-92 (Amvac Ref. #1395)

SPECIES: *Aedes taeniorhynchus*
STAGE: Larvae
AGE: Not reported
SEX: Not reported
PLOT SIZE: N/A
NUMBER TRIALS: 4
APPLICATION TECHNIQUE/EQUIPMENT: Beaker bioassay in laboratory
EVALUATION PROCEDURES: LC 50 and LC 90 compared to lab susceptible strain
SAMPLING TECHNIQUE: Larvae reared from wild populations
PERFORMANCE: Resistance ratios: 0.9 – 1.5. No resistance. Almost as susceptible as lab strains

SPECIES: *Culex nigripalpus*
STAGE: Larvae
AGE: Not reported
SEX: Not reported
PLOT SIZE: N/A
NUMBER TRIALS: 5
APPLICATION TECHNIQUE/EQUIPMENT: Beaker bioassay in laboratory
EVALUATION PROCEDURES: LC 50 and LC 90 compared to lab susceptible strain
SAMPLING TECHNIQUE: Larvae reared from wild populations
PERFORMANCE: Resistance rations: 1.1 – 1.7. No resistance. Almost as susceptible as lab strains

SPECIES: *Culex quinquefasciatus*
STAGE: Larvae
AGE: Not reported
SEX: Not reported
PLOT SIZE: N/A
NUMBER TRIALS: 6
APPLICATION TECHNIQUE/EQUIPMENT: Beaker bioassay in laboratory
EVALUATION PROCEDURES: LC 50 and LC 90 compared to lab susceptible strain
SAMPLING TECHNIQUE: Colony from eggs, larvae, and adult from wild
PERFORMANCE: Resistance ratios: 1.0 – 5.6. One population had high RR (5.3 and 5.6); remainder was almost as susceptible as lab strains.

1982 Erickson, L. A.
Effectiveness of Aerial Applications of Naled 85 Concentrate on Rocky Point, Florida
J. Florida Anti-Mosquito Association 34-38 (Amvac Ref. #1396)

SPECIES: *Aedes taeniorhynchus*
STAGE: Adult
AGE: Unknown, wild
SEX: Mixed
PLOT SIZE: 9000 acres
NUMBER TRIALS: 6
APPLICATION TECHNIQUE/EQUIPMENT: Aerial ULV
EVALUATION PROCEDURES: Change in New Jersey light trap counts
SAMPLING TECHNIQUE: Trapping of natural populations
PERFORMANCE: Reduction of New Jersey light trap counts: 147 to 9; 142 to 76 to 17; 62 to 35 to 1. Reduced complaints.

1982 Haile, D. G., T. L. Biery, J. F. Reinert, and N. W. Pierce
Aerial Applications of Naled Diluted in HAN with UC-123K Aircraft for Adult Mosquito Control
Mosquito News 42: 41-48 (Amvac Ref. #1397)

SPECIES: *Aedes taeniorhynchus*
STAGE: Adult
AGE: 3 – 6 days old (lab)
SEX: Not reported
PLOT SIZE: 1.4 – 2.0 miles
NUMBER TRIALS: 4
APPLICATION TECHNIQUE/EQUIPMENT: Aerial ULV; 8003 – 8004 TeeJet nozzles
EVALUATION PROCEDURES: Mortality of caged mosquitoes
SAMPLING TECHNIQUE: No population assessment
PERFORMANCE: Mortality = 56% (1 test); 92% (average of 3 tests); 70% (average of 2 tests); 93% (1 test). 1.5 oz/acre more effective than 0.25 oz/acre

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1982 Parsons, R. E.
Effect of Ground Ultra Low Volume Insecticide Applications on Natural Mosquito Populations
Journal of the Florida Anti-Mosquito Association 53: 31-35 (Amvac Ref. #1398)

SPECIES: Various (natural populations)
STAGE: Adult
AGE: Unknown (wild)
SEX: Female
PLOT SIZE: Small community, not reported
NUMBER TRIALS: 6
APPLICATION TECHNIQUE/EQUIPMENT: Leco HD ULV aerosol generator
EVALUATION PROCEDURES: Changes in CDC light trap collections; changes in truck trap collections;
SAMPLING TECHNIQUE: All counts were based on natural populations
PERFORMANCE: 60% reduction in light traps; 40% reduction in truck trap collections; controls were reduced by 50%

1982 Rathburn, Jr., C. B., A. H. Boike, Jr., L. A. Sizemore, and M. W. Peters
Laboratory Tests of Mosquito Adulticides
J. Florida Anti-Mosquito Association 92-96 (Amvac Ref. #1394)

SPECIES: *Aedes taeniorhynchus*
STAGE: Adult
AGE: 3 – 8 days old (lab colony)
SEX: Female
PLOT SIZE: N/A
NUMBER TRIALS:
APPLICATION TECHNIQUE/EQUIPMENT: Wind tunnel
EVALUATION PROCEDURES: Mortality at 24 hours, LC 50 and LC 90
SAMPLING TECHNIQUE: No population assessment
PERFORMANCE: LC 50 = 0.079 mg AI/ml, LC 90 = 0.161 mg AI/ml; Naled more toxic than Malathion

SPECIES: *Culex nigripalpus*
STAGE: Adult
AGE: 3 – 8 days old (lab colony)
SEX: Female
PLOT SIZE: N/A
NUMBER TRIALS:
APPLICATION TECHNIQUE/EQUIPMENT: Wind tunnel
EVALUATION PROCEDURES: Mortality at 24 hours, LC 50 and LC 90
SAMPLING TECHNIQUE: No population assessment
PERFORMANCE: LC 50 = 0.057 mg AI/ml, LC 90 = 0.110 mg AI/ml; Naled more toxic than Malathion

SPECIES: *Culex quinquefasciatus*
STAGE: Adult
AGE: 3 – 8 days old (lab colony)
SEX: Female
PLOT SIZE: N/A
NUMBER TRIALS:
APPLICATION TECHNIQUE/EQUIPMENT: Wind tunnel
EVALUATION PROCEDURES: Mortality at 24 hours, LC 50 and LC 90
SAMPLING TECHNIQUE: No population assessment
PERFORMANCE: LC 50 = 0.071 – 0.098 mg AI/ml, LC 90 = 0.118 – 0.266 mg AI/ml; Naled more toxic than Malathion

1981 Kline, D. L., D. G. Haile, and K. F. Baldwin
Wind Tunnel Tests with Seven Insecticides Against Adult Culicoides mississippiensis
Mosquito News 41: 745-747 (Amvac Ref. #1393)

SPECIES: *Culicoides mississippiensis*
STAGE: Adult
AGE: Unknown, wild
SEX: Female
PLOT SIZE: N/A
NUMBER TRIALS: 3
APPLICATION TECHNIQUE/EQUIPMENT: Wind tunnel, air atomizing nozzle #12891 1/8 JJ
EVALUATION PROCEDURES: Mortality and knockdown at 1 and 24 hours to establish LD 50 and LD 90
SAMPLING TECHNIQUE: No population assessment
PERFORMANCE: % concentration for 1-hour knockdown: 0.03523; 24 hour LC 50 = 0.01143; 24 hour LD 90 = 0.07379
Naled and Malathion had equal knockdown capability; naled was more effective than Malathion; data will be used to design field application experiments

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1981 Rathburn Jr., C. B., A. H. Boike, Jr., C. F. Hallmon and R. L. Welles
Field Tests of Insecticides Applied as ULV Sprays by Ground Equipment for the Control of Adult Mosquitoes
Mosquito News 41: 132-135 (Amvac Ref. #1399)

SPECIES: *Aedes taeniorhynchus*
STAGE: Adult
AGE: 2 – 8 days old (lab colony, OP susceptible)
SEX: Female
PLOT SIZE: Not reported (open beach residential area)
NUMBER TRIALS: 3 - 4
APPLICATION TECHNIQUE/EQUIPMENT: Ground ULV; Leco HD ULV cold aerosol generator
EVALUATION PROCEDURES: Mortality of caged mosquitoes
SAMPLING TECHNIQUE: No population assessment
PERFORMANCE: naled + HAN: 97% mortality; naled + Chevron 400: 99% mortality; naled + 3% diesel oil: 94% mortality; naled + 2% diesel oil: 81% mortality

SPECIES: *Culex nigripalpus*
STAGE: Adult
AGE: 2 – 8 days old (lab colony, OP susceptible)
SEX: Female
PLOT SIZE: Not reported (open beach residential area)
NUMBER TRIALS: 3 – 4
APPLICATION TECHNIQUE/EQUIPMENT: Ground ULV; Leco HD ULV cold aerosol generator
EVALUATION PROCEDURES: Mortality of caged mosquitoes
SAMPLING TECHNIQUE: No population assessment
PERFORMANCE: naled + HAN: 99% mortality; naled + Chevron 400: 100% mortality; naled + 3% diesel oil: 100% mortality; naled + 2% diesel oil: 95% mortality

1979 Boike, A. H., Jr., C. B. Rathburn, Jr., C. F. Hallmon, and S. G. Cotterman
Insecticide Susceptibility Levels of Some Florida Mosquitoes
Proceedings of the Florida Anti-Mosquito Association 62-67 (Amvac Ref. #1392)

SPECIES: *Aedes taeniorhynchus*
STAGE: Larvae, Adults
AGE: Not reported
SEX: Not reported
PLOT SIZE: N/A
NUMBER TRIALS: 70 (L); 7 (A)
APPLICATION TECHNIQUE/EQUIPMENT: Beaker bioassay in laboratory (L), Wind tunnel (A)
EVALUATION PROCEDURES: LC 50 and LC 90 compared to lab susceptible strains
SAMPLING TECHNIQUE: Test specimens were from wild collections
PERFORMANCE: Still susceptible to naled; no differences in lab strain

SPECIES: *Culex nigripalpus*
STAGE: Larvae
AGE: Not reported
SEX: Not reported
PLOT SIZE: N/A
NUMBER TRIALS: 22 (L)
APPLICATION TECHNIQUE/EQUIPMENT: Beaker bioassay in laboratory (L)
EVALUATION PROCEDURES: LC 50 and LC 90 compared to lab susceptible strains
SAMPLING TECHNIQUE: Test specimens were from wild collections
PERFORMANCE: Still susceptible to naled; no differences in lab strain

SPECIES: *Culex quinquefasciatus*
STAGE: Larvae
AGE: Not reported
SEX: Not reported
PLOT SIZE: N/A
NUMBER TRIALS: 37 (L)
APPLICATION TECHNIQUE/EQUIPMENT: Beaker bioassay in laboratory (L)
EVALUATION PROCEDURES: LC 50 and LC 90 compared to lab susceptible strains
SAMPLING TECHNIQUE: Test specimens were from wild collections
PERFORMANCE: One strain resistant : 3.0X (LC 50) – 8.1X (LC 90); other strains still susceptible to naled

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1979 Focks, D. A., D. A. Dame, A. L. Cameron, and M. D. Boston
Susceptibility of *Toxorhynchites Rutilus Rutilus* to Five Adulticides Currently Used for Mosquito Control
Mosquito News 39: 304-306 (Amvac Ref. #1391)

SPECIES: *Toxorhynchites rutilus rutilus*
STAGE: Adult
AGE: 14 days old (lab colony)
SEX: Male and female
PLOT SIZE: N/A
NUMBER TRIALS: 3
APPLICATION TECHNIQUE/EQUIPMENT: Wind tunnel
EVALUATION PROCEDURES: 1-hour knockdown and 24 hour mortality of caged mosquitoes; LC 50 and LC 90
PERFORMANCE: Relatively quick knockdown – within one hour (no data presented); % concentration LC 50 = 0.0139; LC 90 = 0.0212*

*Naled was the second least toxic of five adulticides; this species is predacious on other mosquitoes, the more tolerant they are to the insecticide, the better for biological control efforts.

1978 Boike, A. H., Jr., C. B. Rathburn, Jr., C. F. Hallmon, and S. G. Cotterman
Insecticide Susceptibility Tests of Aedes Taeniorhynchus and Culex Nigripalpus in Florida, 1974-1976
Mosquito News 38: 210-217 (Amvac Ref. #1384)

SPECIES: *Aedes taeniorhynchus*
STAGE: Larvae from wild adults
AGE: Not reported
SEX: Not reported
PLOT SIZE: N/A
NUMBER TRIALS: 104
APPLICATION TECHNIQUE/EQUIPMENT: Beaker tests in laboratory
EVALUATION PROCEDURES: LC 50 and LC 90 compared to laboratory susceptible strain
SAMPLING TECHNIQUE: Test samples were from wild material and compared to colony material
PERFORMANCE: Larvae from over 3-year period were as susceptible as the laboratory-susceptible strain

SPECIES: *Aedes taeniorhynchus*
STAGE: Adults from wild adults
AGE: Not reported
SEX: Not reported
PLOT SIZE: N/A
NUMBER TRIALS: 15
APPLICATION TECHNIQUE/EQUIPMENT: Wind tunnel
EVALUATION PROCEDURES: LC 50 and LC 90 compared to laboratory susceptible strain
SAMPLING TECHNIQUE: Test samples were from wild material and compared to colony material
PERFORMANCE: Adults from over 3-year period were as susceptible as the laboratory-susceptible strain

SPECIES: *Culex nigripalpus*
STAGE: Larvae from wild adults
AGE: Not reported
SEX: Not reported
PLOT SIZE: N/A
NUMBER TRIALS: 50
APPLICATION TECHNIQUE/EQUIPMENT: Beaker tests in laboratory
EVALUATION PROCEDURES: LC 50 and LC 90 compared to laboratory susceptible strain
SAMPLING TECHNIQUE: Wild larvae were compared to lab larvae
PERFORMANCE: Larvae were as tolerant as the laboratory strain

SPECIES: *Culex nigripalpus*
STAGE: Adults from wild adults
AGE: Not reported
SEX: Not reported
PLOT SIZE: N/A
NUMBER TRIALS: 11
APPLICATION TECHNIQUE/EQUIPMENT: Wind tunnel
EVALUATION PROCEDURES: LC 50 and LC 90 compared to laboratory susceptible strain
SAMPLING TECHNIQUE: Wild adults were compared to lab adults
PERFORMANCE: Adults were 2X (LC 50) and 4X (LC 90) less tolerant than the laboratory strain

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1978 Bourg, J. A., M. K. Carroll and A. J. Blake
AG-CAT ULV Spray System Development, Calibration, and Field Tests Using Naled.
Mosquito News 38: 36-38 (Amvac Ref. #1385)

SPECIES: *Aedes sollicitans, Culex salinarius*
STAGE: Adult
AGE: Unknown, wild
SEX: Female
PLOT SIZE: 125 ha
NUMBER TRIALS: Not reported
APPLICATION TECHNIQUE/EQUIPMENT: Aerial ULV; Grumman Ag-Cat; 8001 Teejet nozzles
EVALUATION PROCEDURES: Mortality of caged mosquitoes
SAMPLING TECHNIQUE: Landing rates of natural populations
PERFORMANCE: 1.5 hour mortality = 100%; 71% (*Aedes*) - 88% (*Culex*) reduction in landing rate counts

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1978 Hester, P. G., B. W. Clements, Jr., J. C. Dukes, and W. N. Swenson
Effects of Dibrom Applied as Aerial Sprays on Non-Target Salt Marsh Organisms in Northwest Florida
Proceedings of the Florida Anti-Mosquito Association 3-5 (Amvac Ref. #1388)

SPECIES: *Stomoxys calcitrans*
STAGE: Adult
AGE: Not reported (lab colony)
SEX: Not reported
PLOT SIZE: 840 acres
NUMBER TRIALS: 3
APPLICATION TECHNIQUE/EQUIPMENT: Aerial; 25% Dibrom by volume in soybean oil
EVALUATION PROCEDURES: 24 hour Mortality of caged stable flies
SAMPLING TECHNIQUE: No population assessment; studied effects on non-targets
PERFORMANCE: Average mortality in four tests = 91%*
*Non-target effects = no obvious adverse effects to any of the marsh inhabiting organisms tested.

1978 Meek, L., G. Faget, and T. Morganti
Horse Flies Target Of Insecticide Tests
Louisiana Agriculture 21: 14-15 (Amvac Ref. #1386)

SPECIES: *Tabanus nigrivittatus*
STAGE: Adult
AGE: Unknown (wild)
SEX: Not reported
PLOT SIZE: Up to 300' from line of spray
NUMBER TRIALS: 8
APPLICATION TECHNIQUE/EQUIPMENT: Truck mounted ULV
EVALUATION PROCEDURES: Mortality of caged flies
SAMPLING TECHNIQUE: Flies were trapped from local populations
PERFORMANCE: Average mortality over 8 tests at various distances:
1 hour post-treat: 50' = 100%; 6 hours post-treat = 100%
1 hour post-treat 100' = 100%; 6 hours post-treat = 100%
1 hour post-treat 150' = 100%; 6 hours post-treat = 100%
1 hour post-treat 200' = 98.7%; 6 hours post-treat = 100%
1 hour post-treat 250' = 98.7%; 6 hours post-treat = 100%
1 hour post-treat 300' = 85%; 6 hours post-treat = 100%

1978 Meisch, M. V.
Ultralow Volume Aerial Applications Of Insecticides For Mosquito Control In Arkansas Riceland Communities
Mosquito News 38: 343-346 (Amvac Ref. #1387)

SPECIES: Mixed, wild. Primarily *Psorophora columbiae, Anopheles quadrimaculatus*
STAGE: Adult
AGE: Unknown, wild
SEX: Mix
PLOT SIZE: 16 sq. miles
NUMBER TRIALS: 1
APPLICATION TECHNIQUE/EQUIPMENT: Aerial ULV; Hollow cone Flat fan Tee Jet nozzles (D-3)
EVALUATION PROCEDURES: Percent reduction in landing rates and light trap counts
SAMPLING TECHNIQUE: Landing rates; New Jersey light trap counts
PERFORMANCE: Light traps = 89% reduction night of treatment; 50% reduction at 24 hours post-treat; 50% reduction at 5 days post-treat; Landing rates = 92% reduction night of treatment; 76% reduction at 24 hours post-treat; 74% reduction at 5 days post-treat

1978 Mount, G. A., N. W. Pierce, K. F. Baldwin and F. Washington
Control Of Aedes Taeniorhynchus At Crescent Beach, Florida, With Aerosols Of Propoxur (Baygon® Mos) And Naled (Dibrom® 14)
Mosquito News 38: 54-56 (Amvac Ref. #1389)

SPECIES: *Aedes taeniorhynchus*
STAGE: Adult
AGE: Caged: 3 – 5 days old (OP susceptible lab colony); Natural population: age unknown
SEX: Female
PLOT SIZE: 50 acres
NUMBER TRIALS: 3
APPLICATION TECHNIQUE/EQUIPMENT: Ground ULV; Leco HD aerosol generator
EVALUATION PROCEDURES: Mortality of caged mosquitoes; Percent control of natural population
SAMPLING TECHNIQUE: Landing rates before and after treatment
PERFORMANCE: 24 hour mortality of caged mosquitoes: 65%; Control of native population: 85%

1978 Sutherland, D. J., R. Kent and J. Downing
The Effect Of Aerial ULV Adulticiding With Malathion And Naled On Field Populations Of Aedes Sollicitans
Mosquito News 38: 488-491 (Amvac Ref. #1390)

SPECIES: *Aedes sollicitans*
STAGE: Adult
AGE: Unknown, wild
SEX: Female
PLOT SIZE: 1600 ha
NUMBER TRIALS: 50 operational applications
APPLICATION TECHNIQUE/EQUIPMENT: Aerial ULV; 8 – 14 nozzles (size range 80015 to 8005)
EVALUATION PROCEDURES: Change in landing rates 3 days pre- and post-application
SAMPLING TECHNIQUE: Landing rates
PERFORMANCE: Day 1 post-treat = reduction occurs 77.75 of time; Day 2 post-treat = reduction occurs 92% of time; Day 3 post-treat = reduction occurs 83.4% of time
Decrease in landing rates on day 1 higher than Malathion; general decrease in the reduction over the 3 days

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1978 Altman, R.
Maryland Uses Naled Against Salt March Mosquitoes
Pest Control 14-18 (Amvac Ref. #1423)

SPECIES: *Aedes sollicitans*
STAGE: Adult
AGE: Unknown, wild
SEX: Not given
PLOT SIZE: 640 Acres
NUMBER TRIALS: 1
APPLICATION TECHNIQUE/EQUIPMENT: Aerial ULV; single engine aircraft
EVALUATION PROCEDURES: Mortality estimated post-application
SAMPLING TECHNIQUE: Not given
PERFORMANCE: Estimated >80% mortality

1977 Dukes, J. C. and R. C. Axtell
Chemical Control Of Coastal Biting Flies And Gnats
Proceedings of the New Jersey Mosquito Extermination Association 62: 232-233 (Amvac Ref. #1382)

SPECIES: *Chrysops atlanticus, C. fuliginosus, Tabanus nigrovittatus*
STAGE: Adult
AGE: Not reported
SEX: Not reported
PLOT SIZE: Up to 150' downwind of spray
NUMBER TRIALS:
APPLICATION TECHNIQUE/EQUIPMENT: Ground ULV aerosol; Leco ULV-HD
EVALUATION PROCEDURES: Mortality of caged flies
SAMPLING TECHNIQUE: Unknown
PERFORMANCE: 90% or better at 12 oz/acre

1977 Moseley, K., J. Mullenix, and R. T. Taylor
Organophosphorous Resistance In The Memphis, Tennessee, *Culex Pipiens* Complex
Mosquito News 37: 271-275 (Amvac Ref. #1383)

SPECIES: *Culex pipiens* complex
STAGE: Adult
AGE: Unknown, wild
SEX: Female
PLOT SIZE: 150 – 300 ft from spray discharge
NUMBER TRIALS: 3
APPLICATION TECHNIQUE/EQUIPMENT: Ground; truck mounted Leco HC ULV Fog Generator
EVALUATION PROCEDURES: Mortality at 12 and 24 hours post-treat
SAMPLING TECHNIQUE: Test mosquitoes were from natural field collections
PERFORMANCE: 24 hour mortality: 75' = 21%; 150' = 25%; 300' = 37%

SPECIES: *Culex pipiens* complex
STAGE: Adult
AGE: 3 day old (laboratory colony)
SEX: Female
PLOT SIZE: 150 – 300 ft from spray discharge
NUMBER TRIALS: 3
APPLICATION TECHNIQUE/EQUIPMENT: Hoskins-Caldwell Spray Chamber, No. 631 Atomizer
EVALUATION PROCEDURES:
SAMPLING TECHNIQUE: No population assessment
PERFORMANCE: High mortality at lower dosages; 30% kill

1977 Jolivet, P.H.A., Hong, H.K., Lee, C.S., and H.L. Mathis
Ground Aerosol of Ultra-Low-Volume Dibrom Against *Culex tritaeniorhynchus* in Pusan, Korea
Korean Journal of Entomology 2: 29-32 (Amvac Ref. #1427)

SPECIES: *Culex tritaeniorhynchus*
STAGE: Adult
AGE: Unknown, wild
SEX: Not given
PLOT SIZE: 76 ha
NUMBER TRIALS: 3
APPLICATION TECHNIQUE/EQUIPMENT: Ground; trailer mounted LECO cold aerosol machine
EVALUATION PROCEDURES: Mortality at 1, 2, 3, and 4 days post-treat
SAMPLING TECHNIQUE: Bioassays of caged adults
PERFORMANCE: 24 hour mortality: 40% to 50%; Overall 4-day mortality: 24% to 32%

SPECIES: *Culex tritaeniorhynchus*
STAGE: Larva
AGE: Unknown, wild
SEX: Not given
PLOT SIZE: 76 ha
NUMBER TRIALS: 3
APPLICATION TECHNIQUE/EQUIPMENT: Ground; trailer mounted LECO cold aerosol machine
EVALUATION PROCEDURES: Mortality at 1, 2, 3, and 4 days post-treat
SAMPLING TECHNIQUE: Bioassays of caged larvae
PERFORMANCE: Natural reductions similar to control group

1976 Palmisano, C. T., C. D. Steelman and P. E. Schilling
Relative Effects Of Insecticide Usage In Louisiana Mosquito Control Programs On The Susceptibility Of Adult Female Culex Pipiens Quinquefasciatus Populations
Mosquito News 36: 521-527 (Amvac Ref. #1380)

SPECIES: *Culex pipiens quinquefasciatus*
STAGE: Adult
AGE: 3 – 7 day old
SEX: Females
PLOT SIZE: Not applicable
NUMBER TRIALS:
APPLICATION TECHNIQUE/EQUIPMENT: Wind tunnel
EVALUATION PROCEDURES: Comparison of LC 50 and LC 90 for different localities
SAMPLING TECHNIQUE: Test adults were from wild larvae
PERFORMANCE: Less than 2X difference (LC 50) in 6/7 localities; LC 50 significantly different in Jefferson (area where MCD used naled for 5 years)

1976 Steelman, C. D., and D. S. Devitt
Development Of Organophosphate Tolerance In Field Populations Of Culex Pipiens Quinquefasciatus Say In Louisiana
Mosquito News 36: 361-363 (Amvac Ref. #1381)

SPECIES: *Culex pipiens quinquefasciatus*
STAGE: Larvae
AGE: Not reported
SEX: Not reported
PLOT SIZE: N/A
NUMBER TRIALS: 11
APPLICATION TECHNIQUE/EQUIPMENT: Beaker tests in laboratory
EVALUATION PROCEDURES: LC 50 and LC 90 compared over years
SAMPLING TECHNIQUE: Test larvae were field collected from 4 areas of Louisiana
PERFORMANCE: Orleans = no change in susceptibility; Jefferson = 2X increased in LC 50 over 5 years; St. Tammany = 20x (LC50) and 50X (LC90) less susceptible over 5 year period; St. Bernard = no comparative data, only one year

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1975 Boike, A. H., and C. B. Rathburn, Jr.
Laboratory Susceptibility Tests Of Some Florida Strains Of *Aedes Taeniorhynchus* (Wied.) And *Culex Nigripalpus* Theob. To Malathion And Naled, 1972-1974
Mosquito News 35: 137-140 (Amvac Ref. #1379)

SPECIES: *Aedes taeniorhynchus*
STAGE: Adults
AGE: 2 – 8 days old
SEX: Not reported
PLOT SIZE: N/A
NUMBER TRIALS: 8
APPLICATION TECHNIQUE/EQUIPMENT: Wild tunnel
EVALUATION PROCEDURES: LC 50 and LC 90 compared to laboratory colony
SAMPLING TECHNIQUE: Test samples were from various wild collections
PERFORMANCE: No resistance to naled.

SPECIES: *Aedes taeniorhynchus*
STAGE: Larvae
AGE: Not reported
SEX: Not reported
PLOT SIZE: N/A
NUMBER TRIALS:
APPLICATION TECHNIQUE/EQUIPMENT: Beaker tests in laboratory
EVALUATION PROCEDURES: LC 50 and LC 90 compared to laboratory colony
SAMPLING TECHNIQUE: Test samples were from various wild collections
PERFORMANCE: LC 50 and LC 90 values were less than twice the lab colony; No resistance to naled.

SPECIES: *Culex nigripalpus*
STAGE: Adults
AGE: 2 -8 days old
SEX: Not reported
PLOT SIZE: N/A
NUMBER TRIALS:
APPLICATION TECHNIQUE/EQUIPMENT: Wind tunnel
EVALUATION PROCEDURES: LC 50 and LC 90 compared to laboratory colony
SAMPLING TECHNIQUE: Test samples were from various wild collections
PERFORMANCE: Generally susceptible to naled. No resistance found.

SPECIES: *Culex nigripalpus*
STAGE: Larvae
AGE: Not reported
SEX: Not reported
PLOT SIZE: N/A
NUMBER TRIALS:
APPLICATION TECHNIQUE/EQUIPMENT: Beaker tests in laboratory
EVALUATION PROCEDURES: LC 50 and LC 90 compared to laboratory colony
SAMPLING TECHNIQUE: Test samples were from various wild collections
PERFORMANCE: Some populations were more tolerant to naled than the lab colony, however, no resistance found.

1975 Boike, A. H., Jr., and C. B. Rathburn, Jr.
Laboratory Non-Thermal Aerosol Tests Of Insecticides For The Control Of Adult Mosquitoes
Mosquito News 35: 488-490 (Amvac Ref. #151)

SPECIES: *Aedes taeniorhynchus*
STAGE: Adult
AGE: Not reported
SEX: Not reported
PLOT SIZE: N/A
NUMBER TRIALS: 34
APPLICATION TECHNIQUE/EQUIPMENT: Wind tunnel
EVALUATION PROCEDURES: LC 50 and LC 90 comparisons to Malathion
SAMPLING TECHNIQUE: No population assessment
PERFORMANCE: 1.7 – 1.3X more toxic than Malathion

SPECIES: *Culex nigripalpus*
STAGE: Adult
AGE: Not reported
SEX: Not reported
PLOT SIZE: N/A
NUMBER TRIALS: 34
APPLICATION TECHNIQUE/EQUIPMENT: Wind tunnel
EVALUATION PROCEDURES: LC 50 and LC 90 comparisons to Malathion
SAMPLING TECHNIQUE: No population assessment
PERFORMANCE: 11 – 13X more toxic than Malathion

1975 Rathburn, C. B., Jr., and A. H. Boike, Jr.
Ultra Low Volume Tests Of Several Insecticides Applied By Ground Equipment For The Control Of Adult Mosquitoes
Mosquito News 35: 26-29 (Amvac Ref. #149)

SPECIES: *Aedes taeniorhynchus*
STAGE: Adult
AGE: 2 – 8 days old (lab colonies)
SEX: Female
PLOT SIZE: Not reported
NUMBER TRIALS: 4
APPLICATION TECHNIQUE/EQUIPMENT: Ground ULV; Buffalo Turbine Model M; 5 Sonicore nozzles
EVALUATION PROCEDURES: Mortality of caged mosquitoes at 15 hours post-treat
SAMPLING TECHNIQUE: No population assessment
PERFORMANCE: Average kill = 95%

SPECIES: *Culex nigripalpus*
STAGE: Adult
AGE: 2 – 8 days old (lab colonies)
SEX: Female
PLOT SIZE: Not reported
NUMBER TRIALS: 4
APPLICATION TECHNIQUE/EQUIPMENT: Ground ULV; Buffalo Turbine Model M; 5 Sonicore nozzles
EVALUATION PROCEDURES: Mortality of caged mosquitoes at 15 hours post-treat
SAMPLING TECHNIQUE: No population assessment
PERFORMANCE: Average kill = 95%

1974 Gorham, J. R.
Malathion And Naled As Mosquito Adulticides In Alaska
Mosquito News 34: 286-290 (Amvac Ref. #1375)

SPECIES: 15 species including *Aedes intrudens, Ae, fitchii, Ae. communis, Ae. punctor*
STAGE: Adult
AGE: Not reported
SEX: Females
PLOT SIZE: 100, 200, 300 ft from spray discharge
NUMBER TRIALS: 2 - 23
APPLICATION TECHNIQUE/EQUIPMENT: Ground; low volume fog
EVALUATION PROCEDURES: Mortality of caged mosquitoes at 6' and on ground
SAMPLING TECHNIQUE: Test specimens were from natural wild populations
PERFORMANCE: Mortality at 100' = 99% (100% at 6': 65% on ground);
200' = 86% (100% at 6': 18% on ground);
300' = 66% (44% at 6', 4% on ground)
Naled is effective and reduced satisfactory levels of mortality of caged mosquitoes

1974 Mount, G. A. and N. W. Pierce
Ultralow Volume Ground Aerosols Of Naled For Control Of Aedes Taeniorhynchus (Wiedemann) In The Florida Keys
Mosquito News 34: 268-269 (Amvac Ref. #1376)

SPECIES: *Aedes taeniorhynchus*
STAGE: Adult
AGE: Unknown, wild
SEX: Female
PLOT SIZE: 120 – 350 acres
NUMBER TRIALS: 4 (0.01 lb/acre) ,3 (0.015 lb/acre), and 3 (0.02 lb/acre)
APPLICATION TECHNIQUE/EQUIPMENT: Ground; Leco HD ULV aerosol generator
EVALUATION PROCEDURES: Change in pre- and post-treat landing counts
SAMPLING TECHNIQUE: Landing counts
PERFORMANCE: Average reduction in landing counts after 30 – 45 min = 72% (0.01 lb.acre), 73% (0.015 lb/acre), and 86% (0.02 lb/acre). Early morning applications gave more satisfactory control

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1974 Mount, G. A., J. A. Seawright, and N. W. Pierce
Selection Response And Cross Susceptibility Of A Malathion-Resistant Strain Of *Aedes Taehiorhynchus* (Wiedmann) To Other Adulticides
Mosquito News 34: 276-277 (Amvac Ref. #1377)

SPECIES: *Aedes taehiorhynchus*
STAGE: Adult
AGE: Not reported
SEX: Female
PLOT SIZE: N/A
NUMBER TRIALS: Not reported
APPLICATION TECHNIQUE/EQUIPMENT: Wind tunnel
EVALUATION PROCEDURES: LC 90 at 24 hours compared to resistant and susceptible strain
SAMPLING TECHNIQUE: No population assessment
PERFORMANCE: High degree of resistance to Malathion in this species does not cause cross-resistance to naled

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1974 Stains, G. S
Emergency Mosquito Adulticiding Operations Conducted In The Palo Verde Valley, Eastern Riverside County, California
Proceedings of the California Mosquito Control Association, Inc. 98 (Amvac Ref. #1378)

SPECIES: *Culex tarsalis*
STAGE: Adult
AGE: Unknown (wild)
SEX: Mixed
PLOT SIZE: 42 square miles
NUMBER TRIALS: Operational, not reported
APPLICATION TECHNIQUE/EQUIPMENT: Micro-Gen Non-thermal aerosol generators
EVALUATION PROCEDURES: Changes in light trap counts
SAMPLING TECHNIQUE: Natural populations were trapped
PERFORMANCE: Trap counts reduced from 246 per night to 3 per night

1973 Ludlam, K. W., R. A. Berry, and S. R. Joseph
The Effect Of Ground ULV Applications On Natural Populations As Evaluated By Landing Rate Counts
Proceedings of the New Jersey Mosquito Extermination Association 60: 93-96 (Amvac Ref. #1373)

SPECIES: *Aedes sollicitans, Ae. atlanticus, Ae. canadensis, Ae. taeniorhynchus, Ae. cantator, Ae. vexans, Ae. triseriatus, Ae. trivittatus, Psorophora ferox, Ps. ciliata, Ps.confinnis, Ps. cyanescens, Anopheles crucians/bradelyi, An. punctipennis, An. quadrimaculatus, Culex salinarius, Coquillettidia perturbans*
STAGE: Adults
AGE: Unknown (wild)
SEX: Female
PLOT SIZE:
NUMBER TRIALS:
APPLICATION TECHNIQUE/EQUIPMENT: Leco Model HD cold aerosol fog generator
EVALUATION PROCEDURES: Percent change in landing rates
SAMPLING TECHNIQUE: Landing rates of natural populations
PERFORMANCE: Night treatments: 1 hour: 44% reduction; 24 hours: 80% reduction; 48 hours: 82% reduction; 72 hours: 72% reduction
Day treatments: 12 hours: 49% reduction

1973 Mount, G. A., and N. W. Pierce
Toxicity Of Selected Adulticides To Six Species Of Mosquitoes
Mosquito News 33: 368-370 (Amvac Ref. #1374)

SPECIES: *Aedes taeniorhynchus, Aedes aegypti, Culex p. quinquefasciatus, C. nigripalpus, Anopheles quadrimaculatus, An. albimanus*
STAGE: Adult
AGE: Not reported
SEX: Female
PLOT SIZE: N/A
NUMBER TRIALS: 1 - 4
APPLICATION TECHNIQUE/EQUIPMENT: Wind tunnel
EVALUATION PROCEDURES: LC 90 at 24 hours
SAMPLING TECHNIQUE: No population assessment
PERFORMANCE: 2-fold range between the most and least susceptible species. Naled was most consistent of the adulticides

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1972 Boike, Jr. A. H., and C. B. Rathburn, Jr.
The Susceptibility Of Mosquito Larvae To Insecticides In Florida, 1969-1971
Mosquito News 32: 328-331 (Amvac Ref. #1366)

SPECIES: *Aedes taeniorhynchus, Aedes sollicitans, Culex nigripalpus, Culex salinarius*
STAGE: Larvae
AGE: Not reported
SEX: Not reported
PLOT SIZE: N/A
NUMBER TRIALS: 45
APPLICATION TECHNIQUE/EQUIPMENT: Beaker tests in laboratory
EVALUATION PROCEDURES: LC 50 and LC 90 compared to laboratory susceptible colony
SAMPLING TECHNIQUE: Test specimens were collected from natural populations in various areas over two years
PERFORMANCE: Little variation in susceptibility for all populations when compared to lab strains. No resistance detected.

1972 Gillies, P. A., E. M. Fussell, and D. J. Womeldorf
Mortality Of Cages Organophosphorous-Resistant Culex Tarsalis Coquillette Using Various Adulticides Applied As Nonthermal Aerosols (Amvac Ref. #1367)

SPECIES: *Aedes nigromaculis*
STAGE: Adults
AGE: Unknown (wild)
SEX: Not reported
PLOT SIZE: Up to 5000' downwind
NUMBER TRIALS: Not reported
APPLICATION TECHNIQUE/EQUIPMENT: Truck mounted nonthermal aerosol generator
EVALUATION PROCEDURES: Mortality of caged mosquitoes
SAMPLING TECHNIQUE: Tests conducted on wild caught mosquitoes
PERFORMANCE: 100% mortality out to 1500'

SPECIES: *Culex tarsalis*
STAGE: Adults
AGE: Unknown (wild)
SEX: Not reported
PLOT SIZE: Up to 5000' downwind
NUMBER TRIALS: Not reported
APPLICATION TECHNIQUE/EQUIPMENT: Truck mounted nonthermal aerosol generator
EVALUATION PROCEDURES: Mortality of caged mosquitoes
SAMPLING TECHNIQUE: Tests conducted on wild caught mosquitoes
PERFORMANCE: 100% mortality out to 1500'

SPECIES: *Culex pipiens*
STAGE: Adults
AGE: Not reported (lab)
SEX: Not reported
PLOT SIZE: Up to 5000' downwind
NUMBER TRIALS: Not reported
APPLICATION TECHNIQUE/EQUIPMENT: Truck mounted nonthermal aerosol generator
EVALUATION PROCEDURES: Mortality of caged mosquitoes
SAMPLING TECHNIQUE: No population assessment
PERFORMANCE: 100% mortality at all distances

1972 Gilotra, S., W. Schulte, C. Anderson, G. Carmichael, G. Stokes, and S. Richie.
Determination Of Susceptibility Levels Of Mosquitoes To Non-Persistent Insecticides By Microinjections
Mosquito News 32: 358-362 (Amvac Ref. #1368)

SPECIES: *Aedes sollicitans*
STAGE: Adult
AGE: 2-5 days old
SEX: Not reported
PLOT SIZE: N/A
NUMBER TRIALS: Not reported
APPLICATION TECHNIQUE/EQUIPMENT: Microinjections of technical grade naled under the cuticle
EVALUATION PROCEDURES: Percent mortality per nanogram of material
SAMPLING TECHNIQUE: Cannot determine
PERFORMANCE: 100% mortality with 8 nanograms/mosquito; 90% mortality with 4 nanograms/mosquito

SPECIES: *Aedes aegypti*
STAGE: Adult
AGE: 2-5 days old
SEX: Not reported
PLOT SIZE: N/A
NUMBER TRIALS: Not reported
APPLICATION TECHNIQUE/EQUIPMENT: Microinjections of technical grade naled under the cuticle
EVALUATION PROCEDURES: Percent mortality per nanogram of material
SAMPLING TECHNIQUE: Cannot determine
PERFORMANCE: 100% mortality with 4 nanograms/mosquito

SPECIES: *Culex quinquefasciatus*
STAGE: Adult
AGE: 2-5 days old
SEX: Not reported
PLOT SIZE: N/A
NUMBER TRIALS: Not reported
APPLICATION TECHNIQUE/EQUIPMENT: Microinjections of technical grade naled under the cuticle
EVALUATION PROCEDURES: Percent mortality per nanogram of material
SAMPLING TECHNIQUE: Cannot determine
PERFORMANCE: 100% mortality with 8 nanograms/mosquito with 4 different strains; 100% mortality with 4 nanograms/mosquito with 2 strains

SPECIES: *Culex salinarius*
STAGE: Adult
AGE: 2-5 days old
SEX: Not reported
PLOT SIZE: N/A
NUMBER TRIALS: Not reported
APPLICATION TECHNIQUE/EQUIPMENT: Microinjections of technical grade naled under the cuticle
EVALUATION PROCEDURES: Percent mortality per nanogram of material
SAMPLING TECHNIQUE: Cannot determine
PERFORMANCE: 98% - 100% mortality with 8 nanograms/mosquito with 3 different strains; 81 – 90% mortality with 4 nanograms/mosquito with 3 different strains.

1972 Mount, G. A., M. V. Meisch, J. T. Lee, N. W. Pierce, and K. F. Baldwin.
Ultralow Volume Ground Aerosols Of Insecticides For Control Of Rice Field Mosquitoes In Arkansas.
Mosquito News 32: 444-446 (Amvac Ref. #1370)

SPECIES: Mixed, wild; Primarily *Psorophora confinnis*
STAGE: Adult
AGE: Unknown, wild
SEX: Mixed, wild
PLOT SIZE: Large scale, no precise size reported
NUMBER TRIALS: 2
APPLICATION TECHNIQUE/EQUIPMENT: ULV ground; Leco ULV aerosol generator
EVALUATION PROCEDURES: Percent change in landing rates; Comparison of New Jersey light trap collections in treated and control areas
SAMPLING TECHNIQUE: Landing rates; Light trap counts
PERFORMANCE: Trial 1: 1 – 2 hours: 100% reduction in landing; 24 hours: 62% reduction in landing. 24 hours: 58% reduction in light trap counts
Trial 2: 1 – 2 hours: 93% reduction in landing rates; 24 hours: 74% reduction in landing. 24 hours: 90% reduction in light trap counts

1972 Mount, G. A. and N. W. Pierce.
Adult Mosquito Kill And Droplet Size Of Ultralow Volume Ground Aerosols Of Insecticides.
Mosquito News 32: 354-357 (Amvac Ref. #1369)

SPECIES: *Aedes taeniorhynchus*
STAGE: Adult
AGE: 2 – 5 days old
SEX: Female
PLOT SIZE: 150' – 300' downwind
NUMBER TRIALS: Various
APPLICATION TECHNIQUE/EQUIPMENT: Ground ULV; Leco ULV cold aerosol generator
EVALUATION PROCEDURES: Mortality of caged mosquitoes at 18 hours; Estimation of LD 90
SAMPLING TECHNIQUE: No population assessment
PERFORMANCE: Naled in HAN: 7 reps at 1.5 PSI; 94% mortality (0.025 lb/acre) 80% (0.0125 lb/acre), LD 90 = 0.019 lb/acre;
Naled in HAN: 2 reps at 2.5 PSI; 67% mortality (0.025 lb/acre), LD 90 > 0.025 lb/acre;
Naled in HAN: 5 reps at 4.0 PSI; 64% mortality (0.025 lb/acre), 28% (0.0125 lb/acre), LD 90 > 0.025 lb/acre;
Naled in mineral seal oil: 2 reps at 1.5 PSI; 92% mortality (0.025 lb/acre), LD 90 = 0.022 lb/acre;
Naled in mineral seal oil: 1 rep at 4.0 PSI; 53% mortality (0.025 lb/acre), LD 90 > 0.025 lb/acre;
Naled in soybean oil: 5 reps at 4.0 PSI; 88% mortality (0.025 lb/acre), 60% mortality (0.0125 lb/acre), LD 90 = 0.027 lb/acre;
Dibrom 14: 5 reps at 4.0 PSI; 89% mortality (0.025 lb/acre), 73% mortality (0.0125 lb/acre), LD 90 = 0.025 l/acre
Dibrom 14: 2 reps at 2.5 PSI; 86% mortality (0.025 lb/acre), LD 90 = 0.03 lb/acre

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1972 Pinkovsky, D. D.
United States Air Force Aerial Spray Activities In Operation Combat VEE.
Mosquito News 32: 332-334 (Amvac Ref. #1371)

SPECIES: Mixed; Unknown; 12 target species including *Aedes sollicitans, Psorophora confinnis, Psorophora discolor*
STAGE: Adult
AGE: Unknown; wild
SEX: Mixed; wild
PLOT SIZE: 586,287 acres
NUMBER TRIALS: Operational
APPLICATION TECHNIQUE/EQUIPMENT: Aerial; 14 nozzles with 8004 tips; 45 PSI
EVALUATION PROCEDURES: Percent change in landing rates
SAMPLING TECHNIQUE: Landing rates of adult mosquitoes
PERFORMANCE: 94% - 98% control

1972 Rathburn, Jr., C. B. and A. H. Boike, Jr.
Laboratory Thermal Aerosol Tests Of New Insecticides For The Control Of Adult Mosquitoes
Mosquito News 32: 179-183 (Amvac Ref. #156)

SPECIES: *Aedes taeniorhynchus*
STAGE: Adult
AGE: 2 – 8 days old (lab colony)
SEX: Female
PLOT SIZE: N/A
NUMBER TRIALS: 14 (in kerosene), 16 (in diesel oil)
APPLICATION TECHNIQUE/EQUIPMENT: Wind tunnel
EVALUATION PROCEDURES: LC 50 and LC 90
SAMPLING TECHNIQUE: No population assessment
PERFORMANCE: Naled in kerosene: LC 50 = 0.53 mg/ml, LC 90 = 0.80 mg/ml;
Naled in diesel oil: LC 50 = 1.93 mg/ml, LC 90 = 2.77 mg/ml
Naled was more toxic than the Malathion standard

SPECIES: *Culex nigripalpus*
STAGE: Adult
AGE: 2 – 8 days old (lab colony)
SEX: Female
PLOT SIZE: N/A
NUMBER TRIALS: 10 (in kerosene), 12 (in diesel oil)
APPLICATION TECHNIQUE/EQUIPMENT: Wind tunnel
EVALUATION PROCEDURES: LC 50 and LC 90
SAMPLING TECHNIQUE: No population assessment
PERFORMANCE: Naled in kerosene: LC 50 = 0.48 mg/ml, LC 90 = 0.78 mg/ml;
Naled in diesel oil: LC 50 = 1.34 mg/ml, LC 90 = 2.10 mg/ml
Naled was more toxic than the Malathion standard

1972 Rogers, A. J., B. W. Clements, Jr., C. B. Rathburn Jr., A. H. Boike, Jr., and N. E. Thomas, Jr.
ULV Strip Spraying Of Naled By Aircraft For Control Of Adult Stable Flies And Mosquitoes
28-32 (Amvac Ref. #1372)

SPECIES: *Aedes taeniorhynchus, Culex nigripalpus*
STAGE: Adult
AGE: Not reported
SEX: Not reported
PLOT SIZE: 2700 acres
NUMBER TRIALS: 7 *Culex nigripalpus;* 4 *Aedes taeniorhynchus*
APPLICATION TECHNIQUE/EQUIPMENT: Aerial ULV; 32-800067 flat spray nozzles; 40 PSI boom pressure
EVALUATION PROCEDURES: Mortality of caged mosquitoes
SAMPLING TECHNIQUE: No population assessment
PERFORMANCE: 90% and greater mortality in vegetation: average distance downwind 1500 – 2500 feet (*Culex nigripalpus*), 800 – 1200 feet (*Aedes taeniorhynchus*)

SPECIES: *Aedes taeniorhynchus*
STAGE: Adult
AGE: Not reported
SEX: Not reported
PLOT SIZE: 2700 acres
NUMBER TRIALS: 5
APPLICATION TECHNIQUE/EQUIPMENT: Aerial ULV; 32-800067 flat spray nozzles; 40 PSI boom pressure
EVALUATION PROCEDURES: Mortality of caged mosquitoes; % control through trapping
SAMPLING TECHNIQUE: Trapping of natural populations
PERFORMANCE: 100% cage mortality (pine); 52 – 100% cage mortality (cypress); 56 – 96% cage mortality (titi); % control from trapping at day 1: 65 – 95%; day 2: 48 – 80%

SPECIES: *Culex nigripalpus*
STAGE: Adult
AGE: Not reported
SEX: Not reported
PLOT SIZE: 2700 acres
NUMBER TRIALS: 3
APPLICATION TECHNIQUE/EQUIPMENT: Aerial ULV; 32-800067 flat spray nozzles; 40 PSI boom pressure
EVALUATION PROCEDURES: Mortality of caged mosquitoes; % control through trapping
SAMPLING TECHNIQUE: Trapping of natural populations
PERFORMANCE: 100% cage mortality (pine); 83 - 89% cage mortality (cypress); 100 % cage mortality (titi); % control from trapping at day 1: 65 – 95%; day 2: 48 – 80%

SPECIES: *Stomoxys calcitrans*
STAGE: Adult
AGE: Not reported
SEX: Not reported
PLOT SIZE: 8 – 25 miles long
NUMBER TRIALS: 5 per test period
APPLICATION TECHNIQUE/EQUIPMENT: Aerial ULV; 32-800067 flat spray nozzles; 40-50 PSI boom pressure
EVALUATION PROCEDURES: Change in landing rates
SAMPLING TECHNIQUE: Landing rates
PERFORMANCE: Morning – afternoon: Immediately after treatment: 86% reduction in landing rates; 13-24 hours post-treat 79% reduction in landing rates.;
Afternoon – next morning: Immediately after treatment: 97% reduction in landing rates; 13-24 hours post-treat 86% reduction in landing rates;

SPECIES: *Stomoxys calcitrans*
STAGE: Adult
AGE: Not reported
SEX: Not reported
PLOT SIZE: 2700 acres
NUMBER TRIALS: 22
APPLICATION TECHNIQUE/EQUIPMENT: Aerial ULV; 32-800067 flat spray nozzles; 50 - 55 PSI boom pressure
EVALUATION PROCEDURES: Mortality of caged stable flies
SAMPLING TECHNIQUE: No population assessment
PERFORMANCE: 90% and greater mortality open roadway: average distance downwind 1700 – 5200 feet; In vegetation: average distance downwind 1000 – 5200 feet

1971 Mount, G. A., D. A. Dame and C. S. Lofgren.
Susceptibility Of A Florida Strain Of *Aedes Taeniorhynchus* (Weidemann) To Insecticides.
Mosquito News 31: 438-440 (Amvac Ref. #1364)

SPECIES: *Aedes taeniorhynchus*
STAGE: Larvae
AGE: 4th Instar (F1 reared from wild adults)
SEX: Not reported
PLOT SIZE: N/A
NUMBER TRIALS: 1
APPLICATION TECHNIQUE/EQUIPMENT: Laboratory bioassay in beakers
EVALUATION PROCEDURES: Mortality at 24 hours (Lethal concentration: LC 50, 90, and 99)
SAMPLING TECHNIQUE: No population assessment
PERFORMANCE: (Wild) LC 50 = 0.1 ppm; LC 90 = 0.2 ppm; LC 99 = 0.3 ppm.
(Laboratory) LC 50 = 0.06 ppm; LC 90 = 0.07 ppm; LC 99 = 0.09 ppm.
Susceptibilities of wild and lab strain were not significantly different.

SPECIES: *Aedes taeniorhynchus*
STAGE: Adult
AGE: Not reported (F1 reared from wild adults)
SEX: Female
PLOT SIZE: N/A
NUMBER TRIALS: 1
APPLICATION TECHNIQUE/EQUIPMENT: Wind tunnel
EVALUATION PROCEDURES: Knockdown and mortality counts at 1 and 24 hours
SAMPLING TECHNIQUE: No population assessment
PERFORMANCE: (Wild) One hour knockdown concentration = 0.032%; LC 50 = 0.013%; LC 90 = 0.027%; LC 99 = 0.048%.
(Laboratory) One hour knockdown concentration = 0.035%; LC 50 = 0.016 %; LC 90 = 0.031%; LC 99 = 0.054%.
Susceptibilities of wild and lab strain were not significantly different.

1971 Wilkinson, R. N., W. W. Barnes, A. R. Gillogly, and C. D. Minnemeyer.
Field Evaluation Of Slow-Release Mosquito Larvicides.
Journal of Economic Entomology 64: 1-3 (Amvac Ref. #1365)

SPECIES: *Culex quinquefasciatus*
STAGE: Larvae
AGE: 2nd Instar (lab reared)
SEX: Not reported
PLOT SIZE: 4 x 5 x 1.5 ft holes
NUMBER TRIALS: 3
APPLICATION TECHNIQUE/EQUIPMENT: In-pool bioassays
EVALUATION PROCEDURES: Mortality at 48 hours
SAMPLING TECHNIQUE: Larval dipping of natural populations (# weeks control)
PERFORMANCE: 0.5 ppm = 2 2/3 weeks control; 1.0 ppm = 2 1/3 weeks control; 2.5 ppm = 2 2/3 weeks control

1971 Rathburn, C.B. Jr., Rogers, A.J., Boike, A.H. Jr., and R.M. Lee
The Effectiveness of Aerial Sprays For The Control of Adult Mosquitoes In Florida As Assessed By Three Methods
Mosquito News 31:1:52-54 (Amvac Ref. #145)

SPECIES: *Culex nigripalpus*
STAGE: Adult
AGE: unknown, wild (2 to 8 days for caged)
SEX: Female
PLOT SIZE: 575 to 1400 Acres
NUMBER TRIALS: 4
APPLICATION TECHNIQUE/EQUIPMENT: Aerial ULV, Stearman aircraft
EVALUATION PROCEDURES: Percent change in landing rates / trap collections, and mortality of caged mosquitoes
SAMPLING TECHNIQUE: Miniature CDC light traps baited with dry ice (3 or 4 /treatment area); landing rates taken from 5 minutes to several hours (dark) after treatment
PERFORMANCE: Mortality of caged mosquitoes ranged from 58% to 100%; Trap collections ranged from ----57% to 58% reduction; Landing rates ranged from -22% to 100% reduction.

1970 Berry, R. A., S. R. Joseph, and J. Mallack
The Status Of ULV Sprays For Adult Mosquito Control In Maryland
Proceedings of the New Jersey Mosquito Extermination Association 57: 159-162 (Amvac Ref. #154)

SPECIES: *Culex pipiens, Culex salinarius, Culiseta melanura, Aedes sollicitans, Aedes taeniorhynchus, Anopheles bradleyi*
STAGE: Adult
AGE: Unknown (wild)
SEX: Female
PLOT SIZE: Not reported
NUMBER TRIALS: Not reported
APPLICATION TECHNIQUE/EQUIPMENT: Aerial ULV
EVALUATION PROCEDURES: Mortality of caged mosquitoes, landing rates
SAMPLING TECHNIQUE: Landing rates of local populations
PERFORMANCE: 94 – 100% mortality after 8 hours; Reduction in landing counts from 4.27/min to zero at 6 – 8 hours post-treat.

1970 Mount, G. A., N. W. Pierce, C. S. Lofgren, and J. B. Gahan
A New Ultra-Low Volume Cold Aerosol Nozzle For Dispersal Of Insecticides Against Adult Mosquitoes
Mosquito News 30: 56-59 (Amvac Ref. #1363)

SPECIES: *Aedes taenirohynchus*
STAGE: Adult
AGE: Not reported
SEX: Female
PLOT SIZE:
NUMBER TRIALS:
APPLICATION TECHNIQUE/EQUIPMENT: LECO ULV cold aerosol nozzle used on Leco 120 thermal aerosol generator and Curtis 55,000 cold aerosol generator
EVALUATION PROCEDURES: Mortality of caged mosquitoes
SAMPLING TECHNIQUE: No population assessment
PERFORMANCE: Average percent mortality at 18 hours: 0.006 lb/acre = 76% mortality; 0.012 lb.acre = 94% mortality

1970 Taylor, D. J. and C. B. Rathburn.
Large Area Tests Of Ultra Low Volume Naled For Control Of Adult Mosquitoes
Mosquito News 30: 383-387 (Amvac Ref. #147)

SPECIES: *Culex nigripalpus*
STAGE: Adult
AGE:
SEX: Female
PLOT SIZE: 17,920 acres, 2,880 acres, and 2,485 acres
NUMBER TRIALS: 3
APPLICATION TECHNIQUE/EQUIPMENT: Aerial; Nozzles 80015 and 8003
EVALUATION PROCEDURES: Percent reduction on landing counts, Percent change in CDC traps, Mortality of caged mosquitoes
SAMPLING TECHNIQUE: Landing counts and trapping of local populations
PERFORMANCE:
Test 1: 81% reduction in landing counts; 80% reduction in trap counts; 44% mortality in caged mosquitoes
Test 2: 64% reduction in landing counts; 14% reduction in trap counts; 3% mortality in caged mosquitoes
Test 3: 84% reduction in landing counts; 59% reduction in trap counts; 85% mortality in caged mosquitoes

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1969 Boike Jr., A. H., and C. B. Rathburn.
Laboratory Tests Of The Susceptibility Of Mosquito Larvae To Insecticides In Florida, 1968
Mosquito News 29: 392-395 (Amvac Ref. #1358)

SPECIES: *Aedes taeniorhynchus, Aedes aegypti, Culex nigripalpus, Culex salinarius*
STAGE: Larvae
AGE: 3rd Instar
SEX: Not reported
PLOT SIZE: N/A
NUMBER TRIALS: 4 – 40
APPLICATION TECHNIQUE/EQUIPMENT: Beaker bioassay in laboratory
EVALUATION PROCEDURES: LC 50 and LC 90 compared to susceptible strain
SAMPLING TECHNIQUE: Larvae from wild populations
PERFORMANCE: No resistance reported

1969 Machado, W. C., E. S. Bordes, Jr., A. J. Blake and G. T. Carmichael.
A Technique For ULV Insecticide Application From High Altitudes.
Mosquito News 29: 353-360 (Amvac Ref. #1359)

SPECIES: *Aedes sollicitans*
STAGE: Adult
AGE: Unknown (wild)
SEX: Female
PLOT SIZE: 8,000 and 7,000 acres
NUMBER TRIALS: 4
APPLICATION TECHNIQUE/EQUIPMENT: Aerial ULV
EVALUATION PROCEDURES: Change in landing rates
SAMPLING TECHNIQUE: Landing rates pre-and post-treat
PERFORMANCE: Treat 1 = 69% and 58% reduction in 16 hours; both zones reinfested within 24 hours; Treat 2 = 90% and 65% reduction; Treat 3 = 71% reduction, no reinfestation; Treat 4 = 95% and 77% reduction. Control was less than desirable.

1969 Mount, G. A., N. W Pierce, and C. S. Lofgren
New Insecticides Evaluated As Nonthermal Aerosols Against Aedes Taeniorhynchus (Weidmann)
Mosquito News 29: 53-54 (Amvac Ref. #1360)

SPECIES: *Aedes taeniorhynchus*
STAGE: Adult
AGE: 2 – 7 days old
SEX: Female
PLOT SIZE: Open field, not reported
NUMBER TRIALS: 1 - 4
APPLICATION TECHNIQUE/EQUIPMENT: Curtis Model 55,000 nonthermal aerosol generator
EVALUATION PROCEDURES: Mortality of caged mosquitoes at 18 hours post-treat
SAMPLING TECHNIQUE: No population assessment
PERFORMANCE: 18 hour mortality: 4% naled = 100% mortality; 2% naled = 100% mortality; 1% naled = 57%; 0.5% naled = 76%; 0.25% naled = 11%

1969 Shepard, M., and J. D. Gorman
The Effects Of Ultra-Low Volume Dibrom From A C-47 Aircraft On Adult Mosquitoes
Proceedings of the Florida Anti-Mosquito Association 31-36 (Amvac Ref. #1361)

SPECIES: *Culex nigripalpus*
STAGE: Adult
AGE: Unknown (wild)
SEX: Not reported
PLOT SIZE: 12 square miles
NUMBER TRIALS: 4
APPLICATION TECHNIQUE/EQUIPMENT: ULV spray system; 4 – 80015 Tee Jet flat fan nozzles
EVALUATION PROCEDURES: Mortality of caged mosquitoes; Changes in New Jersey light trap collections; Landing rates
SAMPLING TECHNIQUE: Landing rates and trapping of natural populations
PERFORMANCE: Mortality of caged mosquitoes: 100% at 3.5 hours post-treat in clear, medium, and heavy vegetation; 70 – 100% at 24 hours. Some reduction in New Jersey traps; difficult to assess. Landing rates not reported.

SPECIES: *Aedes taeniorhynchus, Culex nigripalpus, Psorophora columbiae*
STAGE: Adult
AGE: Unknown (wild)
SEX: Not reported
PLOT SIZE: 12 square miles
NUMBER TRIALS: 4
APPLICATION TECHNIQUE/EQUIPMENT: ULV spray system; 4 – 80015 Tee Jet flat fan nozzles
EVALUATION PROCEDURES: Changes in CDC light trap counts
SAMPLING TECHNIQUE: Trapping of natural populations
PERFORMANCE: Percent reduction in CDC light traps at 24 hours: *Ae. t:* 78% reduction, *Cx. n*: 5% reduction,, *Ps. c.* 74% reduction

1969 Stains, G. S., E. M. Fussell, and J. P. Keathley
Caged Insect Kills Of Up To Two Miles Utilizing A New Low-Volume Aerosol Generator
Mosquito News 29: 535-544 (Amvac Ref. #1362)

SPECIES: *Culex tarsalis*
STAGE: Adult
AGE: Not reported
SEX: Mixed
PLOT SIZE: Six square miles
NUMBER TRIALS: 1
APPLICATION TECHNIQUE/EQUIPMENT: ULV aerosol generator
EVALUATION PROCEDURES: Mortality of caged mosquitoes
SAMPLING TECHNIQUE: No population assessment
PERFORMANCE: 100% mortality out to 5550 feet; 97% cumulative mortality at 21 hours post-treat

SPECIES: *Musca domestica*
STAGE: Adult
AGE: Not reported
SEX: Mixed
PLOT SIZE: Six square miles
NUMBER TRIALS: 1
APPLICATION TECHNIQUE/EQUIPMENT: ULV aerosol generator
EVALUATION PROCEDURES: Mortality of caged flies
SAMPLING TECHNIQUE: No population assessment
PERFORMANCE: 98% cumulative mortality at 21 hours post-treat

1969 Berry, R., Joseph, S., and E.E. Lynch
Adult Mosquito Control With ULV Ground Equipment
Reprinted from the Proceedings of the 56th Annual Meeting of the New Jersey Mosquito Extermination Association, Atlantic City, March 1969 in Maryland State Board of Agriculture 30: 137-141 (Amvac Ref. #143)

SPECIES: *Culex pipiens*
STAGE: Adult
AGE: Not reported
SEX: Female
PLOT SIZE: 50, 100, and 200 feet from spraying unit
NUMBER TRIALS: 10
APPLICATION TECHNIQUE/EQUIPMENT: Ground truck mounted LECO 120 cold-fogger
EVALUATION PROCEDURES: Mortality of caged mosquitoes
SAMPLING TECHNIQUE: Mortality measured at 1, 2, 4, and 8 hours after treatment
PERFORMANCE: 100% mortality at 1 hour for most treatments, 2 hours required for 100% kill at 200 feet.

1968 Boike, Jr., A. H., and C. B. Rathburn.
Tests of The Susceptibility Of Florida Mosquitoes To Insecticides, 1967
Mosquito News 28: 313-316 (Amvac Ref. #1350)

SPECIES: *Aedes taeniorhynchus, Aedes aegypti, Culex nigripalpus, Culex salinarius, Culex quinquefasciatus*
STAGE: Larvae
AGE: Not reported
SEX: Not reported
PLOT SIZE: N/A
NUMBER TRIALS: 102
APPLICATION TECHNIQUE/EQUIPMENT: Beaker bioassay in laboratory
EVALUATION PROCEDURES: LC 50 and LC 90 compared to susceptible lab strain
SAMPLING TECHNIQUE: Test specimens reared from wild populations
PERFORMANCE: No resistance to naled detected

1968 Craven, B. R. and C. D. Steelman
Studies On A Biological And A Chemical Method Of Controlling The Dark Rice Field Mosquito In Louisiana
Journal of Economic Entomology 61: 1333-1336 (Amvac Ref. #1351)

SPECIES: *Psorophora confinnis*
STAGE: Larvae
AGE: Unknown (wild)
SEX: Not reported
PLOT SIZE: 5- 3 x 6 m
NUMBER TRIALS: 5
APPLICATION TECHNIQUE/EQUIPMENT: Small plot logarithmic sprayer prior to flooding
EVALUATION PROCEDURES: Change in population densities
SAMPLING TECHNIQUE: Density of wild larvae
PERFORMANCE: 28.1% control at 0.005 lb/acre; 56.6% control at 0.05 lb/acre; 12.1% control at 0.1 lb/acre

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1968 Craven, B. R., and C. D. Steelman
Relative Susceptibility Of Psorophora Confinnis (Lynch-Arribalzaga) Larvae In The Rice Producing Area Of Southern Louisiana To Selected Insecticides.
Mosquito News 28: 586-597 (Amvac Ref. #1352)

SPECIES: *Psorophora confinnis*
STAGE: Larvae
AGE: F1 from wild adults; late 3rd and 4th instar
SEX: Not reported
PLOT SIZE: N/A
NUMBER TRIALS: Not reported
APPLICATION TECHNIQUE/EQUIPMENT: Serial dilutions in distilled water
EVALUATION PROCEDURES: Mortality assessed at 24 hours; relative LC 50 and LC 90
SAMPLING TECHNIQUE: F1 from wild populations were tested
PERFORMANCE: LC 50 = 0.0365 ppm, LC 90 = 0.1373 ppm: Baselines only.

1968 Harden, F. W., and B. J. Ethridge
Unique Problems In Insect And Pest Control Of NASA's Mississippi Test Facility
Mosquito News 28: 141-143 (Amvac Ref. #1353)

SPECIES: *Aedes sollicitans, Aedes taeniorhynchus*
STAGE: Adult
AGE: Unknown (wild)
SEX: Female
PLOT SIZE: Not reported
NUMBER TRIALS: On going control program
APPLICATION TECHNIQUE/EQUIPMENT: nonthermal fogger
EVALUATION PROCEDURES: Change in work efficiency
SAMPLING TECHNIQUE: Natural populations at the facility site
PERFORMANCE: No loss of work efficiency since 1964 when control program began; Down from 25% lost efficiency in 1963

1968 Knapp, F. W., and C. E. Rogers
Low Volume Aerial Insecticide Application For The Control Of Aedes Sollicitans Walker
Mosquito News 28: 535-540 (Amvac Ref. #1354)

SPECIES: *Aedes sollicitans*
STAGE: Adult
AGE: Not reported
SEX: Female
PLOT SIZE: 200 – 300 acres
NUMBER TRIALS: 5
APPLICATION TECHNIQUE/EQUIPMENT: Aerial application; Fischer EA-12 electro atomizers
EVALUATION PROCEDURES: Landing rates
SAMPLING TECHNIQUE: Landing rates of natural populations
PERFORMANCE: 0.05 lb/acre: % reduction post-treat – 0.5 hr = 0 - 43; 1.0 hr = 78 - 83; 1.5 hr = 87 - 96; 2.0 hr = 44.0 - 98.9; 6.0 hr = 97 - 100; 10 hr = 66 - 100; 36 hr = 86 - 90
0.10 lb/acre: % reduction post-treat – 0.5 hr = 85 - 88; 1.0 hr = 97 - 100; 1.5 hr = ; 6.0 hr = 100; 10 hr = 100; 36 hr = 84.

1968 Mount, G. A., C. S. Lofgren, N. W. Pierce and C. N. Husman.
Ultra-Low Volume Nonthermal Aerosols Of Malathion And Naled For Adult Mosquito Control.
Mosquito News 28: 99-103 (Amvac Ref. #1355)

SPECIES: *Aedes taeniorhynchus*
STAGE: Adult
AGE: Not reported
SEX: Female
PLOT SIZE: Not reported for caged trials; 6 acres for landing rates
NUMBER TRIALS: 2 - 3
APPLICATION TECHNIQUE/EQUIPMENT: ULV non-thermal and high volume thermal aerosol; Leco Model 120 for thermal aerosols; Curtis 55,000 for nonthermal generator
EVALUATION PROCEDURES: Mortality of caged mosquitoes; Landing rates
SAMPLING TECHNIQUE: Landing rates
PERFORMANCE: Average percent mortality in ULV applications: 0.0045 lb/acre = 53%; 0.009 lb/acre = 87%; 0.018 lb/acre = 88%;
Average percent mortality in High Volume applications: 0.0045 lb/acre = 14%; 0.009 lb/acre = 47%; 0.018 lb/acre = 81%; ULV more effective;
Percent reduction in landing rates:
High volume (0.036 lb/acre) = 74% (0.5 hours); 20% (12 hours)
ULV (0.036 lb/acre) = 95% (0.5 hours); 24% (12 hours)
ULV (0.018 lb/acre) = 85% (0.5 hours); 0% (12 hours)

1968 Taylor, R. T., and H. F. Schoof
Evaluation Of Thermal And Nonthermal Fogs Against Four Species Of Mosquitoes
Mosquito News 28: 8-11 (Amvac Ref. #1356)

SPECIES: *Aedes aegypti*
STAGE: Adult
AGE: Not reported
SEX: Female
PLOT SIZE:
NUMBER TRIALS: 10 - 12
APPLICATION TECHNIQUE/EQUIPMENT: Leco 120 thermal fog generator; Curtis "Cold Fogger"
EVALUATION PROCEDURES: Mortality of caged mosquitoes
SAMPLING TECHNIQUE: No population assessment
PERFORMANCE:
Thermal
10 reps: 150' = 69%; 300' = 24%
Nonthermal
12 reps: 150' = 74%; 300' = 24%

SPECIES: *Anopheles albimanus*
STAGE: Adult
AGE: Not reported
SEX: Female
PLOT SIZE:
NUMBER TRIALS: 10 - 12
APPLICATION TECHNIQUE/EQUIPMENT: Leco 120 thermal fog generator; Curtis "Cold Fogger"
EVALUATION PROCEDURES: Mortality of caged mosquitoes
SAMPLING TECHNIQUE: No population assessment
PERFORMANCE:
Thermal
10 reps: 150' = 84%; 300' = 49%
Nonthermal
12 reps: 150' = 92%; 300' = 51%

SPECIES: *Culex quinquefasciatus*
STAGE: Adult
AGE: Not reported
SEX: Female
PLOT SIZE:
NUMBER TRIALS: 10 - 12
APPLICATION TECHNIQUE/EQUIPMENT: Leco 120 thermal fog generator; Curtis "Cold Fogger"
EVALUATION PROCEDURES: Mortality of caged mosquitoes
SAMPLING TECHNIQUE: No population assessment
PERFORMANCE:
Thermal
10 reps: 150' = 71%; 300' = 28%
Nonthermal
12 reps: 150' = 75%; 300' = 31%

SPECIES: *Aedes taeniorhynchus*
STAGE: Adult
AGE: Not reported
SEX: Female
PLOT SIZE:
NUMBER TRIALS: 2
APPLICATION TECHNIQUE/EQUIPMENT: Leco 120 thermal fog generator; Curtis "Cold Fogger"
EVALUATION PROCEDURES: Mortality of caged mosquitoes
SAMPLING TECHNIQUE: No population assessment
PERFORMANCE:
Thermal
2 reps: 150' = 59%; 300' = 27%
Nonthermal
2 reps: 150' = 62%; 300' = 8%

1968 Whitlaw, J. T., Jr., and E. S. Evans, Jr.
Selected Plastic Formulations For Use As Mosquito Larvicides
Journal of Economic Entomology 61: 889-892 (Amvac Ref. #1357)

SPECIES: *Culex pipiens quinquefasciatus*
STAGE: Larvae
AGE: Not reported
SEX: Not reported
PLOT SIZE: N/A
NUMBER TRIALS: 37 (polyvinyl chloride); 24 (polyamide)
APPLICATION TECHNIQUE/EQUIPMENT: Naled incorporated into various plastics; Beaker bioassay in laboratory
EVALUATION PROCEDURES: Mortality of larvae at 24 hours
SAMPLING TECHNIQUE: No population assessment
PERFORMANCE: Number of tests with 90 – 100% at various concentrations
POLYVINYL CHLORIDE
0.5% naled = 17/37
1.0% naled = 23/37
5.0% naled = 33/37
10.0% naled = 33/37
20.0% naled = 34/37
POLYAMIDE
0.5% naled = 3/24
1.0% naled = 5/24
5.0% naled = 8/24
10.0% naled = 9/24
20.0% naled = 16/24

1967 Mount, G. A., and C. S. Lofgren
New Insecticides As Nonthermal Aerosols For Control Of Adult Mosquitoes
Mosquito News 27: 470-473Amvac Ref. #1346)

SPECIES: *Aedes taeniorhynchus, Culex pipiens quinquefasciatus, Anopheles quadrimaculatus*
STAGE: Adult
AGE: 2 – 7 days old
SEX: Female
PLOT SIZE: 150 – 300' downwind
NUMBER TRIALS:
APPLICATION TECHNIQUE/EQUIPMENT: Truck mounted Curtis Model 55,000 nonthermal aerosol generator
EVALUATION PROCEDURES: Mortality of caged mosquitoes
SAMPLING TECHNIQUE: No population assessment
PERFORMANCE: Average mortality of 3 species : 0.5% naled = 61%; 1.0% naled = 67% 2.0% naled = 94%; 4% naled = 98%; 96 – 100% for all species at 4% naled

1967 Mount, G. A., and C. S. Lofgren.
Ultra-low Volume And Conventional Aerial Sprays For Control Of Adult Salt-Marsh Mosquitoes, Aedes Sollicitans (Walker) And Aedes Taeniorhynchus.
Mosquito News 27: 473-477 (Amvac Ref. #1347)

SPECIES: *Aedes sollicitans, Aedes taeniorhynchus*
STAGE: Adult
AGE: Unknown (wild)
SEX: Female
PLOT SIZE: 10 – 40 acre citrus groves
NUMBER TRIALS: 2 - 10
APPLICATION TECHNIQUE/EQUIPMENT: Aerial; For ULV - self-contained system with four flat fan Tee Jet nozzles, No. 800067 to 8003; conventional – 17 flat fan Tee Jet (#6510) nozzles
EVALUATION PROCEDURES: Change in landing rates
SAMPLING TECHNIQUE: Landing rates of natural populations
PERFORMANCE: Percent reduction in landing rates at various times and concentrations of Dibrom:
ULV:
0.05 lb/acre: 10 reps – 6 hours: 65% reduction; 24 hours: 17% reduction
0.1 lb/acre: 6 reps – 6 hours: 88% reduction; 24 hours: 36% reduction
0.2 lb/acre: 5 reps – 6 hours: 94% reduction; 24 hours: 78% reduction; 48 hours: 33% reduction
CONVENTIONAL
0.05 lb/acre: 4 reps – 6 hours: 79% reduction; 24 hours: 24% reduction
0.1 lb/acre: 2 reps – 6 hours: 82% reduction; 24 hours: 44% reduction
0.2 lb/acre: 2 reps – 6 hours: 99% reduction; 24 hours: 73% reduction

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1967 Knapp, F. W., and C. H. Gayle
ULV Aerial Insecticide Application For Adult Mosquito Control In Kentucky
Mosquito News 27: 478-482 (Amvac Ref. #1345)

SPECIES: *Aedes sollicitans*
STAGE: Adult
AGE: Unknown, wild
SEX: Female
PLOT SIZE: 250 – 400 acres
NUMBER TRIALS: 5
APPLICATION TECHNIQUE/EQUIPMENT: Aerial ULV, TeeJet nozzles
EVALUATION PROCEDURES: Changes in landing rates
SAMPLING TECHNIQUE: Landing rates of natural population
PERFORMANCE: PM Treatment: 0.5 hours post-treat: 97.7% reduction in landing rates; 1 hour post-treat: 100% reduction in landing rates; 2 hours post-treat: 100% reduction in landing rates; 6 hours post-treat: 100% reduction in landing rates; 24 hours post-treat: 100% reduction in landing rates
AM Treatment: 0.5 hours post-treat: 90.7% reduction in landing rates; 1 hour post-treat: 72.7% reduction in landing rates; 2 hours post-treat: 96% reduction in landing rates; 6 hours post-treat: 100% reduction in landing rates; 24 hours post-treat: 82.7% reduction in landing rates

1967 Rathburn, Jr., C. B. and A. H. Boike, Jr.
Studies of Insecticide Resistance In Florida Mosquitoes.
Mosquito News 27: 377-387 (Amvac Ref. #1348)

SPECIES: *Aedes taeniorhynchus, Aedes sollicitans, Culex nigripalpus, Culex salinarius*
STAGE: Larvae
AGE: 3rd Instar
SEX: Not reported
PLOT SIZE: N/A
NUMBER TRIALS:
APPLICATION TECHNIQUE/EQUIPMENT: Beaker bioassay in laboratory
EVALUATION PROCEDURES: Larval mortality; LC 50 and LC 90 compared to susceptible strain
SAMPLING TECHNIQUE: Larvae were reared from wild adults from various areas of the state
PERFORMANCE: No resistance reported

1967 Steelman, C. D., J. M. Gassie, and B. R. Craven
Laboratory And Field Studies On Mosquito Control In Waste Disposal Lagoons In Louisiana
Mosquito News 27: 57-59 (Amvac Ref. #1349)

SPECIES: *Culex quinquefasciatus*
STAGE: Larvae
AGE: Unknown (wild)
SEX: Unknown
PLOT SIZE: Not reported
NUMBER TRIALS: Not reported
APPLICATION TECHNIQUE/EQUIPMENT: Material applied to water with hand sprayers and pressure sprayers
EVALUATION PROCEDURES: Number of days with 100% control
SAMPLING TECHNIQUE: Larval dipping of natural populations in lagoons
PERFORMANCE: 19 days of 100% control

1966 Gahan, J. B., C. N. Smith and B. M. Glancey.
Resistance In Florida And Countermeasures Involving Chemicals.
Mosquito News 26: 330-337 (Amvac Ref. #1341)

SPECIES: *Aedes taeniorhynchus*
STAGE: Larvae
AGE: Not reported
SEX: Not reported
PLOT SIZE: Not reported
NUMBER TRIALS: Not reported
APPLICATION TECHNIQUE/EQUIPMENT: Not reported
EVALUATION PROCEDURES: LC 50 and LC 90 compared to susceptible lab strain
SAMPLING TECHNIQUE: Larvae from natural populations of 4 different Florida counties
PERFORMANCE: No resistance to naled in 4 different strains

SPECIES: *Aedes taeniorhynchus*
STAGE: Adult
AGE: Not reported
SEX: Not reported
PLOT SIZE: N/A
NUMBER TRIALS: Not reported
APPLICATION TECHNIQUE/EQUIPMENT: Wind tunnel
EVALUATION PROCEDURES: LC 50 and LC 90 compared to susceptible laboratory colony
SAMPLING TECHNIQUE: Adult mosquitoes from wild population
PERFORMANCE: No resistance reported

1966 Glancey, B. M., A. C. White, C. N. Husman, and J. Salmela.
Low Volume Applications Of Insecticides For The Control Of Adult Mosquitoes
Mosquito News 26: 356-359 (Amvac Ref. #1342)

SPECIES: *Aedes taeniorhynchus*
STAGE: Adult
AGE: Unknown/wild
SEX: Female
PLOT SIZE: 50 acres
NUMBER TRIALS: 3
APPLICATION TECHNIQUE/EQUIPMENT: Aerial; low volume; mini-spin nozzles; undiluted technical material
EVALUATION PROCEDURES: Pre and post-treatment landing rates
SAMPLING TECHNIQUE: Landing rates of natural populations
PERFORMANCE: 6 hours post-treat: 98.5% reduction; 24 hours post-treat: 32% reduction

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1966 Lofgren, C. S., N. Pennington, and W. Young
Evaluation Of Insecticides Against Two Species Of Culex Mosquitoes On Okinawa
Mosquito News 26: 52-59 (Amvac Ref. #1343)

SPECIES: *Culex tritaeniorhynchus*
STAGE: Adult
AGE: 3 – 11 days old
SEX: Female
PLOT SIZE: Small airfield; not reported
NUMBER TRIALS: Average 3 - 8
APPLICATION TECHNIQUE/EQUIPMENT: Truck mounted nonthermal aerosol generator developed by US Army Engineer Research and Development Laboratories
EVALUATION PROCEDURES: Mortality of caged mosquitoes
SAMPLING TECHNIQUE: Adult mosquitoes were collected as wild larvae or pupae
PERFORMANCE: Average percent mortality at various concentrations:
6 oz/gal: 99.7%
4 oz/gal: 99%
2 oz/gal: 96%
1 oz/gal: 57%

SPECIES: *Culex quinquefasciatus*
STAGE: Adult
AGE: 3 – 11 days old
SEX: Female
PLOT SIZE: Small airfield; not reported
NUMBER TRIALS: Average 3 - 8
APPLICATION TECHNIQUE/EQUIPMENT: Truck mounted nonthermal aerosol generator developed by US Army Engineer Research and Development Laboratories
EVALUATION PROCEDURES: Mortality of caged mosquitoes
SAMPLING TECHNIQUE: Adult mosquitoes were collected as wild larvae or pupae
PERFORMANCE: Average percent mortality at various concentrations:
6 oz/gal: 98%
4 oz/gal: 91%
2 oz/gal: 89%
1 oz/gal: 57%

SPECIES: *Culex tritaeniorhynchus*
STAGE: Larvae
AGE: Late 3rd and early 4th instar
SEX: Not reported
PLOT SIZE: N/A
NUMBER TRIALS: 3 per concentration
APPLICATION TECHNIQUE/EQUIPMENT: Beaker bioassay in Laboratory
EVALUATION PROCEDURES: WHO larval resistance kit (mortality in beakers at 24 hours post-treat)
SAMPLING TECHNIQUE: Larvae were collected from field populations
PERFORMANCE: Percent mortality at various concentrations
0.04 ppm = 100%
0.02 ppm = 70%
0.01 ppm = 12%
0.008 ppm = 4%
LC50 = 0.017; LD 90 = 0.026

SPECIES: *Culex quinquefasciatus*
STAGE: Larvae
AGE: Late 3rd and early 4th instar
SEX: Not reported
PLOT SIZE: N/A
NUMBER TRIALS: 2 per concentration
APPLICATION TECHNIQUE/EQUIPMENT: Beaker bioassay in Laboratory
EVALUATION PROCEDURES: WHO larval resistance kit (mortality in beakers at 24 hours post-treat)
SAMPLING TECHNIQUE: Larvae were collected from field populations
PERFORMANCE: Percent mortality at various concentrations
0.1 ppm = 100%
0.08 ppm = 99%
0.06 ppm = 72%
0.05 ppm = 59%
0.04 ppm = 34%
0.03 ppm = 6%
LC50 = 0.017; LD 90 = 0.026

1966 Mount, G. A., C. S. Lofgren, J. B. Gahan, and N. W. Pierce
Comparisons Of Thermal And Nonthermal Aerosols Of Malathion, Fenthion, And Naled For Control Of Stable Flies And Salt-Marsh Mosquitoes
Mosquito News 26: 132-138 (Amvac Ref. #1344)

SPECIES: *Stomoxys calcitrans*
STAGE: Adult
AGE: 2 – 7- days old
SEX: Mixed
PLOT SIZE: 300' from discharge line
NUMBER TRIALS: 16
APPLICATION TECHNIQUE/EQUIPMENT: Leco Model 120 thermal aerosol generator; Curtis Model 55,000 nonthermal generator
EVALUATION PROCEDURES: Mortality of caged flies
SAMPLING TECHNIQUE:
PERFORMANCE: Percent mortality at various concentrations:
Thermal (fuel oil diluent): 5% = 99% mortality; 2.5% = 97% mortality; 1.25% = 89% mortality; 0.62% = 61% mortality; 0.31% = 34% mortality
Non-Thermal (fuel oil diluent): 5% = 100% mortality; 2.5% = 94% mortality; 1.25% = 92% mortality; 0.62% = 52% mortality; 0.31% = 33% mortality
Non-Thermal (water diluent): 5% = 100% mortality; 2.5% = 100% mortality; 1.25% = 97% mortality; 0.62% = 64% mortality; 0.31% = 30% mortality

SPECIES: *Aedes taeniorhynchus*
STAGE: Adult
AGE: 2 – 7- days old
SEX: Female
PLOT SIZE: 300' from discharge line
NUMBER TRIALS: 3
APPLICATION TECHNIQUE/EQUIPMENT: Leco Model 120 thermal aerosol generator; Curtis Model 55,000 nonthermal generator
EVALUATION PROCEDURES: Mortality of caged mosquitoes
SAMPLING TECHNIQUE: No population assessment
PERFORMANCE: Percent mortality at various concentrations:
Thermal (fuel oil diluent): 2% = 96% mortality; 1.5% = 89% mortality; 1% = 82% mortality; 0.5% = 64% mortality; 0.25% = 45% mortality
Non-Thermal (fuel oil diluent): 2% = 96% mortality; 1.5% = 93% mortality; 1% = 92% mortality; 0.5% = 57% mortality; 0.25% = 68% mortality
Non-Thermal (water diluent): 2% = 93% mortality; 1.5% = 94% mortality; 1% = 89% mortality; 0.5% = 38% mortality; 0.25% = 24% mortality

SPECIES: *Aedes taeniorhynchus, Aedes sollicitans*
STAGE: Adult
AGE: Unknown (wild)
SEX: Female
PLOT SIZE: Citrus groves, not reported
NUMBER TRIALS: 4 - 8
APPLICATION TECHNIQUE/EQUIPMENT: Leco Model 120 thermal aerosol generator; Curtis Model 55,000 nonthermal generator
EVALUATION PROCEDURES: Mortality of caged mosquitoes and changes in landing rates
SAMPLING TECHNIQUE: Landing rates of natural populations
PERFORMANCE: Average percent reduction of landing rates:
Thermal: 8 trials: 1 – 3 hours post-treat: 77%; 15 – 24 hours post-treat = increase of 17%
Nonthermal: 4 trials: 1 – 3 hours post-treat: 82%; 15 – 24 hours post-treat = increase of 37%
Nonthermal: 7 trials: 1 – 3 hours post-treat: 79%; 15 – 24 hours post-treat = 41%

Average mortality of caged mosquitoes:
Thermal = 70%; Nonthermal = 76%

1965 Gahan, J. B., W. W. Young, N. E. Pennington, and G. C. Lebrecque
Thermal Aerosol And Larvicide Tests With New Insecticides To Control Two Species Of Culex Mosquitoes On Okinawa
Mosquito News 25: 165-169 (Amvac Ref. #1340)

SPECIES: *Culex tritaeniorhynchus*
STAGE: Adult
AGE: Not reported
SEX: Female
PLOT SIZE: Airstrip, not reported
NUMBER TRIALS: 3
APPLICATION TECHNIQUE/EQUIPMENT: Tifa 4145 (P.E. #608) Fog Generator
EVALUATION PROCEDURES: Mortality of caged mosquitoes
SAMPLING TECHNIQUE: No population assessment
PERFORMANCE: Average mortality a various dosages:
1 oz/gal = 69%; 2 oz/gal = 95%; 4 oz/gal = 97%; 6 oz/gal = 100%

SPECIES: *Culex quinquefasciatus*
STAGE: Adult
AGE: Not reported
SEX: Female
PLOT SIZE: Airstrip, not reported
NUMBER TRIALS: 3
APPLICATION TECHNIQUE/EQUIPMENT: Tifa 4145 (P.E. #608) Fog Generator
EVALUATION PROCEDURES: Mortality of caged mosquitoes
SAMPLING TECHNIQUE: No population assessment
PERFORMANCE: Average mortality a various dosages:
1 oz/gal = 52%; 2 oz/gal = 94%; 4 oz/gal = 90; 6 oz/gal = 100%

SPECIES: *Culex tritaeniorhynchus*
STAGE: Larvae
AGE: all instars
SEX: Not reported
PLOT SIZE: Rice fields, not reported
NUMBER TRIALS: 3
APPLICATION TECHNIQUE/EQUIPMENT: Compressed air sprayer with fan-type nozzle
EVALUATION PROCEDURES: Change in density of larval population
SAMPLING TECHNIQUE: Larval dipping of natural populations
PERFORMANCE: Average mortality a various concentrations:
3rd and 4th instar: 0.05 lb/acre = 44%; 0.1 lb/acre = 95%; 0.25 lb/acre = 93%; 0.5 lb/acre = 97%
All instars: 0.05 lb/acre = 22%; 0.1 lb/acre = 88%; 0.25 lb/acre = 89%; 0.5 lb/acre = 93%

1965 Rogers, A.J., Rathburn, C.B. Jr., and R.W. Clements, Jr.
Tests with Aerial Fogs and Sprays Against Adult Mosquitoes
Mosquito News 25: 94-100 (Amvac Ref. #159)

SPECIES: *Culex nigripalpus*
STAGE: Adult
AGE: 2 to 8 days
SEX: Female
PLOT SIZE: 40 to 100 Acres
NUMBER TRIALS: 54
APPLICATION TECHNIQUE/EQUIPMENT: Aerial -- Stearman airplane at 80 mph
EVALUATION PROCEDURES: Mortality of caged mosquitoes in different habitats
SAMPLING TECHNIQUE: Mortality counts 24 hours post-treatment
PERFORMANCE: Average mortality at various dosages:
0.05 lb/A = 70%; 0.1 lb/A = 83%; 0.15 lb/A = 93%

SPECIES: *Aedes taeniorhynchus*
STAGE: Adult
AGE: 2 to 8 days
SEX: Female
PLOT SIZE: 40 to 100 Acres
NUMBER TRIALS: 54
APPLICATION TECHNIQUE/EQUIPMENT: Aerial -- Stearman airplane at 80 mph
EVALUATION PROCEDURES: Mortality of caged mosquitoes in different habitats
SAMPLING TECHNIQUE: Mortality counts 24 hours post-treatment
PERFORMANCE: Average mortality at various dosages:
0.05 lb/A = 80%; 0.1 lb/A = 89%; 0.15 lb/A = 92%

1964 Rogers, A. J., and C. B. Rathburn, Jr.
Present Status Of Insecticides For Mosquito Control In Florida
Mosquito News 24: 286-291 (Amvac Ref. #1339)

SPECIES: *Aedes taeniorhynchus*
STAGE: Larvae
AGE: 4th Instar
SEX: Not reported
PLOT SIZE: N/A
NUMBER TRIALS: Not reported
APPLICATION TECHNIQUE/EQUIPMENT: WHO Resistance Test
EVALUATION PROCEDURES: WHO Resistance Test
SAMPLING TECHNIQUE: Larvae were collected from natural populations
PERFORMANCE: LC 50 = 0.140 ppm; No resistance reported

SPECIES: *Culex nigripalpus*
STAGE: Larvae
AGE: 4th Instar
SEX: Not reported
PLOT SIZE: N/A
NUMBER TRIALS: Not reported
APPLICATION TECHNIQUE/EQUIPMENT: WHO Resistance Test
EVALUATION PROCEDURES: WHO Resistance Test
SAMPLING TECHNIQUE: Larvae were collected from natural populations
PERFORMANCE: LC 50 = 0.047 ppm; No resistance reported

1964 Rathburn, C. B., Jr., B. W. Clements, Jr., and A. J. Rogers
Comparative Thermal Aerosol Tests With Dibrom And Malathion Against Aedes Taeniorhynchus (Weid) And Culex Nigripalpus Theob.
Mosquito News 24: 292-294 (Amvac Ref. #142)

SPECIES: *Aedes taeniorhynchus*
STAGE: Adult
AGE: 2 – 8 days old
SEX: Female
PLOT SIZE: Up to 330' downwind
NUMBER TRIALS: 15
APPLICATION TECHNIQUE/EQUIPMENT: Ground; Leco 80 or Tifa 40-E thermal aerosol generator
EVALUATION PROCEDURES: Mortality of caged mosquitoes
SAMPLING TECHNIQUE: No population assessment
PERFORMANCE: Average percent mortality at various rates:
1.75 oz = 96%; 1.5 oz = 90%

SPECIES: *Culex nigripalpus*
STAGE: Adult
AGE: 2 – 8 days old
SEX: Female
PLOT SIZE: Up to 330' downwind
NUMBER TRIALS: 15
APPLICATION TECHNIQUE/EQUIPMENT: Ground; Leco 80 or Tifa 40-E thermal aerosol generator
EVALUATION PROCEDURES: Mortality of caged mosquitoes
SAMPLING TECHNIQUE: No population assessment
PERFORMANCE: Average percent mortality at various rates:
1.75 oz = 93%; 1.5 oz = 86%

1963 Rathburn, C. B., Jr., and A. J. Rogers
Thermal Aerosol Insecticide Tests For The Control Of Adult Mosquitoes, 1961-62
Mosquito News 23: 218-220 (Amvac Ref. #144)

SPECIES: *Aedes taeniorhynchus*
STAGE: Adult
AGE: 2 – 8 days old
SEX: Female
PLOT SIZE: up to 330' downwind
NUMBER TRIALS: 42
APPLICATION TECHNIQUE/EQUIPMENT: Ground; Leco thermal aerosol generator
EVALUATION PROCEDURES: Mortality of caged mosquitoes
SAMPLING TECHNIQUE: No population assessment
PERFORMANCE: Average percent mortality at various application rates:
1 oz = 71%; 1 ¼ oz = 83%; 1 ½ oz = 92%; 1 ¾ oz = 96%

1961 Davis, A. N., and J. B. Gahan
New Insecticides For The Control Of Salt-Marsh Mosquitoes
Florida Entomologist 44:11-14 (Amvac Ref. #1337)

SPECIES: *Aedes taeniorhynchus*
STAGE: Larvae
AGE: 4th Instar
SEX: Not reported
PLOT SIZE: N/A
NUMBER TRIALS: 6
APPLICATION TECHNIQUE/EQUIPMENT: Beaker bioassay in laboratory
EVALUATION PROCEDURES: Mortality at 24 hours
SAMPLING TECHNIQUE: No population assessment
PERFORMANCE: Percent mortality at various concentrations:
1 ppm = 100% mortality; 0.1 ppm = 84% mortality; 0.05 ppm = 27% mortality; 0.025 ppm = 5% mortality

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1961 Rathburn, C. B., and A. J. Rogers
Tests Of Insecticides For The Control Of Adult Mosquitoes, 1959-1960
Proceedings of the Florida Anti-Mosquito Association 36-40 (Amvac Ref. #1338)

SPECIES: *Aedes taeniorhynchus*
STAGE: Adult
AGE: Not reported
SEX: Female
PLOT SIZE: Up to 330' downwind
NUMBER TRIALS: 3 - 4
APPLICATION TECHNIQUE/EQUIPMENT: Ground application; Jeep mounted Leco fogger
EVALUATION PROCEDURES: Mortality of caged mosquitoes
SAMPLING TECHNIQUE: No population assessment
PERFORMANCE: Average mortality at 1.75 oz = 96%; 1.00 oz. = 73%

SPECIES: *Aedes taeniorhynchus*
STAGE: Adult
AGE: Not reported
SEX: Not reported
PLOT SIZE: N/A
NUMBER TRIALS:
APPLICATION TECHNIQUE/EQUIPMENT: Wind tunnel
EVALUATION PROCEDURES: Mortality of caged mosquitoes
SAMPLING TECHNIQUE: No population assessment
PERFORMANCE:
Mortality at various concentrations:
0.025 ppm = 100%; 0.01 ppm = 78%; 0.005 ppm = 17%; 0.0025 = 2%

SPECIES: *Aedes taeniorhynchus*
STAGE: Adult
AGE: Unknown (wild)
SEX: Female
PLOT SIZE: 50 acres
NUMBER TRIALS: 9
APPLICATION TECHNIQUE/EQUIPMENT: Aerial application
EVALUATION PROCEDURES: Change in landing counts
SAMPLING TECHNIQUE: Landing counts of natural population
PERFORMANCE: Percent reduction of landing counts at various concentrations 6 hours post-treat: 0.05 lb/acre = 100% reduction; 0.025 lb/acre = 99% reduction; 0.012 lb/acre = 56% reduction

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1961 Joseph, S.R., Berry, R.A. Jr., and L.W. Smith
Some Results on Insecticides Used As Mist Sprays For Adult Mosquito Control
Reprinted from the Proceedings of the 48th Annual Meeting of the New Jersey Mosquito Extermination Association 422: 131-134 (Amvac Ref. #153)

SPECIES: *Culex pipiens*
STAGE: Adult
AGE: Not given
SEX: Not given
PLOT SIZE: 100, 200, and 300 feet from spraying unit
NUMBER TRIALS: 3
APPLICATION TECHNIQUE/EQUIPMENT: Truck mounted John Bean Rotomist 100-E mister
EVALUATION PROCEDURES: Mortality of caged mosquitoes
SAMPLING TECHNIQUE: Mortality measured at 1, and 4 hours after treatment
PERFORMANCE: 100% mortality for all treatments except at 300 feet, which resulted in average 90% mortality.

1961 Mallack, J., Kulp, L.A., Joseph, S.R., and R.A. Berry, Jr.
Dibrom as an Adulticide for Mosquito Control
Reprinted from the Proceedings of the 48th Annual Meeting of the New Jersey Mosquito Extermination Association 418: 183-185 (Amvac Ref. #148)

SPECIES: *Culex pipiens*
STAGE: Adult
AGE: Not given
SEX: Not given
PLOT SIZE: 100, 200, and 300 feet from spraying unit
NUMBER TRIALS: 13
APPLICATION TECHNIQUE/EQUIPMENT: Truck mounted John Bean Rotomist 100-E mister
EVALUATION PROCEDURES: Mortality of caged mosquitoes
SAMPLING TECHNIQUE: Mortality measured at 1, 4, and 8 hours after treatment
PERFORMANCE: Generally 100% mortality achieved at 100 feet for all concentrations; Inconsistent results at 200 and 300 feet at the less that 6 lbs rate.

SPECIES: Salt-marsh (wild) *Aedes spp*
STAGE: Adult
AGE: Not given
SEX: Not given
PLOT SIZE: 400 Acres
NUMBER TRIALS: 1
APPLICATION TECHNIQUE/EQUIPMENT: Aerial spray
EVALUATION PROCEDURES: Mortality of caged mosquitoes
SAMPLING TECHNIQUE: Mortality measured at 20 and 50 minutes after treatment
PERFORMANCE: 100% mortality achieved at 20 minutes for open-area caged mosquitoes; 98% mortality at 20 minutes for cover of trees caged mosquitoes—100% at 50 minutes

SPECIES: Not given
STAGE: Adult
AGE: Unknown (wild)
SEX: Not given
PLOT SIZE: Not given
NUMBER TRIALS: 11
APPLICATION TECHNIQUE/EQUIPMENT: Ground – Todd "Tifa" Series 40-E fogger
EVALUATION PROCEDURES: Landing rate counts or NJ light traps
SAMPLING TECHNIQUE: Landing rate counts performed each evening before and after morning applications
PERFORMANCE: At 12 lb rate, average reduction of 81% based on landing counts and 92% based on light traps; At 10 lb rate, average reduction of 43% for landing counts and 67% for light traps; At 8 lb rate, average reduction of 7% for landing counts and 29% for light traps; No reduction noticed at 3 lb or less rate.

1960 Davis, A. N., J. Salmela, and C. B. Spencer, Jr.
Aerial Spray Tests Against Adult Salt-Marsh Mosquitoes In Florida. – 1959
Proceedings of the New Jersey Extermination Association 47: 92-94 (Amvac Ref. #1336)

SPECIES: Salt-marsh (wild) *Aedes spp.*
STAGE: Adult
AGE: Unknown (wild)
SEX: Female
PLOT SIZE: 50 acres
NUMBER TRIALS: 6
APPLICATION TECHNIQUE/EQUIPMENT: Aerial application
EVALUATION PROCEDURES: Change in landing counts
SAMPLING TECHNIQUE: Landing counts of natural populations
PERFORMANCE: Landing count reduction:
0.1 lb/acre: 3 hours post-treat: 100%; 4 hours post-treat: 100%; 24 hours post-treat: 61%
0.05 lb/acre 3 hours post-treat: 99%; 4 hours post-treat: 99%; 24 hours post-treat: 0%
0.025 lb/acre 3 hours post-treat: 56%; 4 hours post-treat: 56%; 24 hours post-treat: 54%

APPENDIX B

Literature Reviewed

1999 Ham, C. M., M. V. Meisch, and C. L. Meek
Efficacy of Dibrom®, Trumpet®, and Scourge® Against Four Mosquito Species in Louisiana
J. American Mosquito Control Association 15: 433-436 (Amvac Ref. #1003)

1003

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CONTENTS

ARTICLES

(Continued on inside front cover)

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Journal of the American Mosquito Control Association, 15(4):433–436, 1999

EFFICACY OF DIBROM®, TRUMPET®, AND SCOURGE® AGAINST FOUR MOSQUITO SPECIES IN LOUISIANA

C. M. HAM,[1] M. V MEISCH[1] AND C. L. MEEK[2]

ABSTRACT. Adult mortality of *Anopheles quadrimaculatus*, *Culex quinquefasciatus* and the *Aedes* spp complex (*Aedes sollicitans* and *Aedes taeniorhynchus*) was observed after aerial ultra-low volume (ULV) exposure to Dibrom®, Trumpet®, and Scourge®. Dibrom was applied at 112 g active ingredient (AI)/ha, Trumpet at 112 g AI/ha, and Scourge at 1.96 g AI/ha. At all time intervals, Dibrom and Trumpet were significantly more effective against the *Aedes* spp. complex than against *An. quadrimaculatus* and *Cx. quinquefasciatus*. Scourge was significantly more effective against *An. quadrimaculatus* and *Cx. quinquefasciatus* than Dibrom or Trumpet. Trumpet was evaluated at lower labeled rates (28, 56, and 84 g AI/ha) against *Cx. quinquefasciatus* and the *Aedes* spp. complex. Adult mortality with Trumpet increased significantly at 1 and 24 h against *Cx. quinquefasciatus*. With the *Aedes* spp. complex, mortality increased with rate at 1 h, but at 12 and 24 h, the medium and high dosages were not significantly different from each other. *Culex quinquefasciatus* and the *Aedes* spp. complex were also subjected to ULV ground applications of Dibrom, Trumpet, and Scourge. Dibrom was applied at 22.4 g AI/ha, Trumpet at 22.4 g AI/ha, and Scourge as a 1:6 mineral oil mixture at 1.96 g AI/ha. Relative to Dibrom and Trumpet, mortality from Scourge differed greatly with mosquito species. Against *Cx. quinquefasciatus*, Scourge was significantly more effective than Dibrom and Trumpet at all times and distances, but against the *Aedes* spp. complex Scourge was significantly less effective.

KEY WORDS Adulticide, Dibrom®, Trumpet®, Scourge®, *Anopheles quadrimaculatus*, *Culex quinquefasciatus*, *Aedes sollicitans*, *Aedes taeniorhynchus*

INTRODUCTION

Pest mosquito management programs rely on economical and effective means for the control of adult mosquito populations. The use of aerial and ground ultra-low volume (ULV) adulticide applications of organophosphate and synthetic pyrethroid insecticides is an important components of these management programs. Because organophosphates and synthetic pyrethroids have long been used in abatement programs to control adult mosquitoes, studies are continually necessary to evaluate effectiveness of control and to monitor potential development of insecticide resistance in mosquito species (Meek and Meisch 1997). The frequent use of the few available materials that perform adequately as mosquito adulticides demands a search for new alternative control methods (Weathersbee et al. 1991). In an effort to reduce insecticide resistance, alternative insecticides must be placed in a rotational scheme to reduce the selective pressure placed on mosquito populations by the few available compounds (Efird et al. 1991).

A study was conducted in the summer of 1997 to compare 2 formulations of naled (Trumpet® and Dibrom®) and 1 formulation of resmethrin (Scourge®) in aerial and ground trials against *Anopheles quadrimaculatus* Say, *Culex quinquefasciatus* Say, and the *Aedes* spp. complex (i.e., *Aedes sollicitans* (Walker) and *Aedes taeniorhynchus* (Wiedemann)). An aerial trial also was conducted to evaluate Trumpet at 3 lower labeled rates against *Cx. quinquefasciatus* and the *Aedes* spp. complex.

MATERIALS AND METHODS

Three adulticide tests were conducted on the evenings of July 14, 15, and 16, 1997, at Calcasieu Parish Mosquito Control District in Lake Charles, LA. Adult *Cx. quinquefasciatus* were collected along septic ditches in East Baton Rouge Parish 24 h before treatment for all tests and adult *An. quadrimaculatus* were collected in Vermillion Parish with battery-powered, handheld aspirators described by Meek et al. (1985) and battery-powered, backpack aspirators equipped with screened collection cups as developed by the U.S. Department of Agriculture at the Medical and Veterinary Entomology Research Laboratory in Gainesville, FL. *Aedes* spp. complex (*Ae. sollicitans* and *Ae. taeniorhynchus*) were collected as 4th instars from St. Bernard Parish before the test and allowed to emerge into adults. The *Aedes* spp. adults used in the test were approximately 3 days old for each test. The ratio of *Ae. sollicitans* to *Ae. taeniorhynchus* was approximately 50:50.

Mosquito adults of all species were anesthetized with CO_2 in the laboratory, and approximately 20 mosquitoes per each genus were transferred to separate 10.2 × 25.4-cm cylindrical screened cages (as described by Weathersbee et al. 1991). The cages were held at room temperature until testing time.

Each evening before the aerial or ground adulticide applications, screened cages of each mosquito species (ca. 20 mosquitoes/cage) used as the untreated mosquitoes (controls) were placed on 9 1.5-m-high stakes (i.e., 3 × 3 pattern with stakes separated by 30.5 m) within each of 3 test plots for

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Table 1 Mean percentage mortalities for Dibrom®, Trumpet®, and Scourge® applied as an aerial application treatment against the *Aedes* spp. complex (salt-marsh mosquitoes)[1], *Anopheles quadrimaculatus*, and *Culex quinquefasciatus* adults in Lake Charles, LA, in 1997.

Time posttreatment (h)	Formulation/rate (g AI/ha)	Percent mortality[2,3]		
		Aedes[1]	*Anopheles*	*Culex*
1	Dibrom (112)	99.8aA	64.0bB	56.1bB
1	Trumpet (112)	99.5aA	56.2bB	55.4bB
1	Scourge (1.96)	99.4aA	99.6aA	97.7aA
12	Dibrom (112)	99.7aA	69.7bB	65.6bB
12	Trumpet (112)	100aA	66.7bB	68.9bB
12	Scourge (1.96)	100aA	100aA	98.9aA
24	Dibrom (112)	99.7aA	73.4bB	68.0bB
24	Trumpet (112)	100aA	69.2bB	70.9bB
24	Scourge (1.96)	100aA	100aA	98.8aA

[1] *Aedes sollicitans* and *Aedes taeniorhynchus* complex.
[2] Means for each time period followed by a different letter within rows (lowercase) and columns (uppercase) are significantly different ($P \leq 0.05$) for species and formulation/rate, respectively.
[3] Untreated controls did not exceed 3.0%.

10 min, removed, and transported to the laboratory. The untreated mosquitoes were anesthetized again with CO_2 and transferred to clean 237-ml unwaxed paper cups with screened lids (=half-pint ice cream containers). Each screened lid was supplied with a cotton pad of 10% sucrose solution for adult sustenance.

Aerial test 1: Three identical test plots consisting of 3 rows of 3 1.5-m-high stakes (i.e., 3 × 3 pattern) were arranged in a flat grassy field on the evening of July 14. Rows were separated from one another by 30.5 m. Slide rotators (Hock Equipment Co., Gainesville, FL) were used to monitor the spray cloud in each adulticide test. Rotators equipped with Teflon®-coated slides were placed on each of the 3 stakes in the center row of each plot to collect droplets. The rotators were started immediately before spraying and were allowed to spin for approximately 10 min after application. Before the adulticide applications, 1 cage of each mosquito species (*Cx. quinquefasciatus*, *An. quadrimaculatus*, and *Aedes* complex) was suspended from each stake. Aerial ULV applications of 1 of 3 chemicals (Dibrom, Trumpet, or Scourge) were applied using a single-engine Cessna Ag Wagon plane equipped with an Obendorfer 24-V motor, a brass-geared pump (Cessna Aircraft Co., Wichita, KS), and 6 80015 tee-jet® nozzles (Spraying Systems, St. Louis, MO). Three swaths were made, 1 test with 1 pass directly over the plot and the subsequent passes 15.0 m upwind. Altitude was 33 m, air speed 177 kph, and windspeed > 3.2 kph. Dibrom was applied at a rate of 112 g AI/ha, Trumpet at 112 g AI/ha, and Scourge at 1.96 g AI/ha. Each of the 3 plots was treated individually with each insecticide, that is, replicated 3 times. Droplet sizes (mass median diameters [MMDs]) for compounds tested averaged 30.1, 37.1, and 43.6 µm for Dibrom, Trumpet, and Scourge, respectively, for all replications.

Aerial test 2: Trumpet was administered as described above at 28 g AI/ha, 56 g AI/ha, and 84 g AI/ha. Each treatment was replicated 3 times as described above. Three test plots consisting of 3 rows of 3 1.5-m-high stakes (i.e., 3 × 3 pattern) were arranged in a flat grassy field on the evening of July 15. Rows were seperated from one another by 30.5 m. Before the adulticide applications, 1 cage of each mosquito species (*Cx. quinquefasciatus* and *Aedes* spp. complex) was suspended from each stake. Aerial ULV applications of 3 dosages of Trumpet were applied as described above. Droplet sizes (MMDs) for Trumpet dosages tested averaged 51.2, 47.3, and 40.5 µm for 28 g AI/ha, 56 g AI/ha, and 84 g AI/ha, respectively, for all replications.

Ground test: Three test plots consisting of 3 rows of 3 1.5-m stakes (i.e., 3 × 3 pattern as described previously) were arranged in a flat grassy field on the evening of July 16. Rows were situated perpendicular to and downwind of the spray route and separated from one another by 30.5 m. Stakes within each row were set at 30.5, 61.0, and 91.4 m, respectively, downwind from the spray route. Before the adulticide applications, 1 cage of each species of mosquitoes (*Cx. quinquefasciatus* and *Aedes* spp. complex) was suspended from each stake approximately 1.5 m from the ground. Ground ULV applications of 3 chemicals (Dibrom, Trumpet, and Scourge) were applied using 3 separate cold foggers. Two of the cold fogger trucks were equipped with identical Leco HD ULV sprayers (Lowndes Engineering, Valdosa, GA), and 1 Londonaire 1820 sprayer (London Fog, Long Lake, MN) was used. Dibrom was administered at 22.4 g AI/ha with the Londonaire sprayer, Trumpet at 22.4 g AI/ha with the Leco sprayer, and Scourge as a 1:6 mineral oil mixture at 177.6 ml/min using a Leco sprayer. Each treatment was replicated 3 times, and ca 25 min lapsed between applications.

Ten minutes after each insecticide treatment, the cages of mosquitoes were collected from the plot

Table 2. Mean percentage mortalities for 3 dosages of Trumpet® applied as an aerial application treatment against the *Aedes* spp. complex (salt-marsh mosquitoes)[1] and *Culex quinquefasciatus* adults in Lake Charles, LA, in 1997.

Time posttreatment (h)	Rate (g AI/ha)	Percent mortality[2,3]	
		Aedes	*Culex*
1	Low (28)	64.8aC	17.1bC
1	Medium (56)	98.9aA	57.0bA
1	High (84)	89.0aB	43.0bB
12	Low (28)	85.7aB	24.6bC
12	Medium (56)	100aA	69.0bA
12	High (84)	98.5aA	51.4bB
24	Low (28)	89.5aB	27.0bC
24	Medium (56)	100aA	72.6bA
24	High (84)	98.8aA	56.7bB

[1] *Aedes sollicitans* and *Aedes taeniorhynchus* complex.

[2] Means for each time period followed by a different letter within rows (lowercase) and columns (uppercase) are significantly different ($P \le 0.05$) for species and dosage, respectively.

[3] Untreated controls did not exceed 3.0%.

and transported to the laboratory. The treated mosquitoes were anesthetized with CO_2 and transferred to clean 237-ml paper cups with screened lids. Each screened lid was supplied with a cotton pad of 10% sucrose solution. Posttreatment mortality for untreated and treated adults was observed at 1, 12, and 24 h. Percent mortality data were subjected to a subsequent analysis of variance (GLM) and mean separation was determined using least squared difference (SAS Institute 1985).

RESULTS AND DISCUSSION

Aerial test 1

Against the *Aedes* spp. complex, mortality was higher than 99% at 1, 12, and 24 h, and did not significantly differ with formulation (Table 1). At all time intervals, Dibrom and Trumpet were significantly more effective against the *Aedes* spp. complex than against *An. quadrimaculatus* and *Cx. quinquefasciatus*. No significant difference was found between Dibrom and Trumpet. Scourge caused greater than 97% mortality against all 3 species, and mortality did not differ significantly with species. Scourge also was significantly more effective against *An. quadrimaculatus* and *Cx. quinquefasciatus* than Dibrom and Trumpet. Mortality between *An. quadrimaculatus* and *Cx. quinquefasciatus* was not significantly different (Table 1).

Aerial test 2

Adult mortality increased significantly at 1 and 24 h with Trumpet at the medium rate against *Cx. quinquefasciatus* (Table 2). With the *Aedes* spp. complex, mortality increased with Trumpet at the medium rate at 1 h, but at 12 and 24 h, the medium and high rates were not significantly different from each other. Mortality of *Aedes* was significantly greater than that of *Cx. quinquefasciatus* at all 3 Trumpet rates and time intervals. The medium dosage of Trumpet was significantly more effective than the high dosage at 1 h posttreatment against the *Aedes* spp. complex and at all time intervals against *Cx. quinquefasciatus* (Table 2).

Ground test

No interspecies comparison is given in Table 3. However, the Dibrom and Trumpet numbers exhibit a greater difference between species than does Scourge. Against *Cx. quinquefasciatus*, Scourge was significantly more effective than Dibrom and Trumpet at all times and distances, but against the

Table 3. Mean percentage mortalities for Dibrom®, Trumpet® and Scourge® applied as an ultra-low volume ground-application treatment against the *Aedes* spp. complex (salt-marsh mosquitoes)[1] and *Culex quinquefasciatus* adults in Lake Charles, LA, in 1997.

Time posttreatment (h)	Formulation/rate (g AI/ha at 10 mph)	Mean percentage mortality[2,3]					
		Aedes (distance downwind, m)			*Culex* (distance downwind, m)		
		30.5	60.9	91.4	30.5	60.9	91.4
1	Dibrom (22.4)	85.7aA	91.2aA	78.8bA	12.0aB	16.9aB	12.6aB
1	Trumpet (22.4)	100aA	100aA	87.5aA	14.8aB	8.7aB	6.8aB
1	Scourge (1.96)	69.9aB	60.7aB	48.8aB	89.2aA	78.1aA	75.4aA
12	Dibrom (22.4)	98.9aA	96.8aA	92.2aA	16.1aB	22.4aB	17.2aB
12	Trumpet (22.4)	100aA	99.5aA	98.8aA	17.6aB	14.2aB	9.5aB
12	Scourge (1.96)	76.0aB	67.9aB	60.5aB	82.5aA	71.0abA	56.0bA
24	Dibrom (22.4)	98.9aA	96.8aA	92.7aA	17.7aB	26.0aB	18.4aB
24	Trumpet (22.4)	100aA	98.4aA	99.2aA	21.1aB	14.9aB	10.8aB
24	Scourge (1.96)	75.3aB	63.9aB	56.1aB	78.5aA	66.2abA	51.7bA

[1] *Aedes sollicitans* and *Aedes taeniorhynchus* complex.

[2] Means within each time and species followed by a different letter within rows (lowercase) and columns (uppercase) are significantly different ($P \le 0.05$) for distance and formulation/rate, respectively.

[3] Untreated controls did not exceed 4.0%.

Aedes spp. complex, it was significantly less effective (Table 3). No significant difference was found between Dibrom and Trumpet against either species at any time or distance. Scourge resulted in a high level of mortality against both species at 30 m downwind, with mortality across species and times ranging from 69.9 to 89.2%. Mortality with Dibrom and Trumpet was quite high (>85%) at 30 m downwind against *Aedes* spp. complex, but was low (<22%) against *Cx. quinquefasciatus*. It was noted that some recovery occurred with *Cx. quinquefasciatus* 24 h after treatment with Scourge.

In summary, Trumpet and Dibrom gave comparable control of the 3 mosquito species in both the aerial and ground tests. The 3 lower labeled rates of Trumpet were efficacious against the *Aedes* spp. complex after aerial application. Trumpet and Dibrom were more efficacious than Scourge against the *Aedes* spp. complex in the ground test. However, Scourge was more efficacious against *An. quadrimaculatus* in the aerial test and against *Cx. quinquefasciatus* in both the aerial and ground applications.

REFERENCES CITED

Efird, P. K., A. D. Inman, D. A. Dame and M. V. Meisch. 1991. Efficacy of various ground-applied cold aerosol adulticides against *Anopheles quadrimaculatus*. J. Am. Mosq. Control Assoc. 7:207–209.

Meek, C. L. and M. V. Meisch. 1997. Resistance in a Louisiana strain of *Culex quinquefasciatus* to selected Fyfanon® formulations. Southwest. Entomol. 22:449–452.

Meek, C. L., M. V. Meisch and T. W. Walker. 1985. Portable, battery-powered aspirators for collecting adult mosquitoes. J. Am. Mosq. Control Assoc. 1:102–105.

SAS Institute. 1985. SAS user's guide: statistics. Version 6.0. SAS Institute, Cary, NC.

Weathersbee, A. A., M. V. Meisch, A. E. Inman and D. A. Dame. 1991. Activity of lambda-cyhalothrin applied as an ultralow volume ground treatment against *Anopheles quadrimaculatus* adults. J. Am. Mosq. Control Assoc. 7:238–241.

1998 Sukontason, K., J. K. Olson, W. K. Hartberg, and R. E. Duhrkopf
Organophosphate and Pyrethroid Ausceptibilities of *Culex salinarius* Adults from Texas and New Jersey
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927 ✓

ORGANOPHOSPHATE AND PYRETHROID SUSCEPTIBILITIES OF *CULEX SALINARIUS* ADULTS FROM TEXAS AND NEW JERSEY[1]

KABKAEW SUKONTASON,[2,3] JIMMY K. OLSON,[2] W. KEITH HARTBERG[4] AND RICHARD E. DUHRKOPF[4]

ABSTRACT. Susceptibilities of adults from newly established colonies of *Culex salinarius* from New Jersey and Texas to commonly used mosquito adulticides were assessed using the insecticide-coated vial bioassay technique. Females from both colonies were similar in their susceptibilities to naled, chlorpyrifos, resmethrin, and permethrin. However, females from the New Jersey colony (established from collections made in Cape May County, NJ) were found to be 9 times more tolerant to malathion than were those from the Texas colony (established from collections made in Chambers County, TX), with median lethal concentration values for malathion tested against these 2 colonies of 0.70 and 0.08 μg malathion/vial, respectively. The differences between these 2 colonies with respect to their tolerances to malathion may be a product of the age of each colony at the time assessments were made and/or the degree to which the parent stock used to start each colony was previously exposed to malathion in the field.

KEY WORDS Mosquito adulticides, insecticide tolerance, resistance management, susceptibility baselines

Culex salinarius Coq., a major nuisance mosquito in the eastern one half of the United States, has been implicated as a possible vector of St. Louis encephalitis virus (Clark et al. 1977). Thus, not only are new ways to more effectively manage this pest mosquito necessary, but also ways are needed to monitor the effectiveness of the current control tactics used against it. Mosquito abatement programs generally attempt to target both the larval and adult stages of mosquito populations to be controlled. However, the current control strategy for *Cx. salinarius*, particularly as it occurs in the rice-growing coastal region of southeastern Texas, rests almost entirely on the use of effective chemicals against adult populations. The chemical adulticides are most commonly applied at ultra-low volume (ULV) rates (3 oz. active ingredient or less per acre) by truck-mounted, cold aerosol ground units or by aircraft against adult *Cx. salinarius* populations just as they are emerging or as they migrate from their larval development sites toward more human-populated areas. This one-dimensional approach to controlling problems associated with *Cx. salinarius* makes it imperative that the chemical adulticides being used against this mosquito species are the most effective ones available and that the effectiveness of these chemicals be preserved.

Until now, no in-depth laboratory studies have been conducted on the various adulticides currently available for use against mosquitoes as to their relative effectiveness against *Cx. salinarius* adults because of the difficulty in rearing this species under laboratory conditions. However, laboratory colonies of *Cx. salinarius* were recently established at Texas A&M University using wild mosquito stock collected from Cape May County, NJ, and the U.S. Fish and Wildlife Service's (USFWS) Anahuac Wildlife Refuge in Chambers County, TX. The establishment of these colonies made it possible for us to determine some baselines of susceptibility for *Cx. salinarius* to the adulticidal agents most commonly used against this species in the United States.

Mosquito adulticide susceptibility tests were conducted on 3- to 4-day-old females from the 2 *Cx. salinarius* colonies using the insecticide-coated vial bioassay technique of Plapp (1971). The females used in these bioassays were obtained from the 11th laboratory generation of the Texas colony and the 2nd laboratory generation of the New Jersey colony of *Cx. salinarius* established at Texas A&M University. Methods used in establishing and maintaining these colonies will be the subject of a subsequent paper. The 5 currently labeled adulticides included in the bioassays were malathion, naled, chlorpyrifos, resmethrin, and permethrin. Each technical grade insecticide was serially diluted with acetone to the appropriate concentrations. The insecticide dilutions were pipetted into 20-ml glass scintillation vials (5 vials/concentration/mosquito strain) and, if necessary, acetone was added to bring the total volume to 0.5 ml of liquid being placed into each vial. Only acetone (0.5 ml/vial) was placed in the control vials (5 vials/insecticide/mosquito strain). After adding the acetone solutions, all vials were placed on their sides and rolled manually until the solvent completely evaporated leaving the insecticide residue (when present) even-

[1] This study was conducted in cooperation with the U.S. Department of Agriculture (USDA), Agricultural Research Service, as part of USDA, Cooperative State Research, Education and Extension Service (CSREES) Southern Regional Project S-260 involving State Agricultural Experiment Station personnel in Arkansas, California, Illinois, Louisiana, Mississippi, and Texas

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Table 1. Results of insecticide susceptibility bioassay tests conducted on adult females from laboratory colonies of Texas (TX) and New Jersey (NJ) strains of *Culex salinarius* during 1996.[1]

Insecticide and mosquito strain[2]	LC_{50} (μg/vial)	RR_{50}[3]	LC_{95} (μg/vial)	RR_{95}[3]	Slope ± SE
Malathion					
NJ	0.701	9.22	1.159	3.38	7.527 ± 1.914
TX	0.076	—	0.343	—	2.526 ± 0.647
Naled					
NJ	0.076	1.77	0.162	1.53	5.029 ± 1.497
TX	0.043	—	0.106	—	4.247 ± 1.132
Chlorpyrifos					
NJ	0.087	2.23	0.505	2.34	2.152 ± 0.357
TX	0.039	—	0.216	—	2.209 ± 0.297
Resmethrin					
NJ	0.033	1.83	0.111	0.57	3.124 ± 0.705
TX	0.018	—	0.194	—	1.594 ± 0.296
Permethrin					
NJ	0.039	4.33	0.101	3.88	3.996 ± 1.405
TX	0.009	—	0.026	—	3.591 ± 0.853

[1] Colonies were maintained at 20°C, 80% relative humidity, and 9 h:13 h light:dark with a 2-hr morning and evening crepuscular features. LC_{50}s median lethal concentration; LC_{95}, 95% lethal concentration.

[2] The NJ and TX colonies were in their F_2 and F_{11} laboratory generations, respectively, at the time of testing.

[3] The LC_{50} and LC_{95} resistance ratios (RR_{50} and RR_{95}, respectively) were determined by dividing the LC_{50} and LC_{95} values recorded for the New Jersey strain by the comparable values recorded for the Texas strain of *Cx. salinarius*.

ly coated over the inside surfaces of each vial. A small cotton pad (ca. 0.75 cm^2) soaked with 10% sucrose solution was placed in the bottom of each vial as a carbohydrate source for the mosquitoes.

Female *C. salinarius* aspirated from one of the laboratory colonies, were lightly anesthetized with carbon dioxide and placed on a chill table (set at ca. 7°C) for counting. Five females were placed into each treated and control vial included in a test set for a given insecticide. Separate test sets were prepared for each of the 2 mosquito colonies. The vials of mosquitoes were plugged with cotton, placed in the holding compartments of a scintillation vial carton, covered with moist paper toweling, and held at room temperature for 24 h.

Mosquito mortality occurring in each vial was recorded at the end of the 24-h exposure period. The resulting data were analyzed using the SAS Probit Program (SAS 1985). The analyses corrected for control mortalities and provided median lethal concentration (LC_{50}), 95% lethal concentration (LC_{95}), and 95% confidence interval values in micrograms of insecticide per vial. Slopes (indicators of the degree of homogeneity in each population's response to the insecticides tested) were also provided by this program.

Results of the bioassays involving the 2 colonized strains of *Cx. salinarius* are summarized in Table 1. At the LC_{50} level of comparison, the Texas strain of *Cx. salinarius* females tended to be slightly more susceptible to each of the adulticides tested than were the females of the New Jersey strain of this species. This is indicated by the New Jersey strain to Texas strain LC_{50} resistance ratios (RR_{50}s) ranging from a low of 1.77 for naled to a high of 9.22 for malathion (Table 1).

To gain further insight as to the meaning of these results, the LC_{50} and LC_{95} values for the insecticides tested against the Texas strain of *Cx. salinariu* were compared, via the computation of additional resistance ratios, to the values recorded for tests conducted during the same time period on females from the colony of the insecticide-susceptible UTMB strain of *Culex quinquefasciatus* Say maintained at Texas A&M University. The results of these comparisons are shown in Table 2 and indicate the Texas *Cx. salinarius* strain was just as susceptible (e.g., to malathion) and in most cases, more susceptible to the adulticides tested than was the UTMB strain of *Cx. quinquefasciatus*. The Texas strain of *Cx. salinarius* was thus deemed the best colony to keep on hand as a reference base for future efforts being planned for monitoring the status

Table 2. Insecticide resistance ratios for adult females of the colonized Texas strain of *Culex salinarius* vs. the colonized, insecticide-susceptible UTMB strain of *Culex quinquefasciatus*.

Insecticide	RR_{50}[1]	RR_{95}[1]
Malathion	1.07	2.43
Naled	0.57	0.82
Chlorphyrifos[2]	—	—
Resmethrin	0.17	0.48
Permethrin	0.05	0.06

[1] The median lethal concentration (LC_{50}) and 95% lethal concentration (LC_{95}) resistance ratios (RR_{50} and RR_{95}, respectively) were determined by dividing the LC_{50} and LC_{95} values recorded for the Texas strain of *Cx. salinarius* by the comparable values recorded for the UTMB strain of *Cx. quinquefasciatus*.

[2] Chlorpyrifos was not tested against the UTMB strain of *Cx. quinquefasciatus*.

of resistance in wild populations of this mosquito species in Texas and elsewhere in the United States.

Based on the Texas A&M laboratory's experience in monitoring resistance levels in wild populations of *Cx. quinquefasciatus* using the UTMB strain of this species as a reference base, resistance ratio values that begin to approach a value of 10 indicate that the wild populations for which such values are being recorded are beginning to develop a tolerance to the particular pesticide in question. Ratios exceeding 10 indicate that a significant level of insecticide resistance is present in the target population. If the same trend holds true for *Cx. salinarius*, the RR_{50} value of 9.22 recorded for the New Jersey strain of this species against malathion (Table 1) indicates that resistance to this particular chemical is beginning to develop in the New Jersey population of *Cx. salinarius* from which stock was taken to start our laboratory colony.

Judy A. Hansen (Director of the Cape May County Mosquito Control Commission, personal communication) indicated that the particular *Cx. salinarius* population from which our colonizing stock came had been periodically treated with malathion on an annual basis with aerial ULV applications of malathion for several years prior to our investigation. The overall adulticiding strategy used by the Cape May Mosquito Control Commission is to interdict adult populations of *Aedes sollicitans* (Walker) and sometimes those of *Cx. salinarius* as they migrate enmass from their marshland development sites upland and toward more human-populated areas of the county. This exposure, although limited in nature, may have been enough to cause the elevated tolerances to malathion noted for the New Jersey strain of *Cx. salinarius* used in our assessments. If such is the case, it demonstrates how careful mosquito control agencies must be in using any class of insecticides in their programs to avoid the development of resistance.

In this regard, the continuous use of only one kind or class of insecticide over long periods of time as a sole tactic for controlling a target mosquito population can put a great deal of insecticidal pressure on the population. Eventually, if such a strategy is continued, resistance to the insecticide or to a whole class of insecticides can be selected for in a manner as described by Frisbie et al. (1987). Indeed, the continuous use of malathion over a period of several years has caused increased incidences of resistance in populations of such mosquito species as *Cx. quinquefasciatus* (Bisset et al. 1991) and *Aedes albopictus* (Skuse) (Herbert and Perkins 1973, World Health Organization 1986). Although no evidence of insecticide resistance has yet to be reported in *Cx. salinarius*, our data indicate that such could happen in Cape May County, NJ, if it were not for the fact that the mosquito control commission in this county is following good insecticide resistance management (IRM) practices by using malathion sparingly and alternating classes of chemicals in its adulticiding program when possible. Even with these IRM practices in place, the tolerances of the Cape May County adult *Cx. salinarius* populations appear to be elevated for malathion and these tolerances need to be regularly monitored as long as this agent is used in the Cape May County mosquito adulticiding program.

In contrast to the situation in New Jersey, the Texas population of *Cx. salinarius* included in our bioassay appears to be quite susceptible to all the adulticides tested. This may be due in part to the fact that the Texas strain of this species had been in colony longer (11 generations) than the New Jersey strain (2 generations) before it was tested against insecticides, thereby giving more opportunity for susceptibility to become reestablished in the colony, as would occur in insecticide-free refugia in nature (Frisbie et al. 1987). Also, the fact that the stock used to establish the Texas strain colony of *Cx. salinarius* came from a wildlife refuge that had not been treated with any type of insecticide for at least 15 years (Hoyt Henry, Director, Chambers County Mosquito Control District, Anahuac, TX, personal communications) could explain why the Texas strain of this species proved so susceptible to the adulticides tested.

The research described herein established baselines of susceptibility for select populations of *Cx. salinarius* to commonly used adulticides and established a colony of a susceptible strain of this species for use in subsequent insecticide resistance monitoring programs. Also, our research points out the care that must be taken in using a given chemical in a mosquito control program and the value of maintaining insecticide-free refugia. Guarded and strategic use of any given insecticide and making provision for refugia where susceptible members of a target insect population can continue to survive and extend their susceptibility back into the whole of the target insect population are essential ingredients in any plan developed to proactively manage insecticide resistance in an insect population (Frisbie et al. 1987). Mosquito populations are no exception in this regard.

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REFERENCES CITED

Bisset, J. A., M. M. Rodriguez, J. Hemingway, C. Diaz, G. J. Small and E. Ortiz. 1991. Malathion and pyrethroid resistance in *Culex quinquefasciatus* from Cuba: efficacy of pirimiphosmethyl in the presence of at least three resistance mechanisms. Med. Vet. Entomol. 5: 223–228.

Clark, G. G., H. L. Pretula, T. Jakubowski and M. A. Hurd. 1977. Arbovirus surveillance in Illinois in 1976. Mosq. News 37:389–395.

Frisbie, R. E., W. P. Morrison, C. E. Hoelscher, S. R. Pullen, F. W. Plapp, Jr., C. T. Allen and J. W. Stewart. 1987. Insecticide resistance management. Texas Agricultural Extension Service Leaflet 500.3–87. Texas Agricultural Extension Service, College Station, TX.

Herbert, E. W. and P. V. Perkins. 1973. Comparative tests of five insecticides against *Aedes albopictus* la... from South Vietnam. Mosq. News 33:76–78.

Plapp, F. W., Jr. 1971. Insecticide resistance in *Heliothis*: tolerance in larvae of *H. virescens* as compared with *H. zea* to organophosphate insecticides. J. Econ. Entomol. 64:999–1002.

SAS Institute, Inc. 1985. SAS user's guide statistics, version 5 edition. SAS Institute, Inc., Cary, NC.

World Health Organization. 1986. Resistance of vectors and reservoirs of disease to pesticides. 10th Report of the Expert Committee on Vector Biology and Control. WHO Tech. Rep. Ser. 737. Geneva, Switzerland.

1998 Moore, C.G.
Letter to Editor RE: Impact of Naled (Dibrom 14) on the Mosquito Vectors of Eastern Equine Encephalitis Virus
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LETTER TO THE EDITOR

ABSTRACT. This letter questions the appropriateness of methodology used in a study by Howard and Oliver (*J. Am. Mosq. Control Assoc.* 13:315–325; 1988). Two independent data sets, collected for different purposes by 2 different groups, were subjected to statistical analysis to determine if the data sets differed. The experimental "design," as described by the authors, is an example of pseudoreplication, which arises when replicates are collected at a scale finer than the one for which conclusions of statistical testing are intended to be drawn. All of the components of a properly designed field experiment (control, replication, randomization, and interspersion) are missing from this study. The authors proceed to draw a series of conclusions from the data presented. Few, if any, of the conclusions can be supported by the evidence presented. The assertions put forward in this paper could have a severe negative impact on efforts to prevent transmission of arboviruses or other pathogens to humans and domestic animals.

KEY WORDS Vector control, naled, eastern equine encephalomyelitis, *Culiseta melanura*, experimental design, pseudoreplication

Because I am identified as having "reviewed a previous draft," of the paper by Howard and Oliver (1998), I wish to make several comments about that work. My comments relate to the appropriateness of the methodology and experimental design and the relation between conclusions drawn and the data presented.

1. Methods were not appropriate to the question being asked: In this report, 2 independent data sets, collected for different purposes by different groups, were subjected to statistical analysis to determine if the data sets differed. I pointed out several of the problems in my review of the earlier version of the manuscript, and I do not see that those problems have been corrected. The experimental "design," as described by the authors, is an example of pseudoreplication (Hurlbert 1984). Pseudoreplication arises when replicates are collected at a scale "finer than the one for which conclusions of statistical testing are intended to be drawn" (Dutilleul 1993). All of the components of a properly designed field experiment (control, replication, randomization, and interspersion) are missing.

There were no control sites (i.e., sites that were never treated; Howard and Oliver 1998, p. 317). A 3-year period in which Toad Harbor was not treated is taken to be an indication of "nontreatment population trends of the species of interest. . . ." This can hardly be called a proper control.

There was no replication. Each site basically consisted of a single replicate, sampled multiple times at several locations (pseudoreplicates) within the replicate. A properly replicated study would have followed trends in at least 4–6 swamp areas, with the areas being randomly allocated to either treatment or untreated control status (hence, the randomization quality is also missing). It is important to point out that such an experiment is seldom possible because of the ethical dilemma of not treating an area in the event of an arbovirus outbreak. Finally, there is no interspersion of treated and untreated areas, which would help to overcome the natural variability between swamps. The authors state (p. 321) that "the 2 swamps are remarkably similar." Although this may be true at some spatial scales, it is quite untrue at others. From the air in midsummer, the 2 areas are visibly different, suggesting some underlying ecological differences that might impact the eastern equine encephalomyelitis (EEE) system.

Although the general linear model was probably the best choice for the statistical analysis, I doubt seriously that even the most robust analysis can overcome the basic flaws in the structure of this study.

Additional basic problems exist in the data used in the study. For example, the authors attempted to study the duration of impact of naled application on EEE vectors. Unfortunately, at least at Cicero Swamp, there seems to have been a cessation of trapping on the nights immediately following spraying. In all of the sequences I have examined, there is a gap of several days with no data (apparently because trap collections were too low to make it worthwhile). Although it is possible to confirm that a reduction occurred and that the reductions lasted no more than 1–2 wk, little else can be said (but, see my comments below [2.a.]).

2. The conclusions do not follow from the information presented. The authors offer the following conclusions from their analysis:

a. Application of naled achieved short-term reductions of the 4 vector species and seasonal reductions in the 3 univoltine species, but no long-term impact was observed.

b. The 15-fold increase in *Culiseta melanura* and 83-fold decrease in *Culiseta morsitans* are attributed to multiple long-term impacts of naled.

c. And, finally, "The possibility that applications of naled contributed to increased populations of *Cs. melanura* discredits the rationale that preventive applications of naled reduce the risk of EEE."

I offer the following observations and comments on the conclusions:

a. Naled clearly achieved short-term reductions of the 4 vector species. I am not sure that all of the seasonal reductions (and the 1 multiyear reduction) are due to naled, but it is certainly a possibility. However, weather factors should have been taken into account as well. It is not clear to me why the authors expected to see a long-term (multiyear) impact from the use of such a short-acting pesticide. Their comments seem to indicate confusion between a philosophy of disease prevention and one of disease eradication.

Theoretically, if the basic reproductive rate of a disease (R_0, the average number of secondary infections attributable to a single infectious case introduced into a fully susceptible population; Fine et al. 1982) is driven below 1.0, transmission will cease. Although the value of R_0 for EEE is not known, it is probably fairly low because of the small number of cases per year in humans and domestic animals. If this is the case, then it seems likely that even an interruption of 1 wk might be sufficient to prevent widespread transmission. If only the "bridge vectors" are of concern (i.e., we do not worry about what happens to the enzootic cycle), the interruption seems to be significantly longer on the basis of the data in this paper. This may be a risky strategy if *Cs. melanura* plays a significant role in dispersing EEE virus outside the swamp habitats (see below).

On the basis of a small study conducted by one of my students, the rapid return of *Cs. melanura* at Cicero Swamp appears to be because of immigration from surrounding areas (T. Welch et al., unpublished research). In this study, female *Cs. melanura* from collections before and after the application of naled in Cicero Swamp were dissected, and the ovaries were examined to determine parity. Our hypothesis was that the returning population would be largely composed of newly emerged nullipars because ultra low volume (ULV) has no effect on immatures. An alternate hypothesis is that the population is replaced through immigration. No significant difference in parity occurred between pre- and postspray populations. Thus, apparently migration is an important factor in the rapid return of *Cs. melanura* following spraying. In fact, Howard et al. (1996) documented the importance of dispersal in moving "from swamp to upland areas and between swamp complexes." Thus, focusing on a larger area than just Cicero and Toad Harbor swamps may be important if an EEE prevention program is to be effective. Knowing whether or not the EEE enzootic cycle is being maintained in other areas besides Toad Harbor and Cicero swamps is important. Are there outlying foci that can re-seed the primary foci following control? The data presented by Howard et al. (1996) suggest that either multiple foci exist or *Cs. melanura* (and/or bridge vector) females fly very long distances.

b. A basic tenet of science is that correlation does not prove causation. There is absolutely no reason, on the basis of the data presented, to conclude that the observed changes in the 2 species resulted from the application of naled. The authors mention, but quickly discard, several possible alternative hypotheses (the original review panel raised several of these hypotheses). Only conducting experiments in such a way that they can be falsified can eliminate the alternate hypotheses. The authors suggest, for example, that beavers are unlikely to have had an impact in Cicero Swamp, but beavers can have a massive impact on freshwater habitats (see, e.g., Naiman et al. 1988, Langston 1998). The authors state that, if rising water levels (from beaver activity) were a factor, "one would expect that the same factor would influence population levels of *Cq. perturbans* . . ." Unless their fig. 1 is mislabeled, this is exactly what is shown by the data. It seems to me that there is an opportunity for a very interesting study that is being missed.

Similarly, the "exponential increase in *Cs. melanura*" and concurrent "significant reduction" in *Cs. morsitans* are, at this point, observations of change in the numbers of 2 species. These changes may have resulted from interspecific interactions, or they may not. In fact, much of the authors' case rests on only a single year, 1993, which severely skews the longer term trend.

At this point, one would be hard pressed to decide if this was a pattern or simply random variation. Another possibility that the authors do not mention is the impact of interannual/decadal climate patterns. These patterns are known to have a large impact on vectors and vector borne disease.

c. Conclusions in science should be based on data gathered with an appropriate experimental design and interpreted after an appropriate statistical analysis. Presentation of an unfounded "possibility" as a basis for a conclusion (other than that additional study is indicated) is not warranted. In this article, the authors attempt to discredit the use of a public health tool (ULV adulticiding with naled) by extrapolating a "possibility" from inappropriate data and a poor study design.

The authors imply that there is sufficient evidence to conclude that the mosquito *Cs. melanura* is becoming more predominant because of the spraying. Because of the deficiencies outlined above, concluding that such a relationship exists is impossible. Although a relation between spraying with naled and the apparent increase in *Cs. melanura* cannot be proved on the basis of the data presented, that possibility also cannot be excluded by using these data.

One could ask if it is worthwhile (or even possible) to design and conduct an experiment that would actually answer the question posed by Howard and Oliver. I think it would be worthwhile, but there are a number of hurdles to overcome. A properly designed study, one that would overcome the deficiencies of the present study, would be expensive to design and carry out. In addition, there may be ethical questions if some areas are to be left as untreated controls. (What happens if EEE virus is detected in an untreated control swamp?) Also, a basic difference exists in the way vector surveillance would be conducted in an experimental setting as opposed to the disease surveillance setting. In the latter, we want to have the greatest possible chance of collecting infected females at the earliest possible date—that is an intentional bias that may be undesirable in an experimental setting.

On the other hand, it may be possible to design smaller studies to answer specific questions, such as the issue of beaver impacts on habitats and densities of the major vector species. Similarly, some fairly simple, but labor-intensive, studies might shed light on the issue of competition/displacement between *Cs. melanura* and *Cs. morsitans*.

REFERENCES CITED

Dutilleul, P. 1993. Spatial heterogeneity and the design of ecological field experiments. Ecology 74:1646–1658.

Fine, P. E. M., J. Aron, J. Berger, D. J. Bradley, H. J. Bürger, E. G. Knox, H. P. R. Seeliger, C. E. G. Smith, K. W. Ulm and P. Yekutiel. 1982. The control of infectious disease group report. pp. 121–147. *In:* R. M. Anderson and R. M. May (eds.). Population Biology of Infectious Diseases. Springer-Verlag. New York.

Howard, J. J. and J. Oliver. 1998. Impact of naled on the mosquito vectors of eastern equine encephalitis virus. J. Am. Mosq. Control. Assoc. 13:315–325.

Howard, J. J., M. A. Grayson, D. J. White and J. Oliver. 1996. Evidence for multiple foci of eastern equine encephalitis virus (Togaviridae: *Alphavirus*) in central New York state. J. Med. Entomol. 33:421–432.

Hurlbert, H. S. 1984. Pseudoreplication and the design of ecological field experiments. Ecol. Monogr. 54:187–211.

Langston, N. E. 1998. People and nature: understanding the changing interactions between people and ecological systems. *In:* S. I. Dodson, T. F. H. Allen, S. R. Carpenter, A. R. Ives, R. L. Jeanne, J. F. Kitchell, N. E. Langston and M. G. Turner (eds.). Ecology. Oxford Univ. Press. New York.

Naiman, R. J., C. A. Johnson and J. Kelley. 1988. Alteration of North American streams by beaver. BioScience 38:753–761.

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1997 Howard, J.J., and J. Oliver
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Naled product File

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IMPACT OF NALED (DIBROM 14®) ON THE MOSQUITO VECTORS OF EASTERN EQUINE ENCEPHALITIS VIRUS

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ABSTRACT. In central New York, aerial mosquito adulticide applications have been used in response to eastern equine encephalitis (EEE) outbreaks and have targeted the swamp habitats of the primary enzootic vector of EEE virus, *Culiseta melanura* (Coquillett). The organophosphate insecticide naled (1. 2. dibromo-2. 2-dichloroethyl dimethyl phosphate) has been the insecticide of choice in this region. This study reports on analyses of 11 years (1984–94) of mosquito collection data from Cicero and Toad Harbor swamps in relation to applications of naled. Naled applications were successful in achieving short-term reductions in mosquito abundance. ···vever, despite repetitive applications. populations of the primary vector of EEE virus, *Cs. melanura*. have .reased 15-fold at Cicero Swamp. Preventive applications had no noticeable impact on the enzootic amplification of EEE virus. and isolations of virus following preventive applications have resulted in additional spraying. The possibility that applications of naled contributed to increased populations of *Cs. melanura* discredits the rationale that preventive applications of naled reduce the risk of EEE.

INTRODUCTION

Ultra-low volume (ULV) aerial applications of the mosquito adulticide Cythion® in response to outbreaks of arthropod-borne viruses gained acceptance during the 1960s when used during St. Louis ·phalitis outbreaks in Texas (Kilpatrick and Adams 1967). In 1972 and 1974, aerial ULV applications were used in Massachusetts in response to epidemics of eastern equine encephalitis (EEE). Although evaluations of spraying efficacy produced equivocal results (Grady et al. 1978), in Massachusetts the application of malathion continues to be the recommended response during EEE epidemics (Edman et al. 1993). In central New York, aerial mosquito adulticide applications have also been used in response to EEE outbreaks and have tar- ·l the swamp habitats of the primary enzootic vector of EEE virus, *Culiseta melanura* (Coquillett) (Morris 1988). The organophosphate insecticide naled (1, 2. dibromo-2, 2-dichloroethyl dimethyl phosphate) has been the insecticide of choice in this region. The formulation used is Dibrom 14® mixed with heavy aromatic naphtha, a fast-acting, short-residual adulticide developed for mosquito control (Haile et al. 1982), applied at a rate of 0.2 liter/ha (1 pint/acre). All applications have been performed by the same contractor using Piper Aztecs equipped ı Micromist 900® spray systems (Warm 1986).

Morris (1988) stated that a single well-timed application of an adulticide could control *Cs. melanura*. This statement was based on evaluation of 1-day pre- and postefficacy data from the treated area and the resultant absence of equine EEE from upland areas following adulticide applications (Morris, unpublished data). Following the second human EEE fatality in central New York (Howard et al. 1988), a more liberal mosquito spraying policy was adopted by local municipalities. The 2 areas most ·uently subject to control were Cicero Swamp in ·ondaga County and Toad Harbor Swamp in Oswego County. the recognized enzootic foci of EEE virus in central New York (Morris et al. 1980, Howard et al. 1996). Aerial applications of naled have occurred as preventive measures in response to large numbers of mosquitoes, as a reaction to the detection of Highlands J (HJ; a mosquito-borne virus of birds that is not pathogenic to humans), the detection of EEE virus in mosquitoes, or the occurrence of EEE. With the exception of 1993, when 25% of Toad Harbor Swamp was experimentally treated with Altosid® (methoprene) pellets (Woodrow et al. 1995), larval control activities have not been undertaken in these swamps.

Yearly summaries of mosquito and virus surveillance data question Morris' conclusion regarding the effectiveness of aerial adulticiding. These summaries revealed a trend toward increasing numbers of *Cs. melanura* and EEE virus isolations during the late 1980s and early 1990s (Howard et al. 1994) and led to the current study. During the 1983 EEE outbreak in central New York, a majority (91%, $n = 21$) of EEE virus isolations were made from mosquitoes collected in Cicero Swamp (Howard et al. 1988). There were 11 isolations of EEE virus from 1.118 *Cs. melanura* and 7 isolations from 1,534 *Culiseta morsitans* (Theobald) collected and assayed between July 1 and mid-October 1983. In 1990, there were 86 EEE virus isolations from central New York. of which 27 were from 21,857 *Cs. melanura* and 1 from 816 *Cs. morsitans* collected and assayed from Cicero Swamp between June 7 and late October 1990. In 1992, although there were no EEE virus isolations from central New York (Howard et al. 1994). 55,749 *Cs. melanura* and 157 *Cs. morsitans* were collected and assayed from Cicero Swamp between June 1 and the late September 1992. This paper reports on the evaluation of short-term. seasonal. and long-term quantitative mosquito population data in response to aerial applications of naled to Cicero and Toad Harbor swamps over an 11-year period. 1984–94.

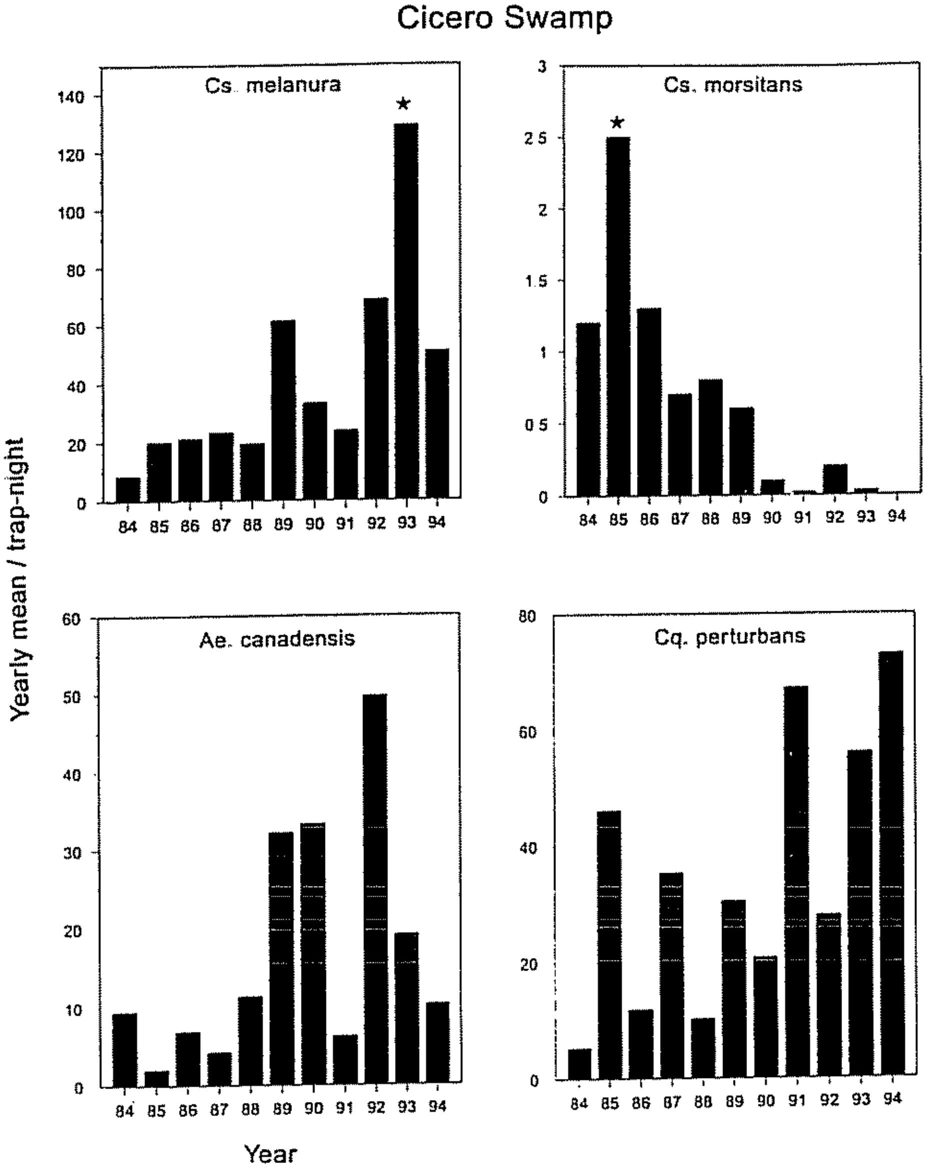


Fig. 1. Yearly trap-night means (Y) for *Cs. melanura*, *Cs. morsitans*, *Ae. canadensis*, and *Cq. perturbans* at Cicero Swamp, NY, 1984–94 (★ mean is significantly higher than all other means; GLM, Duncan's groupings, $P < 0.01$).

MATERIALS AND METHODS

Treatment areas: Cicero Swamp is a 1,600-ha state-owned game management area located in northeastern Onondaga County, 16 km from the city of Syracuse (Morris et al. 1980). Cicero Swamp was sprayed twice prior to 1984, in September 1974 and September 1983. Toad Harbor Swamp is 2,000 ha, of which approximately two-thirds is the Three Mile Bay Game Management Area. Toad Harbor Swamp was sprayed twice prior to 1984, in August 1976 and September 1983. We assume that mosquito populations in both swamps have recovered from any impact of the 1970s' sprays and that the sprays in September 1983 occurred too long after the peak of adult mosquito activity to have an impact on the current study. Spray dates and number of hectares treated during 1984–94 were obtained from documents filed with the New York State Department of Health (NYSDOH). Spray events were categorized as preventive or reactive. Preventive applications were based on numbers of mosquitoes only. Reactive applications were in response to isolations of HJ or EEE viruses or the occurrence of EEE.

Mosquito population data—treatment areas: Adult mosquito population data were derived from

Table 1. Memorial Day to Labor Day yearly trap-night means[1] (Y) for 4 vector species at Cicero Swamp, NY, 1984–94.

Year	n	Cs. melanura	Cs. morsitans	Ae. canadensis	Cq. perturbans
1984	103	9.8h	1.5bc	16.9c	10.0e
1985	99	33.3def	3.3a	2.9e	127.8ab
1986	100	14.5gh	1.9b	13.6cd	24.6de
1987	123	31.2def	1.0cd	5.4e	121.7ab
1988	121	20.1fg	1.0cd	17.7c	23.0de
1989	101	65.0bc	0.6d	44.6b	37.6cd
1990	110	39.6cde	0.2e	94.7a	135.7ab
1991	134	21.1efg	0.03e	6.1de	185.1ab
1992	147	103.5ab	0.2e	116.4a	79.7bc
1993	132	173.3a	0.08e	26.5bc	154.9ab
1994	118	58.5bcd	0.03e	14.0cd	219.0a

[1] Means with different letters are significantly different (general linear models, Duncan's groupings, $P < 0.01$)

collections made in carbon dioxide-baited CDC miniature light traps at 4 trap sites at Cicero Swamp, Onondaga County, and 2 trap sites at Toad Harbor Swamp, Oswego County, from 1984 to 1994. Generally, traps were operated 2 nights/wk throughout the active mosquito season (May–September), with more frequent trapping during the weeks surrounding spray events. Each collection was speciated and enumerated by personnel from the Onondaga and Oswego county health departments.

Mosquito population data—nontreatment data: There were no trap sites in either Cicero or Toad Harbor swamps that were not subject to treatment. Additionally, there were no swamps within central New York of similar physiography with significant populations of *Cs. melanura* or that have been under constant mosquito surveillance to use as control (nontreatment) collection data. Thus, to determine nontreatment population trends of the species of interest, we used the surveillance data from Toad Harbor Swamp collected during 3 years without adulticiding applications, 1984–1986. A comparable data set was not available for Cicero Swamp. Weekly population trends were constructed for the populations of all species collected and for the primary (enzootic) vectors of EEE virus, *Cs. melanura* and *Cs. morsitans*, and secondary (epizootic) vectors, *Aedes canadensis* (Meigen) and *Coquillettidia perturbans* (Coquillett) (Howard et al. 1994).

Data analysis: Raw data provided to the NYSDOH by both county health departments represented daily counts (n) of all species collected from the 6 trap sites. Analyses were performed for the population indices of all mosquitoes collected and each of the 4 vector species. Daily collections (n) were log transformed ($X = \log_{10}[n + 1]$; Williams 1937, Moore et al. 1993) and analyzed using version 6.08 of the statistical analysis system (SAS Institute, Inc. 1989) at Syracuse University. Yearly means for all collection dates and for only collection dates between Memorial Day and Labor Day (last week in May to 1st week in September), representative of the major mosquito activity period in central New York, were compared using general linear models (GLM) with Duncan's mean groupings at $P = 0.01$ for all species and for each of the vector species. Weekly means were the sums of all collections occurring during a 7-day period, Sunday–Saturday, divided by the number of trap-nights. Yearly and weekly trap-night means are reported as anti-log values ($Y = 10^x[-1]$). Impacts on all species and on each of the 4 species were defined as short term (reduced numbers of mosquitoes observed for a week postspray), seasonal (reduced numbers for the remainder of the year), and long term (reduced numbers of mosquitoes seasonally and during the following year[s]).

RESULTS

Cicero Swamp—long-term trends: There has been a trend for increased numbers of *Cs. melanura* collected per year over the past 11 years (Fig. 1). Yearly trap-night means (Y ± SE) for *Cs. melanura* ranged from 8.5 ± 0.17 in 1984 to 129 ± 0.13 in 1993. The 1993 yearly mean for *Cs. melanura* was significantly higher than all other years and the 1984 mean significantly lower than all other years (GLM, Duncan's groupings, $P = 0.01$). For *Cs. morsitans*, yearly means declined over the study period (Fig. 1). Means ranged from 2.5 ± 0.1 in 1985 to 0.03 ± 0.01 in 1994. The 1985 mean was significantly higher than all other years. Means for 1990–1994 were significantly lower than all previous years. Populations of *Ae. canadensis* and *Cq. perturbans* were more variable. There were no obvious trends, and no yearly mean was either significantly higher or significantly lower than other years (Fig. 1). Means for *Ae. canadensis* ranged from 49.7 ± 0.18 in 1992 to 2.0 ± 0.11 in 1985. For *Cq. perturbans*, means ranged from 72.9 ± 0.28 in 1994 to 5.2 ± 0.2 in 1984. Yearly means (GLM, Duncan's grouping, $P = 0.01$) for the period from Memorial Day to Labor Day did not result in any substantial changes in the observed trends for these 4 species (Table 1).

Toad Harbor Swamp—long-term trends: There were no distinguishing trends for *Cs. melanura* at Toad Harbor Swamp (Fig. 2). Yearly means for *Cs. melanura* ranged from 33.4 ± 0.15 in 1985 to 4.7 ± 0.17 in 1988, but no mean was either significantly higher or lower than any other year. Populations of *Cs. morsitans* followed a trend similar to that observed in Cicero Swamp (Fig. 2). The highest yearly mean was 4.0 ± 0.17 in 1985 and the lowest was 0.25 ± 0.05 in 1994, although neither mean was significant. For *Ae. canadensis* and *Cq. perturbans*, no mean was either significantly higher or lower than all other years (Fig. 2). Yearly means for *Ae. canadensis* ranged from 36.9 ± 0.42 in 1989 to 2.4 ± 0.19 in 1987. Yearly means for *Cq.*

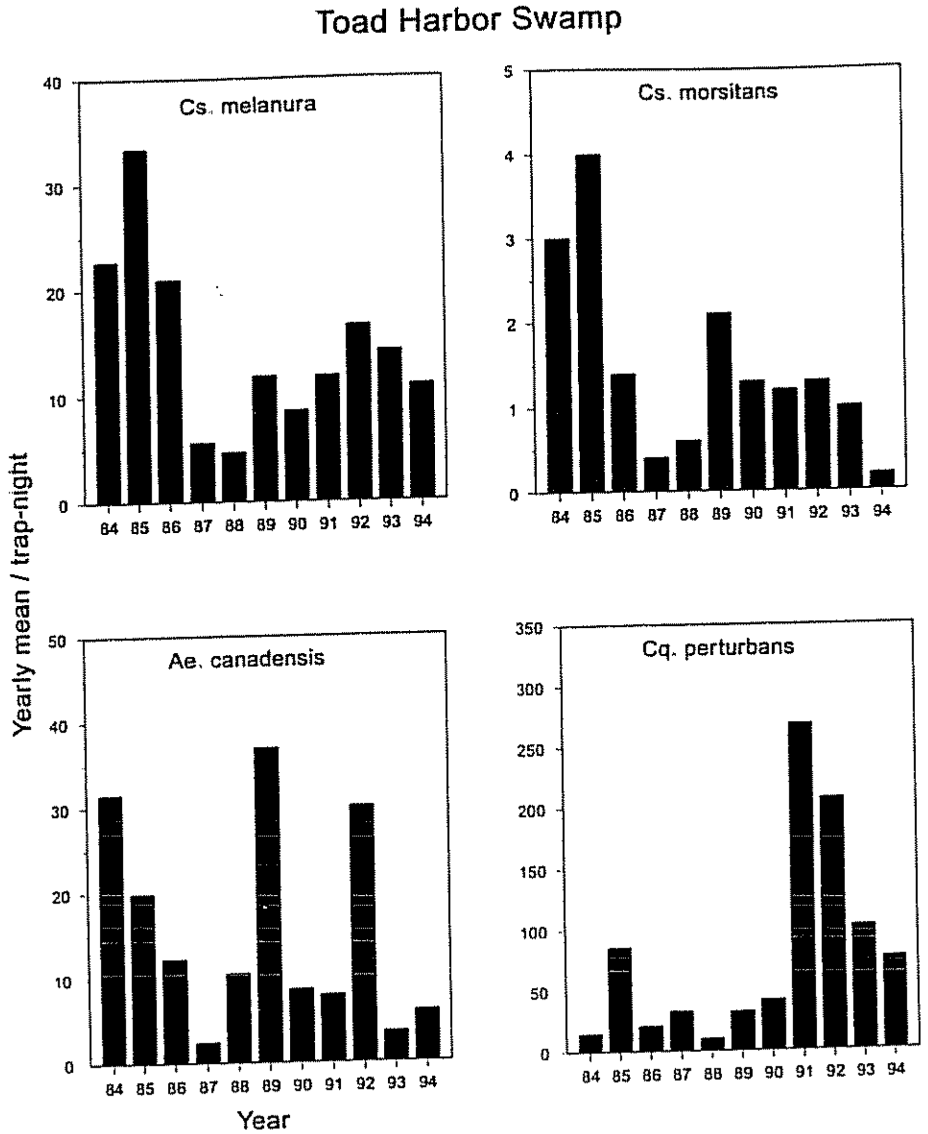


Fig. 2. Yearly trap-night means (Y) for *Cs. melanura*, *Cs. morsitans*, *Ae. canadensis*, and *Cq. perturbans* at Toad Harbor Swamp, NY, 1984–94.

perturbans ranged from 267.9 ± 0.46 in 1991 to 9.9 ± 0.24 in 1988. Yearly means during 1991–1993 were the 3 highest for *Cq. perturbans*. Analyses of data for the Memorial Day–Labor Day period did not result in any substantial changes in these results (Table 2).

Nontreatment seasonal trends: Seasonal population trends for all species and each of the 4 vector species are illustrated in Figs. 3 and 4, respectively. Mosquitoes were collected from mid-May to the end of September in baited light traps, with peak collections occurring in mid-July (Fig. 3). *Culiseta melanura* was the only species collected throughout the season. This species initially peaked in mid-July followed by 2 similar peaks at 3-wk intervals in mid-August and early September (Fig. 4). *Culiseta morsitans* was collected during most of the surveillance season, although at substantially lower numbers than *Cs. melanura* (Fig. 4). Peak collections of *Cs. morsitans* occurred during mid-June–mid-July, and this species gradually declined during the remainder of the season. Collections of *Ae. canadensis* peaked in early June and early July, and then collections declined rapidly (Fig. 4). Few *Ae. canadensis* were collected after mid-August. *Coquillettidia perturbans* was the most abundant of the 4 species. Collections of this species peaked in mid-July, with few individuals collected after mid-August (Fig. 4).

Treatment history. Between 1984 and 1994, Cic-

Table 2. Memorial Day to Labor Day yearly trap-night means[1] (Y) for 4 vector species at Toad Harbor Swamp, NY, 1984–94.

Year	*n*	*Cs. melanura*	*Cs. morsitans*	*Ae. canadensis*	*Cq. perturbans*
1984	52	25.8ab	4.0a	76.0a	36.5cd
1985	49	46.8a	6.1a	35.0ab	218.3ab
1986	52	21.5bc	1.8b	24.0b	55.8cd
1987	69	6.4e	0.6cd	3.0e	71.9bc
1988	61	5.7e	0.7cd	19.7bc	20.6d
1989	52	11.2cde	2.1b	82.3a	64.1bcd
1990	55	8.0de	1.7b	17.5bcd	91.9abc
1991	52	11.9cde	1.2bc	7.9cde	267.9a
1992	55	16.6bcd	1.3bc	30.0ab	206.8ab
1993	56	14.7bcd	1.1bc	3.5e	120.4abc
1994	53	11.0cde	0.3d	6.0de	75.8bc

[1] Means with different letters are significantly different (general linear models, Duncan's groupings, $P < 0.01$).

ero Swamp was sprayed with naled 15 times and with resmethrin (Scourge®) once (Table 3). Cicero Swamp was sprayed once in 1984 and at least once each year from 1987 through 1994. Two applications per year occurred in 1987, 1988, and 1992. Three applications per year occurred during EEE outbreaks in 1990 and 1991, including the application of Scourge on September 18, 1990. There were 8 preventive and 7 reactive applications of naled. The earliest and latest applications of naled to Cicero Swamp were June 4 and September 8, and there were 2 sprays in June, 7 in July, 3 in August, and 3 in September.

Toad Harbor Swamp has been sprayed 7 times with naled, once as a preventive and 6 times as reactive sprays (Table 3). Two naled applications per year occurred in 1987, 1988, and 1990, and there was one application in 1991. The earliest and latest applications at Toad Harbor Swamp were July 22 and September 4, and there were 3 sprays in July and 2 each in August and September.

Impacts of naled—Cicero Swamp: Short-term reductions in all mosquito populations occurred following 13 of the 15 applications of naled. Reductions in collections of all species during postspray weeks ranged from 81% after the preventive application in 1992 to 99% in 1984 (Table 3). Reductions in collections of all species following the 9 initial applications (8 preventive and one reactive) averaged 89%. The average short-term impact is illustrated in Fig. 3 for the preventive application of July 20, 1988. The 2 applications where no short-term impact occurred, and in fact populations increased, were both reactive sprays. Populations increased 200% following the reactive application on September 8, 1988 (Fig. 4) and increased 87% following the application on August 13, 1991. With the exception of the June 1984 spray, no seasonal or long-term impact on collections of all species was achieved by the applications of naled.

The 4 vector species (*Cs. melanura, Cs. morsitans, Ae. canadensis, Cq. perturbans*) represented 73.7% of all collections at Cicero Swamp during the study period, with yearly percentages ranging from 54.7% in 1984 to 82.5% in 1993. Short-term impacts of naled applications for each of the 4 vector species were as described for all species. The 1988 applications are used to illustrate impacts on the 4 vector species (Fig. 5). Additionally, there were seasonal and long-term impacts evident for some of these vector species. Within 2 wk postspraying, populations of *Cs. melanura* generally rebounded to prespray levels. In 1988 (Fig. 5) and 1992, collections of *Cs. melanura* peaked after preventive applications of naled. Naled did not produce any long-term impact on *Cs. melanura* populations (Fig. 1). All applications during July and early August resulted in seasonal impacts on *Cs. morsitans*. This species was virtually absent from collections following the 7 applications during July and August. These applications also produced long-term impacts on *Cs. morsitans* populations at Cicero Swamp (Fig. 1).

Seasonal reductions in *Ae. canadensis* and *Cq. perturbans* were achieved by sprays in June or mid-July. The preventive application in June 1984 also achieved a long-term impact on *Ae. canadensis* through 1985 and possibly through 1987 (Fig. 1). The spray in June 1991 produced a seasonal impact on *Ae. canadensis*, but there was no long-term impact (Fig. 1). Sprays in late July and August occurred too late to produce seasonal or long-term impacts on *Ae. canadensis* and *Cq. perturbans*.

Impacts of naled—Toad Harbor Swamp: Short-term reductions in all species collected following the 7 applications of naled to Toad Harbor Swamp ranged from 32% in 1990 to 98% in 1991; the least effective spraying was the 2nd application in August 1990 (Table 3). With the exception of this application, sprayings to Toad Harbor Swamp achieved 81–98% reductions in all species as illustrated for the earliest spraying of Toad Harbor on July 22, 1988 (Fig. 2). Because all applications to Toad Harbor occurred 2 or more weeks following peak collections of all species, no seasonal or long-term impact was evident.

The 4 vector species accounted for 77% of all mosquitoes collected at Toad Harbor Swamp during the 11-year study period and ranged from 62% of collections in 1984 to 88% in 1985. Seasonal impacts on individual species were similar to Cicero Swamp. *Culiseta melanura* rebounded to prespray levels within 2 wk postspray and, in 1988, reached peak numbers following the naled application on July 22. There was no evidence that naled had a long-term impact on *Cs. melanura* populations (Fig. 2). Applications generally achieved seasonal impacts on *Cs. morsitans, Ae. canadensis*, and *Cq. perturbans* but occurred too late each season to produce long-term impacts (Figs. 2 and 4).

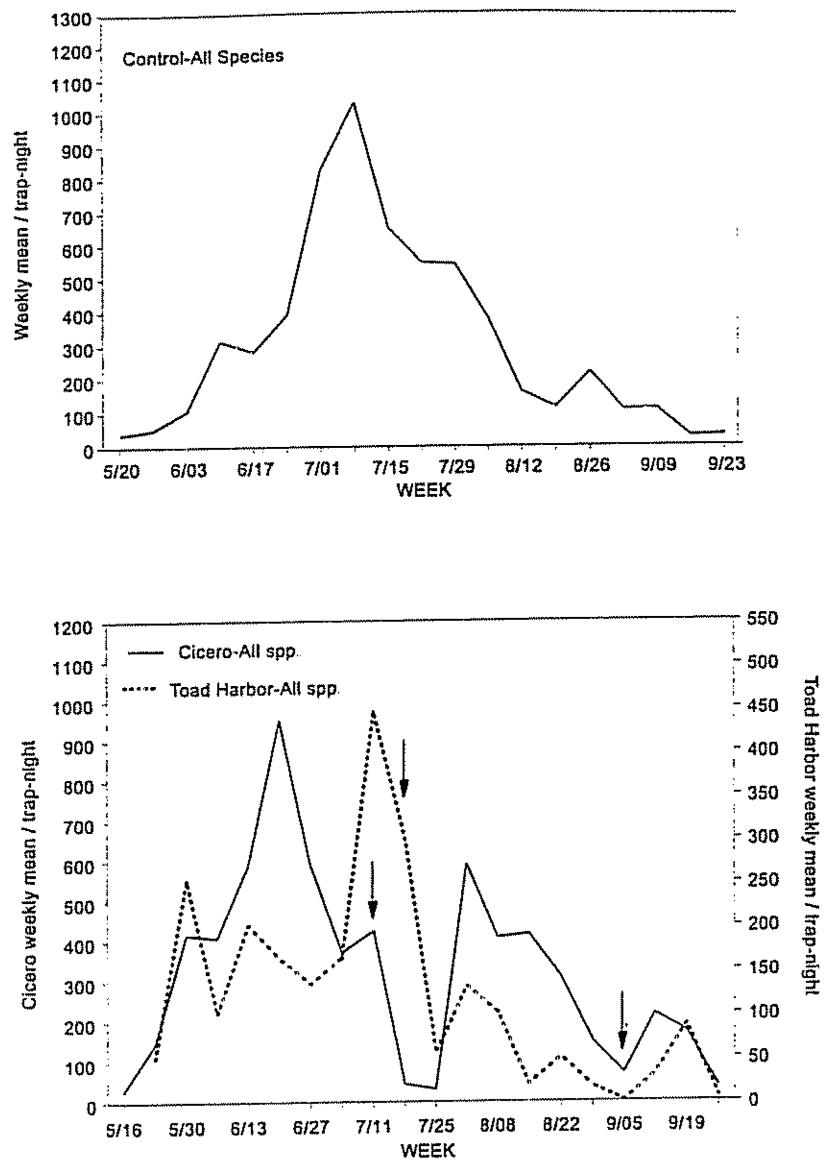


Fig. 3. Weekly trap-night means (Y) for control (nontreatment) collections of all species at Toad Harbor Swamp, 1984–86 and for 1988 collections of all species at Cicero and Toad Harbor swamps, NY. (↓ indicates naled applications).

DISCUSSION

Application of naled was successful in achieving short-term reductions in mosquito populations, including populations of the 4 vector species. Seasonal reductions in numbers of the 3 univoltine species were also achieved. However, with the exception of a single application in 1984, the use of naled did not produce a long-term impact on vector species, and, despite repetitive applications, populations of the primary enzootic vector of EEE virus, *Cs. melanura*, have increased at Cicero Swamp from 1984 to 1994. Over the 11-year study period, populations of *Cs. melanura* have increased 15-fold despite the 2-fold increase in the area treated. Concurrent with this increase, there has been an 83-fold decrease in populations of *Cs. morsitans*. The decrease in *Cs. morsitans* populations at Cicero Swamp during the study period is attributed to multiple long-term impacts of naled (Fig. 1).

Possible explanations for increases in *Cs. melanura* populations at Cicero Swamp are that Cicero Swamp naturally produces larger populations of this species, that the data for Cicero Swamp are somehow biased, that *Cs. melanura* in Cicero Swamp are resistant to naled, or that pest resurgence has contributed to increased populations of

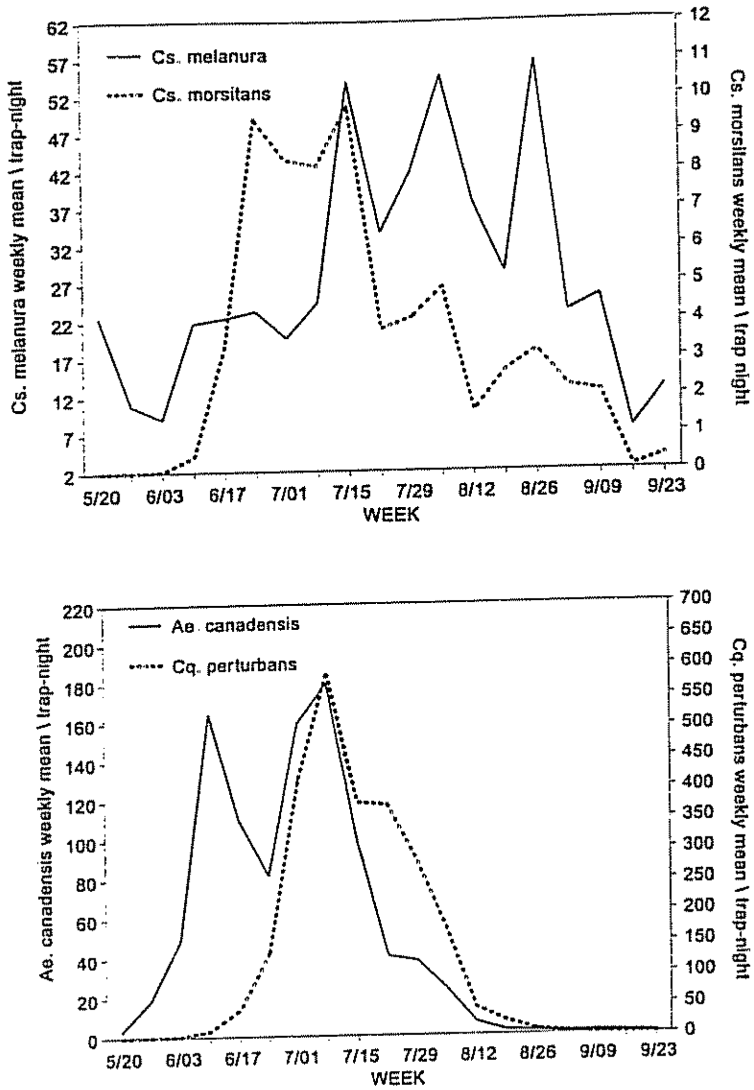


Fig. 4. Weekly trap-night means (Y) for control (nontreatment) populations of *Cs. melanura. Cs. morsitans. Ae. canadensis.* and *Cq. perturbans* based on collections at Toad Harbor Swamp. NY. 1984–86.

Cs. melanura coincident with declines in *Cs. morsitans* populations.

Larger populations: In terms of the physiographic features that could influence mosquito abundance (habitat, size, and precipitation), the 2 swamps are remarkably similar. They are 10 km apart. both are approximately 3,000 ha of similarly vegetated wetlands with muck-peat soil substrates, and each is subjected to lake-effect precipitation created by proximity to Lake Ontario (Morris et al. 1980). It has been suggested that Cicero Swamp is wetter than Toad Harbor Swamp because of the presence of beaver (*Castor canadensis*). Above average populations of *Cs. melanura* in 1 year have been associated with above average summer precipitation that followed excess precipitation the preceding fall (Hayes and Hess 1964). Presumably, high water tables in the fall increase the survival of overwintering larvae. If the increases in *Cs. melanura* were related to higher water levels in Cicero Swamp, one would expect that the same factor would influence population levels of *Cq. perturbans*. which also overwinters as larvae (Wood et al. 1979) This expectation for *Cq. perturbans* was not observed during the study period (Fig. 1). A similar comparison can be made between *Cs. morsitans* and *Ae. canadensis*. Both species overwinter in the egg stage, albeit *Cs. morsitans* as egg rafts and *Ae. canadensis* as individual eggs, deposited on vegetation above the waterline (Wood et al. 1979). Spring rainfall influences seasonal populations of these species. If the decline in *Cs. morsitans* pop-

Table 3. Applications of naled to Cicero and Toad Harbor swamps, NY, 1984–94.

Year	Date	Hectares	Rationale[1]	Efficacy[2] (%)
		Cicero Swamp		
1984	June 22	2.833	Preventive	−99
1987	July 15	2.833	Preventive	−85
	Sept. 4	3.116	Reactive (EEE virus)	−87
1988	July 20	3.116	Preventive	−89
	Sept. 8	3.116	Reactive (EEE virus)	+200
1989	July 15	3.116	Preventive	−92
1990	Aug. 3	3.116	Preventive	−87
	Aug. 23	4.856	Reactive (EEE virus)	−88
	Sept. 18[3]	4.856	Reactive (EEE)	−85
1991	June 4	3.116	Preventive	−82
	July 6	4.856	Reactive (EEE virus)	−91
	Aug. 13	4.856	Reactive (EEE)	+87
1992	July 21	3.116	Preventive	−81
	Sept. 4	3.541	Reactive (HJ virus)	−95
1993	July 8	4.856	Reactive (HJ virus)	−93
1994	July 26	4.856	Preventive	−93
		Toad Harbor Swamp		
1987	July 27	2,752	Preventive	−86
	Sept. 4	2,752	Reactive (EEE virus)	−84
1988	July 22	2.962	Reactive (EEE virus)	−81
	Sept. 1	2.962	Reactive (EEE virus)	−95
1990	Aug. 9	3.237	Reactive (EEE virus)	−94
	Aug. 23	2.978	Reactive (EEE)	−32
1991	July 30	3.237	Reactive (EEE virus)	−98

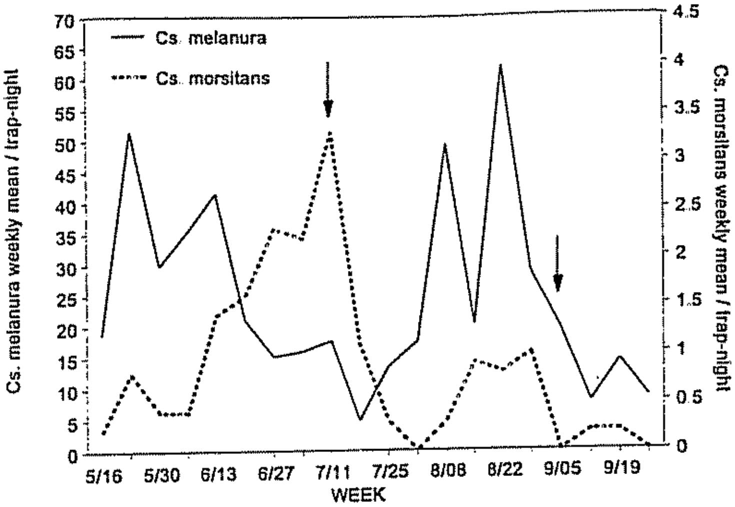
[1] EEE = eastern equine encephalitis; HJ = Highlands J.
[2] Percent change in all mosquito species collected 1 wk postspray.
[3] Application of resmethrin (Scourge®).

ulations at Cicero Swamp, and to a lesser extent at Toad Harbor Swamp, were the result of a series of drier than normal springs, then it would be reasonable to expect that *Ae. canadensis* populations would also decline. This expectation was not observed during the study period. As to the influence of beaver, we have conducted walking surveys around the perimeters of both swamps and observed an equal number of active beaver impoundments (J.J.H., unpublished data).

Biased data: The data sets analyzed were compiled from routine mosquito and virus surveillance activities conducted by county health departments. The extent and nature of surveillance activities are directly related to the level of interest of the participating municipalities and availability of personnel. There are a number of ways in which unintentional biases could have been introduced into the data, such as misidentification of specimens, increased surveillance activities either by number or location of traps set, length of trapping seasons, and different trapping methodologies. Although we had no control over these influences, it is unlikely that they contributed significantly to the results presented herein. Both counties rely on seasonal employees to conduct the surveillance, speciate collections, and tabulate data, but the same supervisors trained surveillance personnel throughout the duration of this study. Certainly minor errors in identification may have occurred, but it would be unreasonable to expect that a majority of the collections were misidentified. Although Onondaga County does operate more traps for longer periods of time in Cicero Swamp, data were analyzed as log transformed values per trap-night for both the season and for a comparable period, Memorial Day–Labor Day. Reported trends appeared in both data sets. Finally, both counties used the same surveillance equipment and generally operated traps the same nights, Monday and Wednesday, each week (Howard et al. 1994).

Resistance: Resistance of mosquitoes has been reported for organophosphates but has not been noted for naled (Boike and Rathburn 1975, Linley and Jordan 1992). A resistant species would not be affected by the chemical. *Culiseta melanura* was affected for 1–2 wk following an application of naled but then rebounded and sometimes exceeded prespray levels. Although repopulation probably results from the staggered larval development of the summer brood of *Cs. melanura* (Joseph and Bickley 1969, Oliver et al. 1996), this does not account for the observed resurgence of this species.

Pest resurgence: Resurgences of pest populations are associated with the elimination of natural predators or parasites (Metcalf 1986) or with species replacement through the elimination of a sympatric species (Service 1993). *Culiseta morsitans* "biologically and epidemiologically parallels *Cs. melanura*" (Morris 1984). Both species occur in



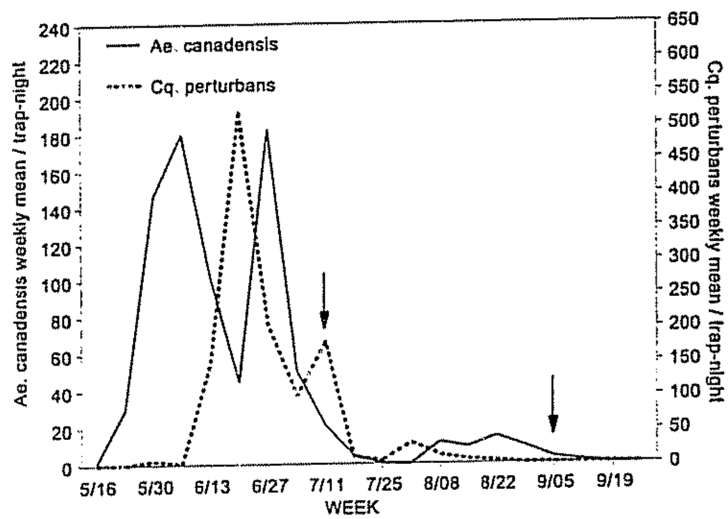


Fig. 5. Weekly trap-night means (Y) for treatment populations of *Cs. melanura*, *Cs. morsitans*, *Ae. canadensis*, and *Cq. perturbans* at Cicero Swamp, NY, during 1988 (↓ indicates naled applications).

the same swamp habitats, both prefer to feed on birds, and associated species of both include *Ae. canadensis* (Means 1987). Reasons that aerial spraying would affect *Cs. morsitans* but not *Cs. melanura* are related to differences in the biologies of the 2 species. Unlike *Cs. melanura*, *Cs. morsitans* is univoltine and overwinters in the egg stage (Wood et al. 1979). Eggs hatch in the spring, and although adult *Cs. morsitans* are present for much of the season, this species has an extended gonotrophic cycle, and few individuals complete more than one ovarian cycle (Morris 1984). Peak adult abundance of *Cs. morsitans* occurs between late June and early July, intermediate between the spring and summer broods of adult *Cs. melanura* (Morris 1984). Nine aerial applications have occurred in Cicero Swamp between mid-June and the end of July and have severely affected reproductive populations of *Cs. morsitans*. These data strongly support the observation that the exponential increase in *Cs. melanura* populations in Cicero Swamp has occurred concurrently with significant reductions of a sympatric species, *Cs. morsitans*. Reduction in the *Cs. morsitans* population has allowed *Cs. melanura* to occupy the niche utilized by *Cs. morsitans*, resulting in the resurgence (increased populations) of *Cs. melanura*. The decline in *Cs. morsitans* may be an indicator of broad-scale ecological impacts on nontarget insects within these swamp communities. Ecological balance between the 2 species may be restored by reducing naled applications to these swamps.

Whether or not any of these factors has contributed to the observed population trends, there is the overriding issue related to the rationale for conducting preventive aerial applications to *Cs. melanura* breeding habitats. Naled is used to control the populations of vector mosquitoes to reduce the risk of EEE. Eastern equine encephalitis results from nonswamp contact with EEE virus (McLean et al. 1985, Howard et al. 1996), and the proposed mechanisms for the movement of virus from swamp to upland foci include dispersion of infected primary (Howard et al. 1996) or secondary vectors or of infected avian hosts (McLean et al. 1985). Although the applications of naled have generally been effective in reducing the numbers of secondary vectors, EEE has occurred despite preventive and reactive applications (Howard et al. 1994, 1996). But, the objective of spraying the swamp habitats of *Cs. melanura* was to prevent the enzootic amplification of EEE virus. Preventive applications have had no noticeable impact on the enzootic amplification of EEE virus, and isolations of virus following preventive applications have resulted in reactive sprayings that were also ineffective in achieving seasonal or long-term impact on virus transmission (Howard et al. 1996). The possibility that frequent applications of naled contributed to increased populations of *Cs. melanura* further discredits the rationale that preventive applications of naled reduce the risk of EEE.

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REFERENCES CITED

Boike, A. H., Jr. and C. B. Rathburn, Jr. 1975. Laboratory susceptibility test of some Florida strains of *Aedes taeniorhynchus* (Wied.) and *Culex nigripalpus* Theob. to malathion and naled. 1972–1974. Mosq. News 35:137–140.

Edman, J. D., R. Timperi and B. Werner. 1993. Epidemiology of eastern equine encephalitis in Massachusetts. J. Fla. Mosq. Control Assoc. 64:84–96.

Grady, G. F., H. K. Maxfield, S. W. Hildreth, R. Timperi, R. Gilfillan, B. J. Rosenau, D. B. Francy, C. H. Calisher, L. C. Marcus and M. A. Madoff. 1978. Eastern equine encephalitis in Massachusetts, 1957–76: a prospective study centered upon analysis of mosquitoes. Am. J. Epidemiol. 107:170–178.

Haile, D. G., T. L. Biery, J. F. Reinert and N. W. Pierce. 1982. Aerial applications of naled diluted in HAN with UC-123K aircraft for adult mosquito control. Mosq. News 42:41–48.

Hayes, R. O. and A. D. Hess. 1964. Climatological conditions associated with outbreaks of eastern encephalitis. Am. J. Trop. Med. Hyg. 13:851–858.

Howard, J. J., M. A. Grayson, D. J. White and C. D. Morris. 1994. Eastern equine encephalitis in New York State. J. Fla. Mosq. Control Assoc. 65:1–7.

Howard, J. J., M. A. Grayson, D. J. White and J. Oliver. 1996. Evidence of multiple foci of eastern equine encephalitis virus (Togaviridae: *Alphavirus*) in central New York State. J. Med. Entomol. 33:421–432.

Howard, J. J., C. D. Morris, D. E. Emord and M. A. Grayson. 1988. Epizootiology of eastern equine encephalitis virus in upstate New York, USA. VII. Virus surveillance 1978–85, description of 1983 outbreak, and series conclusions. J. Med. Entomol. 25:501–514.

Joseph, S. R. and W. E. Bickley. 1969. *Culiseta melanura* (Coquillett) on the eastern shore of Maryland (Diptera: Culicidae). Univ. Md. Agric. Exp. Stn. Bull. A-161. College Park, MD.

Kilpatrick, J. W. and C. T. Adams. 1967. Emergency measures employed in the control of St. Louis encephalitis epidemics in Dallas and Corpus Christi, Texas, 1966. Proc. 23rd Annu. Mtg. Am. Mosq. Control Assoc. p. 53.

Linley, J. R. and S. Jordan. 1992. Effects of ultra-low volume and thermal fog malathion, Scourge® and naled applied against caged adult *Culicoides furens* and *Culex quinquefasciatus* in open and vegetated terrain. J. Am. Mosq. Control Assoc. 8:69–76.

McLean, R. G., G. Frier, G. L. Parham, D. B. Francy, T. P. Monath, E. G. Campos, A. Therrien, J. Kerschner and C. H. Calisher. 1985. Investigation of the vertebrate hosts of eastern equine encephalitis during an epizootic in Michigan, 1980. Am. J. Trop. Med. Hyg. 34:1190–1202.

Means, R. G. 1987. Mosquitoes of New York. Part II. Genera of Culicidae other than *Aedes* occurring in New York. N.Y. State Mus. Bull. 430b.

Metcalf, R. L. 1986. The ecology of insecticides and the chemical control of insects. pp. 251–297 *In*: M. Kogan (ed.). Ecological theory and integrated pest management practice. John Wiley and Sons, New York.

Moore, C. G., R. G. McLean, C. J. Mitchell, R. S. Nasci, T. F. Tsai, C. H. Calisher, A. A. Marfin, P. S. Moore and D. J. Gubler. 1993. Guidelines for arbovirus surveillance programs in the United States. Centers for Disease Control and Prevention, Division of Vector-borne Infectious Diseases, Fort Collins, CO.

Morris, C. D. 1984. Phenology of tropic and gonobiologic states in *Culiseta morsitans* and *Culiseta melanura* (Diptera: Culicidae). J. Med. Entomol. 21:38–51.

Morris, C. D. 1988. Eastern equine encephalitis. pp. 1–20. *In*: T. P. Monath (ed.). Arboviruses: epidemiology and ecology. Volume 3. CRC Press, Boca Raton, FL.

Morris, C. D., M. E. Cory, D. E. Emord and J. J. Howard. 1980. Epizootiology of eastern equine encephalomyelitis in upstate New York, USA. I. Introduction, demography and natural environment of an endemic focus. J. Med. Entomol. 17:442–452.

Oliver, J., J. J. Howard and C. D. Morris. 1996. Fecundity of naturally bloodfed *Culiseta melanura*. J. Am. Mosq. Control Assoc. 12:664–668.

Service, M. W. 1993. Mosquito ecology: field sampling methods. 2nd ed. Elsevier Applied Science. London, United Kingdom.

SAS Institute Inc. 1989. Statistical analysis system. SAS user's guide: statistics, version 6.08 ed. SAS Institute Inc., Cary, NC.

Warm, K. E. 1986. Twin engine spraying is back . . . better than ever. Agric. Aviation 13:10–12.

Williams, C. B. 1937. The use of logarithms in the interpretation of certain entomological problems. Ann. Appl. Biol. 14:404–414.

Wood, D. M., P. T. Dang and R. A. Ellis. 1979. The insects and arachnids of Canada. Part 6. The mosquitoes of Canada. Diptera: Culicidae. Biosystematics Research Institute. Publication 1686. Ottawa, Ontario, Canada.

Woodrow, R. J., J. J. Howard and D. J. White. 1995. Field trials with methoprene, temephos and *Bacillus thuringiensis* serovar *israelensis* for the control of larval *Culiseta melanura*. J. Am. Mosq. Control Assoc 11: 424–427.

1996 Burkett, D. A., T. L. Biery and D. G. Haile
An Operational Perspective on Measuring Aerosol Cloud Dynamics
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AN OPERATIONAL PERSPECTIVE ON MEASURING AEROSOL CLOUD DYNAMICS

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ABSTRACT. Three areas are discussed in this paper: 1) U.S. Air Force Reserve/USDA bioassays to determine the effective swath width of ultra-low volume (ULV) aerial applications conducted with the C-130 Modular Aerial Spray System (MASS), 2) the use of aerial spray computer models to predict spray offset distance and their use as a substitute for field testing, and 3) a demonstration on an aerial spray expert system called ASPEX being developed at the U.S. Air Force Reserve Aerial Spray Branch.

AIR FORCE SPRAY PROGRAM OVERVIEW

Mosquito-borne or other fly-borne epidemics occurring during war or natural disasters may require rapid large-scale aerial adulticiding as the sole means for curbing an imminent disease threat. The logistical complexities of war or natural disasters and the ever-present threat of disease makes the Air Force C-130 Aerial Spray Program uniquely suited as a national asset for rapid large-area aerial applications. The Department of Defense tasks the 910th Airlift Wing of the U.S. Air Force Reserve to maintain an aerial dispersal capability. The unit's assets include 6 Modular Aerial Spray Systems (MASS) and 4 C-130H aircraft modified for spray missions. This is the Department of Defense's sole fixed-wing aerial application asset. The 757 Airlift Squadron of the 910 Airlift Wing at Youngstown Air Reserve Station, Vienna, OH, maintains and performs the aerial spray mission.

CHARACTERIZING LARGE AIRCRAFT FOR ULV MOSQUITO CONTROL USING BIOASSAY CAGES

In June 1988, the Air Force Reserve and the USDA-ARS jointly conducted the initial C-130/MASS prototype characterization trials for ultra-low volume (ULV) mosquito control at Avon Park Air Force Range, near Sebring, FL. The characterization trials employed the methods used by Mount et al. (1970) and Haile et al. (1982). The test site was predominately an open area. In the test area, intersecting roadways allowed cages to be set for 3 different wind directions. The number of cages set for each test varied from 10 to 22 (covering a distance of 0.5 to 2.1 mi.) depending upon the type of test, roadway length, and availability of caged mosquitoes. Cages were set at 0.1-mi. intervals for tests conducted with the desired wind direction perpendicular to the flight path (crosswind) as in normal adulticide applications. For tests to determine the minimum effective swath width, the desired wind direction was parallel to the flight path (into the wind) and cages were set at 0.05-mi. intervals. Two to 4 cages of mosquitoes were used as checks for each replicate.

Female *Aedes taeniorhynchus* (Wied.) mosquitoes reared in the USDA Gainesville laboratory were used in all tests. Mosquitoes used were 3–5-day-old adults. The adult mosquitoes were immobilized in a cold room at 2°C for sex determination and placement into cages. Each cage contained 25 mosquitoes. The cages were cylindrical (3.5 cm diam × 12 cm long) and made of 16-mesh screen wire for exposure to insecticide treatment. The screen wire cage was attached to an uncontaminated sealed plastic cage of the same dimensions, which held the mosquitoes after exposure. The cages of mosquitoes were placed in an ice chest with a cotton pad moistened with water and a container of ice for transport to the site. Mosquitoes were transferred from the screen cage to the plastic holding cage approximately 15 min after exposure. A cotton ball moistened with a 10% sugar–water solution was placed on each holding cage and the cages were held in another ice chest for approximately 12 h before mortality readings were made.

Malathion (American Cyanamid, Wayne, NJ) and Dibrom (Valent USA, Walnut Creek, CA) were used in these tests because they are most often used in military adulticiding operations. Application rates were 0.75 oz./acre for Dibrom and 3 oz./acre for malathion. All applications were made with a U.S. Air Force C-130E aircraft modified to accommodate the Modular Aerial Spray System prototype. Desired flight paths were marked with vehicles and smoke. All bioassay tests were flown at 150 ft. above ground level. For crosswind tests, 3 passes were normally flown over the cage line tests using a 2,000-ft. swath width, and 2 passes were used

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in 3,000-ft. swath width tests. Only one pass was made for each "into-the-wind" test with calibration for a 1,000-ft. swath width. The MASS was equipped with Spraying Systems Company TeeJet® 8005 nozzles on wing booms. The number and size of nozzles, as well as pressure were varied to obtain the proper flow rate for each of the above treatments with a 1,000-, 2,000-, or 3,000-ft. swath width and 200 knots ground speed. For calibration, the flow was collected and measured from 8 nozzles for 30 sec. Calibration for each test was complete when the flow was adjusted to within ±1% of the desired rate.

Minimum swath tests (into wind): The results of these tests show the difficulty of spraying with no crosswind component, especially with light and variable winds or a vertical wind direction gradient. Of 6 measurements (3 replications for each chemical) only 2 gave mortality results that indicated the spray was flown nearly into the wind. Wind direction measured on the ground does not necessarily represent the wind effect on the spray. The results for the 2 measurements suggest minimum effective swaths of 1,000 ft. and 500 ft. for malathion and Dibrom, respectively. The difference between these measurements should be attributed to weather variations rather than a difference between pesticides. From these results, an estimate of 750 ft. can be made for the minimum effective swath width.

Crosswind tests: Results showed excellent mortality of caged mosquitoes in all crosswind applications except the first test application (ULV-4 Rep. 1). This application was faulty because of low chemical load, acceleration effects, and aircraft flight attitude, which caused pump cavitation and intermittent flow. Pump cavitation problems were resolved for subsequent tests. In all other tests, kill of caged mosquitoes was 90% or better for the calibrated swath. Slight reductions in mortality resulted from deviation of wind direction from direct crosswind or light and variable winds. Even a single pass provided excellent mortality for an unusually long distance due to a strong, steady crosswind.

USE OF A FOREST SERVICE COMPUTER MODEL FOR ULV PESTICIDE APPLICATIONS FOR CONTROL OF MOSQUITOES AND OTHER FLIES

The Air Force is the only organization we know of that is currently using the Forest Service Cramer–Barry–Grim (FSCBG) aerial spray computer model for ULV aerial mosquito control. The FSCBG has supplemented the Air Force's spray program in 3 areas. These areas include determining our spray offset, and buffer distance, as a substitute for field research, and evaluating the swath widths and droplet paths of experimental boom and nozzle configurations. For this paper, we will address our use of the FSCBG for predicting offset and as a substitute for field research.

The Air Force's spray program has found the FSCBG to be most useful for estimating spray offset, defined as the horizontal distance the pesticide cloud travels from the aircraft until it first hits the ground. This will differ with each release altitude and wind speed. Offset prediction is extremely important for coastal treatments or applications near environmentally sensitive areas. Determining where a pesticide cloud first hits the ground helps us achieve the best possible coverage of a target pest habitat, particularly those located near environmentally sensitive areas.

Since 1987, Air Force C-130 aerial spray operations have successfully treated Parris Island Marine Corp Training Depot SC for *Culicoides* biting midges and mosquitoes. Prior to the Air Force spray program, new recruits lost thousands of man-hours due to secondary skin infections associated with the *Culicoides* bites. On 4 independent offset spray trials, prior to actual spray missions, data were collected and compared to computer model offset predictions. For 3 of the 4 trials, the FSCBG accurately predicted the spray offset within 100 ft.

The offset field trials used TeeJet® oil-sensitive cards wrapped around the top of ¾-in.-diam, 1-m-long dowel rods. The contrast of the small black spots on the white card background can be easily seen. Using a measuring wheel, the dowel rods were spaced every 100 ft. for several thousand feet. Because the Air Force does all of its ULV sprays using a crosswind, the card lines were oriented with the dominant wind direction and 90° to the aircraft flight path. The spray cloud was allowed to settle for about 10 min before the cards were collected. Weather data was recorded during the run. After the spray cloud had settled, the offset information was radioed to the aircrew who could use the information to effectively treat upwind coastal spray boundaries.

The FSCBG has also proven to be extremely useful as a substitute for field testing. When field trials are unfeasible, the FSCBG provides a best guess for developing a spray strategy.

While preparing for Operation Desert Storm in 1991, planners anticipated a need for Air Force aerial spray services. Massive filth fly and other insect problems were expected in and around Kuwait City due to disruption of sanitation services and accumulation of human corpses and dead animals. To minimize the danger to aircrews, a strategy employing the maximum possible swath width using the fewest number of passes needed to be developed. The Air Force's aerial spray equipment had never been tested against filth flies or in an arid environment. It was unknown if the C-130 aircraft and spray system could consistently generate a swath a mile or more in width. Meteorologists from Dugway Army Proving Grounds helped set up the model to predict the widest possible swath that would be lethal to mosquitoes or other flies in an arid urban environment.

Using field data from the initial C-130 MASS prototype characterization trials discussed in the section on bioassays, the model was run to simulate the field trials using 3 of the single-pass crosswind ULV scenarios. The cage lines were placed every 0.1 mi. for several miles and placed parallel to the dominant wind direction and perpendicular to the aircraft flight heading. Bioassays showed that 90% mosquito mortality ceased at about 8,000 ft. downwind from the aircraft release point. With the help of very capable colleagues at Dugway Army Proving Grounds, the FSCBG was set up and run to simulate the bioassay scenario at Avon Park Air Force Reserve, FL. Using the model results, a dosage of between 0.1 and 0.3 mg/min/m^3 of 85% naled was expected to be lethal to 90% of caged mosquitoes. These values were used to run the model using the conditions expected for Kuwait City. Because of the dangerous nature of using a large, relatively slow-flying aircraft to spray pesticides over a war-torn populated city, our objective was to determine our largest possible swath, enabling us to minimize the number of passes and amount of time aircraft and crews would be exposed to potential ground fire. A spray strategy opening up all nozzles on the wing booms of the C-130 showed we could potentially throw a 3-mi.-wide swath with a 6–10-mph crosswind.

The FSCBG has been a useful tool for improving the effectiveness of our ULV aerial adulticide program. The Air Force has collected preliminary data that validated accuracy of the FSCBG for predicting offset at different release altitudes and wind speeds. With the advent of more stringent environmental laws, computer models can be a very useful tool in developing good aerial mosquito control programs using rotary or fixed-wing aircraft. Additional work needs to be done to validate these models for aerial adulticiding.

AERIAL SPRAY EXPERT SYSTEM

The Aerial Spray Expert System (ASPEX) is being developed at the USDA-ARS Medical and Veterinary Entomology Research Laboratory in Gainesville, FL, in cooperation with the U.S. Air Force and the Armed Forces Pest Management Board. The initial system development team included Danel G. Haile, Terry L. Biery, Gary A. Mount, Daniel L. Kline, Eric Daniels, Murat Taner, Douglas A. Burkett, and Terry Carpenter. This team worked together to capture the expertise of experienced scientists involved with Department of Defense aerial spraying for a combined 80 years. This system will enable their corporate knowledge to be used to the benefit of future aerial spray missions.

Aerial application of pesticides has long been used as an effective weapon against adult mosquito populations and the threat of mosquito-borne diseases. Aerial applications are useful in normal mosquito abatement programs and as part of the emergency response to natural disasters, such as hurricanes Hugo and Andrew (Biery 1989, 1993). These applications also represent a potential source of avoidable environmental contamination and human exposure to pesticides.

There is a need for easier, more user-friendly access to the available information on technology and procedures for safe and effective use of aerial applications for mosquito control. The objective of this project is to develop an expert system that incorporates knowledge from past research and experts in aerial spray technology that will provide information to reduce or eliminate pesticide use and chance of errors, thereby reducing environmental hazards and maximizing efficiency of essential aerial spray missions.

The primary objective of this project is to develop a knowledge-based expert system for control of mosquitoes and other medically important flies. Specific system objectives are:

- To furnish easy access to knowledge from research and experts in aerial spray technology.
- To provide expert opinion and information to inexperienced users.
- To eliminate unnecessary applications.
- To minimize environmental contamination.
- To promote safe and effective use of aerial application technology.
- To provide mission planning guidance.
- To serve as an instructional tool.

Aerial application of pesticides is a very complex and risky business, and many of the factors that must be considered are crucial to achieving an effective application without unwanted collateral effects. In developing ASPEX, the following main elements are being considered:

- Chemicals and biologicals—adulticides primarily, with capability for larvicides, etc.
  - Material Safety Data Sheets
  - Labels
  - The Forest Service computer-based graphics (FSCBG) model—offset, drift
  - Calibration
  - Literature review
  - Maps
  - Equipment configuration
    - Nozzles
  - Droplet spectrum determination
    - Other spectrum information
  - Swath width
  - Weather
    - Observation support
  - Safety/worker protection
  - Costs
  - Go/no-go decisions
  - Drift monitoring
  - Release height
  - Buffer zone/spray offset
  - Pesticide availability and selection
  - Standoff spray
  - Spills
  - Flush and purge procedures
  - Canopy penetration
  - Legal factors
    - Federal, state, local, international
  - Paint spotting
  - Area description/size and terrain
  - Equipment maintenance and cleanup
  - Waste disposal
    - Drums, flush, contaminated equipment
  - FAA requirements
  - Applicator certification
  - Environmental assessment and spray validations
  - Department of Defense, Air Force, Environmental Protection Agency, international, and other pertinent spray or environmental regulations
  - Flight safety
  - Command and control
    - Task force/working group
  - Logistics
  - Flight parameters
  - Spotter/control aircraft
  - Barrier treatment
  - Environmentally sensitive areas
  - Species-specific control strategies
  - Vector biology, behavior, and distribution
  - Population monitoring
  - Urban/rural/open
  - Mission planning
    - Maps
    - Boundaries
  - Crosswind vs. into-wind application
  - Premission aircrew instruction
  - Crew responsibilities
    - Aircrews
    - Ground crews
  - Natural disaster/epidemic/military contingencies
  - Navigational aids
  - Deposition monitoring requirements
  - Efficacy monitoring
    - Target
    - Nontarget
    - Environmental
  - Installation/location spray history
  - Public relations (what to say/not to say)
  - Contingency/emergency/routine requests

The status of the ASPEX program is as follows. In 1994, the team began developing the reference list and reviewing the literature to lay the knowledge groundwork for the system. We obtained funding from the Department of Defense's Legacy Resources Management Program, selected the experts, and met to develop the system framework. We also selected the program language and developed the prototype software for the framework. In 1995, we began expanding the prototype database by reviewing the literature, developing the decision support system, and meeting to identify what factors to consider for determining operational parameters, environmental effects, and success probabilities. We are currently continuing expansion of the software. By the end of 1996, our goal is to finalize the information database and decision support system, conduct extensive software tests, and prepare the software documentation, user's manual, and final report. We anticipate expanding the project to include CD-ROM supportability, which will require some additional funding.

REFERENCES CITED

Biery, T. L. 1989. 1989 USAFR emergency mosquito aerial spray operations as part of FEMA Hurricane Hugo relief effort. 910 AG Report 1-10 with 16 attachments.

Biery, T. L. 1993. 1992 USAFR emergency aerial spray operations as part of the FEMA Hurricane Andrew relief effort in Florida. 910 AG Report 1-7 with 20 attachments.

Haile, D. G., T. L. Biery, J. F. Reinert and N. W. Pierce. 1982. Aerial applications of naled diluted in HAN with UC-123K aircraft for adult mosquito control. Mosq. News 42:41–48.

Mount, G. A., C. T. Adams, C. S. Lofgren and D. E. Weidhaas. 1970. Altitude and drift of ultra-low-volume aerial sprays of technical malathion for mosquito control. Mosq. News 30:580–584.

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A REVIEW OF ULTRALOW-VOLUME AERIAL SPRAYS OF INSECTICIDE FOR MOSQUITO CONTROL[1]

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ABSTRACT. This review of research on ultralow-volume (ULV) aerial sprays for mosquito control is a component of an Aerial SPray EXpert system (ASPEX). Topics include application volume, adulticiding, larviciding, droplet size, and meteorology. The review discusses the efficacy of ULV aerial sprays against many important pest and vector species of mosquitoes in a wide range of locations and habitats in the USA and in some countries of Asia, Africa, and the Americas. Nine conclusions were drawn from this review. 1) ULV applications are as effective for mosquito control as highly-diluted, water-based sprays. 2) More acres can be sprayed per aircraft load with the ULV method than with dilute sprays. 3) High-altitude ULV sprays using wide or stacked swaths could be used in emergencies if wind speed and direction data at appropriate altitudes are available to accurately place the spray. 4) Successful adult mosquito control can be achieved in dense foliage or open housing with ULV aerial sprays, but doses of insecticide must be increased. 5) ULV aerial application of mosquito larvicides can be used successfully in large areas. 6) The optimum droplet size for adult mosquito control is 5–25 μm volume median diameter (VMD). 7) For mosquito adulticiding, near optimum atomization of ULV sprays is achieved with flat-fan nozzles oriented straight down or slightly forward for high-speed aircraft (≥150 mph) or rotary atomizers on slow-speed aircraft (<150 mph). 8) Optimum atomization minimizes paint spotting. 9) Maximum adult mosquito control is achieved just after sunrise and just before sunset with 2–10-mph crosswinds.

INTRODUCTION

The earliest experiments with undiluted formulations of liquid insecticide for insect control were reported by Messenger (1963, 1964), Skoog et al. (1965), and Wilson et al. (1965). The application concept was subsequently adapted for mosquito control by many investigators. After several years of research and development, the term "ultralow volume" or "ULV" was commonly used to describe the application of undiluted insecticide formulations. In practice, the ULV method involves application of the minimum effective volume of undiluted formulation of insecticide (as received from the manufacturer). With the ULV method, the application volume is dependent on the intrinsic toxicity of an insecticide to the target species and its concentration in a liquid formulation. In cases where the applicator mixes the insecticide formulation with limited quantities of a solvent or carrier for various reasons, the application would be considered as low-volume because the minimum volume was not applied. During the early development of the ULV method, some applications of technical undiluted insecticide and moderately diluted formulations were referred to as low-volume. For convenience and simplicity in this review, low-volume and ultralow-volume applications will be referred to as ULV.

After development, the ULV aerial spray method of insecticide application for adult mosquito control was quickly adopted in the USA. ULV has been the worldwide standard aerial spray method of mosquito adulticiding for more than 25 years because of inherent advantages over high-volume water- or oil-based sprays. These advantages include an increased effective payload, more rapid and timely application, elimination of the formulation process, less handling of insecticide, reduced pumping requirement, and reduced application costs.

This review is a component of an Aerial SPray EXpert system (ASPEX) funded by the DoD Legacy Resource Management Program. It includes references published from 1963 to 1995 and unpublished technical reports on operational ULV aerial sprays. ASPEX was developed as a joint project by the USDA-ARS Medical and Veterinary Entomology Research Laboratory and the Aerial Spray Branch, U.S. Air Force Reserve for training and operational use. This expert system also has potential for global use in mosquito control programs. Previous reviews of the ULV application method for mosquito control were made by Lofgren (1970, 1972, 1974) and Lofgren and Mount (1975). In general this review is presented in chronological order within topical area. Major topics include application volume, adulticiding, larviciding, droplet size, and meteorology. In several studies, we performed probit analysis on efficacy data to estimate rates of insecticide needed for 90% mosquito control. Conclusions and summary tables based on the review are provided.

RELATIONSHIP BETWEEN APPLICATION VOLUME AND EFFICACY

Despite the rapid and widespread acceptance of the ULV method and numerous tests demonstrating

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[1] This article reports the results of research only. Mention of a proprietary product does not constitute an endorsement or a recommendation for its use by USDA.

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its efficacy, only 2 studies comparing mosquito kills with ULV and water-based aerial sprays were reported. Direct comparison of the effects of naled applied as ULV (1.6–6.4 fl. oz./acre) or water-based aerial sprays (96 fl. oz./acre) against adult salt-marsh mosquitoes, predominantly *Aedes taeniorhynchus* (Wied.), infesting 10–50-acre citrus groves was made by Mount and Lofgren (1967). Their results showed that ULV and dilute sprays of naled were about equal in effectiveness (0.13 and 0.11 lb. active ingredient [AI]/acre, respectively, for 90% control as estimated by profit analysis). Furthermore, Mount and Lofgen (1967) showed that ULV sprays of fenthion were less effective than dilute sprays at 6 h posttreatment but the application methods were about equal at 24 h posttreatment (0.23 and 0.19 lb. AI/acre, respectively, for 90% control as estimated by probit analysis). A second comparison of ULV (3.2 fl. oz./acre of 2 lb. AI/gal formulation) and water-based (64 fl. oz./acre) sprays at equal doses (0.05 lb. AI/acre) of propoxur (Baygon®) was reported by Knapp and Rogers (1968). Their results showed no difference against Ae. sollicitans (Walker) populations in Kentucky with 92 and 88% mean reductions at 1.5–24 h posttreatment for ULV and water-based sprays, respectively.

With aerosols applied by ground equipment, Mount et al. (1968) showed that ULV applications of malathion and naled (0.2–0.5 fl. oz./acre) were equal to or better than higher-volume applications (14 fl. oz./acre) of the same doses of these insecticides against adult salt-marsh mosquitoes (*Aedes* sp.). Also, Husted et al. (1975) reported no difference in the percentage kill of adult *Culex pipiens* Linn. mosquitoes with a 6-fold range in the volume of chlorpyrifos formulations applied at equivalent doses as ground aerosols.

EFFICACY AGAINST MOSQUITO ADULTS

Efficacy research on ULV aerial sprays for adult mosquito control is divided into small-scale, large-scale, and high-altitude tests. Small-scale tests at normal altitudes (≤200 ft.) were done in relatively small plots (<1 mi.^{2}). The target areas for large-scale tests at normal altitudes were from 4 to more than 700 mi.^{2} High-altitude tests (>200 ft.) were done to explore the feasibility of wide-swath or stacked-swath applications and were, by necessity, conducted over large areas. Also, several tests of ULV aerial sprays for control of midges are covered here.

Small-scale tests. Most of the early trials with ULV aerial sprays against adult mosquitoes were done on a relatively small scale (<1 mi.^{2}) compared to subsequent large-scale testing and most operational applications. The primary purpose of the small-scale tests was to demonstrate the efficacy of ULV aerial sprays of various insecticides against different mosquito species in a variety of locations and habitats. Basic information for small-scale tests against adult mosquitoes is summarized in Table 1. With few exceptions, small-scale tests were done with small, single-engine, fixed-wing aircraft equipped with high-volume spray systems modified to allow ULV applications or with experimental ULV systems. Most applications were made with low capacity, flat-fan nozzles, although some trials were made with various types of rotary atomizers. Obviously, smaller-capacity liquid pumps and transfer pipes were required for ULV flow rates as compared to water-based spray rates. Furthermore, most of these tests were made against natural populations of mosquitoes, though some were done with caged mosquitoes as indicated in Table 1. Crosswind swaths varied from 75 to 200 ft. with release altitudes of 50–175 ft.

The results in Table 1 indicate satisfactory control (89–100%) of various mosquito species with the following rates (fl. oz./acre) of undiluted insecticide: 91–95% malathion, 3.2–8; 50% emulsifiable concentrate (EC) malathion, 13.6; 85% naled, 0.8–1.1; 8 lb. AI/gal fenthion, 0.75–1.8; 93% fenthion, 0.45; 4 lb. AI/gal propoxur, 1.5–1.6. However, tests shown in Table 1 indicate that higher rates of technical malathion (6–8 fl. oz./acre) and 8 lb. AI/gal fenthion (4 fl. oz./acre) were required for satisfactory mosquito control in dense jungle canopy and open houses that offered some protection of adult mosquitoes from the spray droplets. Also, formulations of permethrin diluted in oil provided 81–92% control of *Culex* and *Anopheles* sp. with rates of 0.6–0.9 fl. oz. AI/acre and total application volumes of 40–60 fl. oz./acre (Groves et al. 1994). In other small-scale tests, Patterson et al. (1966) obtained complete control of midges along Florida lake shores with 2 fl. oz./acre of 95% malathion.

Large-scale, normal-altitude tests. Although small-scale tests identified effective rates of insecticide for adult mosquitoes, large-scale tests were required to assess the full potential of ULV aerial sprays and establish minimum effective insecticide rates for operational and emergency mosquito control programs. Large-scale target areas accommodate the horizontal transport of small spray droplets and tend to negate short-term mosquito reinfestation from adjacent untreated areas. A summary of large-scale, normal-altitude tests is presented in Table 2. In all but 3 of the large-scale tests, insecticide was dispersed with large, multiengine, fixed-wing aircraft equipped with flat-fan or hollow-cone nozzles oriented straight down or down and 45° forward to the airstream. Ribeiro (1973) and Uribe et al. (1980) used small, single-engine, fixed-wing aircraft equipped with rotary atomizers and Bourg et al. (1978) used a small, single-engine, fixed-wing aircraft with flat-fan nozzles oriented down and 45° forward to the airstream.

With 91.5–95% technical malathion, rates of 2.6–4 fl. oz./acre produced 90–98% control of *Aedes, Anopheles, Culex* and *Psorophora* sp in 11 of 13 studies and operational applications (see data and references in Table 2). Also, results from 2 tests in open to wooded habitat demonstrated that 1.5 fl. oz./acre of 95% malathion provided only 57–62% control (Mount et al. 1970a, Meisch and Mount 1978). For control of *Ae. aegypti* (Linn.) in urban areas with open houses, 6–9.3 fl. oz./acre of 95% malathion was required for 89–99% control (Lofgren et al. 1970b, Uribe et al. 1980). In dense vegetation, Eliason et al. (1975) and Taylor et al. (1975) obtained ≥99% reduction of *Anopheles albimanus* Wied. populations with 6 sequential applications of 95% malathion, all applied at 4.5 fl. oz./acre except for an initial spray at 6 fl. oz./acre. In another test, Mount et al. (1970d) obtained only 33% control of *An. albimanus* populations in the target area with 6 fl. oz./acre of 95% malathion; however, 99% control was observed in an area 0–0.5 mi. downwind of the target area, indicating excessive horizontal transport of the spray.

Satisfactory levels of control (88–99%) were obtained in 9 of 10 studies at 0.5–1 fl. oz./acre of 85% naled applied for control of *Aedes, Anopheles, Culex* and *Psorophora* sp. in large-scale tests and operational applications (see data and references in Table 2). In one test, Bourg et al. (1978) obtained only 71% control of *Ae. sollicitans* with 1 fl. oz./acre of 85% naled, apparently because of mosquito reinfestation of the 3 mi.² target area. In an operational program, Biery (1987: footnote 7, Table 2) observed 68–99% kill of caged *Ae. aegypti* exposed to sprays of 1 fl. oz./acre of 85% naled with the level of kill dependent on weather conditions.

The effectiveness of ULV aerial application of 95% fenitrothion at 6.1 fl. oz./acre against adult *Cx. tritaeniorhynchus* Giles was shown by Self et al. (1973). The target area (6.25 mi.²) consisted of rice fields, small villages, and occasional marshes with reeds. Based on animal bait and animal shelter collections, fenitrothion provided an average of 71–81% reduction in the population of adult female mosquitoes.

High-altitude tests: The feasibility of dispersing ULV insecticides from wide swaths at a constant high altitude (>200 ft.) or from multiple swaths over the same flight path at increasingly higher altitudes (stacked swaths) was explored by various investigators. These application methods utilize the range in horizontal transport potential of the ULV aerial spray droplet spectrum. One advantage for both methods is increased swath width. A second advantage for the stacked swath method is that an urban area can be treated without actually flying spray aircraft over the target area. Twin-engine, fixed-wing aircraft were used in all high-altitude tests except 2 reported by Akesson et al. (1969). All insecticides were atomized with flat-fan or hollow-cone nozzles oriented straight down or down and 45° forward to the airstream. Basic data and references for 6 tests on high-altitude dispersal of ULV aerial sprays are presented in Table 3.

In 2 California tests (not shown in Table 3), chlorpyrifos (Dursban®) was dispersed at high altitudes in stacked swaths at Bakersville and naled (Dibrom® 14) was similarly dispersed at Colusa (Akesson et al. 1969). Based on insecticide deposits, both tests revealed that droplets were air transported 4,000–14,000 ft downwind from release at 500–2,000 ft of altitude. These investigators observed that droplet size decreased with increased downwind distance and that droplets <50 µm diameter apparently did not fall out because airborne droplets of 10–30 µm diameter were collected with cascade impactors at various distances downwind of the flight path.

In high-altitude, wide-swath tests, Machado et al. (1969b) applied 85% naled from an altitude of 1,000 ft. to 2 large tracts of land (11–12.5 mi.²) in Louisiana for control of *Ae. sollicitans* populations (Table 3). Naled was applied at 0.5–1 fl. oz./acre in 1,000-ft. swaths at a speed of approximately 150 mph. The aircraft and spray system was described by Machado et al. (1969a). For the first 3 tests, because the investigators were concerned about excessive horizontal transport, the nozzles were oriented in a trailing position to the slipstream to minimize shearing action, thus maximizing droplet size. In these tests, 59–86% control was achieved, depending on the amount of vegetation in the treated area. In the fourth test (1 fl. oz./acre), the investigators decided to take advantage of the potential horizontal transport of spray droplets and oriented the nozzles down and 45° forward in relation to the slipstream. Also, the dispersal altitude was reduced to 500 ft. because of surface winds of 8–10 mph. In the fourth test, 94% control was achieved in an urban area and 76% control was achieved in a densely wooded area with heavy underbrush.

High-altitude nighttime ULV applications of 0.55–0.8 fl. oz./acre of 85% naled for control of adult mosquitoes were tested in Florida by Taylor and Rathburn (1970) (Table 3). Pre- and posttreatment light trap collections in the target areas indicated 14–100% control of *Aedes, Culex* and *Psorophora* sp. Also, caged mosquito kills and deposits on cards indicated that the naled spray drifted 0.5–3 mi. downwind from the upwind edge of the target area when surface wind velocities were <2 mph.

Mount et al. (1970a) investigated high-altitude, wide-swath applications of 95% malathion over a 20 mi.² target area in Florida (Table 3). Maximum kills of caged *Ae. taeniorhynchus* mosquitoes occurred 0.5–3 mi. downwind at 150 ft. of spray altitude and 1–5 mi. downwind at 500- and 1,000-ft.

Table 1. ULV aerial sprays of insecticides at altitudes of ≤200 ft. against adult mosquitoes in small target areas (<1 mi.[2]).

Species	Location	Habitat
	Malathion, 95%	
Aedes sollicitans (Walker)	Kentucky	Open to wooded
Ae. taeniorhynchus (Wied.)	Florida	Citrus groves
Glyptotendipes paripes	Florida	Lake shore
Edwards (midges)	Florida	Lake shore
Anopheles albimanus Wied.,	Panama	Dense jungle
An. triannulatus (Neiva and Pinto)	Panama	Dense jungle
Ae. taeniorhynchus	Florida	Open to wooded
Culex nigripalpus Theobald	Florida	Open to wooded
Ae. aegypti (Linn.)	Thailand	Open houses
	Thailand	Open houses
Cx. quinquefasciatus Say	Thailand	Open houses
	Thailand	Open houses
Ae. simpsoni (Theobald)	Ethiopia	False banana
	Ethiopia	False banana
	Malathion, 50% EC	
Ae. aegypti, Ae. africanus Neveu-Lemaire, *Ae. luteocephalus* (Newstead)	Nigeria	Open houses
	Naled, 85% (14 lb. AI/gal)	
Ae. taeniorhynchus	Florida	Citrus groves
Ae. sollicitans	Kentucky	Open to wooded
Ae. taeniorhynchus	Kentucky	Open to wooded
	Fenthion, 8 lb AI/gal (Baytex®)	
Ae. sollicitans	Kentucky	Open to wooded
	Kentucky	Open to wooded
Ae. taeniorhynchus	Florida	Citrus groves
Ae. stimulans (Walker)	Michigan	Wooded
	Michigan	Wooded
An. albimanus,	Panama	Dense jungle
An. triannulatus	Panama	Dense jungle
	Panama	Dense jungle
Cx. quinquefasciatus	Florida	Open field
Ae. stimulans	Michigan	Wooded
	Michigan	Wooded
Ae. sollicitans	Kentucky	Open to wooded
	Fenthion, 93% (Baytex®)	
Cx. quinquefasciatus	Florida	Open field
	Propoxur, 4 lb. AI/gal (Baygon®)	
Ae. stimulans	Michigan	Wooded
	Michigan	Wooded
Ae. sollicitans	Kentucky	Open to wooded
	Permethrin + piperonyl butoxide[3]	
Cx. quinquefasciatus	Louisiana	Open field
An. quadrimaculatus Say	Arkansas	Open field

[1] Reduction of the natural population (n) or kill of caged mosquitoes (c) within 48 h posttreatment.
[2] Volume for 90% reduction estimated by probit analysis of combined data from indicated references.
[3] Biomist® 30:30 or 31:66 diluted 1:19 with Envirotech® oil and applied at 0.9 fl. oz. AI/acre or 0.6–0.67 fl. oz. AI/acre, respectively.

spray altitudes. With 3,000 ft. of spray altitude, little or no mosquito kill occurred within 5 mi. downwind. In general, wind velocity increased with each increase in altitude (5, 10, 12, and 15 mph at altitudes of 150, 500, 1,000, and 3,000 ft., respectively) in a series of 11 tests.

Mount et al. (1970d) used knowledge gained from the Florida tests and results from previous

Table 1. Extended.

Volume (fl oz./acre)	Percentage control	Reference(s)
		Malathion, 95%
3.8	90? n	Knapp and Roberts (1965), Knapp and Pass (1966), Knapp and Gayle (1967)
5.1	90? n	Glancey et al. (1965, 1966); Mount and Lofgren (1967); Mount et al. (1970b, 1970e, 1970f, 1971)
2.0	100 n	Patterson et al. (1966)
4.0	100 n	Patterson et al. (1966)
3.0	62 n	Lofgren et al. (1968)
8.0	90 n	Lofgren et al. (1968)
3.2	54–97 c	Rathburn et al. (1969)
3.2	16–87 c	Rathburn et al. (1969)
3.0	64 c	Kilpatrick et al. (1970b)
6.0	100 c	Kilpatrick et al. (1970b)
3.0	64 c	Kilpatrick et al. (1970b)
6.0	99 c	Kilpatrick et al. (1970b)
6.0	76–89 n	Brooks et al. (1970)
20.2	93–100 n	Brooks et al. (1970)
		Malathion 50% EC
13.6	99 n	Knudsen et al. (1980)
		Naled, 85% (14 lb, AI/gal)
1.1	90? n	Glancey et al. (1966), Mount and Lofgren (1967)
0.8	90? n	Knapp and Gayle (1967), Knapp and Rogers (1968)
1.0	61 c	Rathburn et al. (1969)
		Fenthion, 8 lb. AI/gal (Baytex®)
0.8	93 n	Knapp and Pass (1966)
1.6	100 n	Knapp and Pass (1966)
1.8	90? n	Glancey et al. (1966); Mount and Lofgren (1967); Mount et al. (1970b 1970e, 1970f, 1971)
0.75	93 n	Stevens and Stroud (1966)
1.5	96 n	Stevens and Stroud (1966)
1.6	62 n	Lofgren et al. (1968)
4.0	90 n	Lofgren et al. (1968)
4.8	95 n	Lofgren et al. (1968)
0.45	90? c	Mount et al. (1970b)
1.6	100 n	Stevens and Stroud (1967)
2.4	100 n	Stevens and Stroud (1967)
1.5	90? n	Knapp and Gayle (1967)
		Fenthion, 93% (Baytex®)
0.45	90? c	Mount et al. (1970b)
		Propoxur, 4 lb. AI/gal (Baygon®)
1.6	100 n	Stevens and Stroud (1967)
2.4	100 n	Stevens and Stroud (1967)
1.5	90? n	Knapp and Gayle (1967)
		Permethrin + piperonyl butoxide[3]
60	87 c	Groves et al. (1994)
40–45	81–92 c	Groves et al. (1994)

work (Lofgren et al. 1968) to investigate the practicality of high-altitude, wide-swath sprays of malathion and fenthion for control of anopheline mosquito populations in Panama (Table 3). Spray altitudes were based on the desired swath interval and the altitude of the lowest wind current, as surface conditions were calm during all spray applications. In the target area, control of the natural population with 6 fl. oz./acre of 95% malathion averaged 87% at 24 h posttreatment while 14 h kill of adult female

Table 2. ULV aerial sprays of insecticides at altitudes of ≤200 ft. against adult mosquitoes in large target areas (>1 mi.²).

Species	Location	Habitat	Aircraft
	Malathion, 95%		
Culex quinquefasciatus	Texas	Urban to wooded	C-123
Aedes sp.	Alaska	Open to wooded	C-123
Cx. tarsalis Coquillett, *Ae vexans* (Meigen), *Ae nigromaculis* (Ludlow), *Psorophora signipennis* (Coquillett)	Texas	Urban to wooded	C-123
Ae taeniorhynchus	Florida	Open to wooded	C-47
	Florida	Open to wooded	C-47
	Florida	Open to wooded	C-47
Ae. aegypti	Florida	Open to wooded	C-47
	Thailand	Open houses	C-47
	Thailand	Open houses	C-47
Anopheles albimanus	Panama	Dense jungle	C-47
Ae. sollicitans, Psorophora sp.	Texas	Urban to wooded	C-123, C-47
Ae. aegypti	Angola	Urban to wooded	Piper Pawnee
An. albimanus	Haiti	Sugarcane, banana	Beechcraft D-18
Ae. dorsalis (Meigen), *Ae. melanimon* Dyar	Wyoming	Pasture	Beechcraft C-45
Ps. columbiae (Dyar and Knab),	Arkansas	Urban, rice fields	Beechcraft 18
An quadrimaculatus	Arkansas	Urban, rice fields	Beechcraft 18
Ae aegypti	Colombia	Open houses	Cessna 188
	Colombia	Open houses	Cessna 188
Ae. taeniorhynchus	Florida	Open field	C-130
	Malathion, 91.5%		
Cx. tarsalis	Minnesota	Open to wooded	C-123
	Naled, 85% (14 lb. AI/gal)		
Ae. sollicitans, Psorophora sp.	Texas	Urban to wooded	C-123, C-47
Ae. sollicitans	Louisiana	Urban to wooded	Grumman Ag-Cat
Cx. salinarius Coquillett	Louisiana	Urban to wooded	Grumman Ag-Cat
Ps. columbiae, An. quadrimaculatus	Arkansas	Urban, rice fields	DC-3
Ae. taeniorhynchus	Florida	Open field	C-123
	Florida	Open field	C-123
	Florida	Open field	C-123
Culicoides sp. (biting midges)	South Carolina	Salt-marsh	C-123
Ae. aegypti	Puerto Rico	Urban	C-130
Ae. taeniorhynchus	Florida	Open field	C-130
Psorophora sp., *Ae. vexans, Ae. sollicitans, Ae. atlanticus* Dyar and Knab, *Ae. tormentor* Dyar and Knab, *Anopheles* sp.	South Carolina	Open to wooded	C-130
Ae taeniorhynchus	Florida	Open to wooded	C-130
	Fenitrothion, 95% (Accothion®)		
Cx. tritaeniorhynchus Giles	Korea	Rice fields, villages	C-46

¹ Reduction of the natural population (n) or kill of caged mosquitoes (c) usually within 48 h posttreatment.
² Exact size not indicated in reference.
³ Higher level of control achieved downwind of target area.
⁴ Haile D G and D L Kline 1989 Evaluation of C-130 modular aerial spray system (MASS) for ultra-low-volume application (ULV) of insecticides for adult mosquito control Unpublished USDA-ARS Report. p 61
⁵ Biery T. L 1983 Public health emergency in Minnesota Unpublished U S Air Force Report p 21
⁶ Volume for Dibrom® 14 only which was diluted in heavy aromatic naphtha (1:5)
⁷ Biery, T. L 1987 Aerial spray mission for dengue control in San Juan, P.R Unpublished U S Air Force Report p. 8.
⁸ Biery, T. L. 1989 1989 USAFR emergency mosquito aerial spray operation as part of FEMA Hugo relief effort Unpublished U S Air Force Report, p. 35.
⁹ Biery, T. L 1993 1992 USAFR emergency mosquito aerial spray operations as part of the FEMA Hurricane Andrew relief effort in Florida Unpublished U.S Air Force Report p 27

Table 2. Extended.

Swath (ft.)	Area (mi²)	Volume (fl. oz./acre)	Percentage control[1]	Reference(s)
		Malathion, 95%		
500	742	3.0	>90 n	Kilpatrick and Adams (1967)
500	24	3.0	96 n	Mount et al. (1969)
500	25	3.0	64 n	Mitchell et al. (1969, 1970)
2,112	25	1.5	62 c	Mount et al. (1970a)
1,056	25	3.0	96 c	Mount et al. (1970a)
500	1	3.0	59–97 c	Glancey et al. (1970)
500	1	3.0	97 c	Glancey et al. (1970)
500	>1[2]	3.0	82 n	Lofgren et al. (1970a)
500	7	6.0	91 n	Lofgren et al. (1970b)
1,056	6	6.0	33[3] n	Mount et al. (1970d)
1,000	4,684	2.6	94–98 n	Pinkovsky (1972)
Unlisted	>1[2]	6.8	84–96 n	Ribeiro (1973)
300	31	4.5–6.0	>99 n	Eliason et al. (1975), Taylor et al. (1975)
300	6–7	4.0	86–91 n	Forcum (1976)
350	16	1.5	57 n	Meisch and Mount (1978)
350	16	3.0	97 n	Meisch and Mount (1978)
165	>2	3.9	58–75 n	Uribe et al. (1980)
165	>2	9.3	89–94 n	Uribe et al. (1980)
1,000–3,000	>1[2]	3.0	>90 c	Haile and Kline (1989)[4]
		Malathion, 91.5%		
2,000	820	3.0	94 n	Biery (1983)[5]
		Naled, 85% (14 lb. AI/gal)		
1,000	916	0.75	94–98 n	Pinkovksy (1972)
328	3	1.0	71 n	Bourg et al. (1978)
328	3	1.0	88 n	Bourg et al. (1978)
350	16	1.0	92 n	Meisch and Mount (1978)
2,112	6	0.25[6]	82 c	Haile et al. (1982b)
2,112	6	0.25	83 c	Haile et al. (1982b)
2,112	6	0.75	93 c	Haile et al. (1982b)
1,000	>12	1.0	>99 n	Haile et al. (1984)
1,000	277	1.0	68–99 c	Biery (1987)[7]
1,000–3,000	>1[2]	0.75	>90 c	Haile and Kline (1989)[4]
1,250–2,500	1,337	0.5	90–95 n	Biery (1989)[8]
2,500	436	1.0	93–99 n	Biery (1993)[9]
		Fenitrothion, 95% (Accothion®)		
500	>6	6.1	71–81 n	Self et al. (1973)

An. albimanus averaged 100 and 87% in screen cages placed on a road shoulder and under jungle canopy, respectively. Also, some mosquito control was achieved with malathion for 1 mi. downwind of the target area with 16% control of the natural population at 24 h posttreatment as well as 100 and 52% kill of caged mosquitoes along a road and under jungle canopy. With 1.2 fl. oz./acre of 8 lb. AI/gal fenthion, control of the natural population in the target area averaged 51% while kill of caged mosquitoes on a road and under jungle canopy averaged 92 and 88%, respectively. Fenthion provided mosquito control downwind for 1 mi. of the target area with 61% reduction of the natural pop-

Table 3. ULV aerial sprays of insecticides at altitudes of >200 ft. against adult mosquitoes in large target areas (>1 mi.²).

Species	Location	Habitat	Aircraft
	Malathion, 95%		
Aedes taeniorhynchus	Florida	Open to wooded	C-47
	Florida	Open to wooded	C-47
	Florida	Open to wooded	C-47
	Florida	Open to wooded	C-47
Anopheles albimanus	Panama	Dense jungle	C-47
	Naled, 85% (14 lb. AI/gal)		
Ae. sollicitans	Louisiana	Urban to wooded	DC-3
Psorophora columbiae	Florida	Urban to wooded	C-47
Culex nigripalpus	Florida	Urban to wooded	C-47
Ps. ciliata (Fabr.)	Florida	Urban to wooded	C-47
Ae. infirmatus Dyar and Knab	Florida	Urban to wooded	C-47
Ae. taeniorhynchus	Florida	Open to wooded	C-123
	Florida	Open to wooded	C-123
	Naled, 80%		
An. quadrimaculatus	Arkansas	Urban, rice	Piper Aztec
Ps. columbiae	Arkansas	Urban, rice	Piper Aztec
	Fenthion, 8 lb, AI/gal (Baytex®)		
An. albimanus	Panama	Dense jungle	C-47
	Panama	Dense jungle	C-47
	Fenthion, 93% (Baytex®)		
An. albimanus, An. triannulatus	Panama	Dense jungle	C-123

¹ Reduction of the natural population (n) or kill of caged mosquitoes (c), usually within 48 h posttreatment.
² Apparently most of the insecticide was transported beyond the target area.
³ Volume for Dibrom® 14 only, which was diluted in heavy aromatic naphtha (1:5)
⁴ Higher level of control achieved downwind of target area.

ulation plus 91 and 82% kill of caged adult mosquitoes on a road and under jungle canopy, respectively.

Lofgren et al. (1972) followed up the previous ULV aerial spray studies in Panama (Lofgren et al. 1968, Mount et al. 1970d) by treating a 20 mi.² plot of jungle terrain with 2 aerial sprays of fenthion, an effective mosquito adulticide and larvicide (Table 3). The second application to the same plot was made 9 days following the initial spray to kill new larvae before pupation and new adults before oviposition. The predominant anopheline species in the test were *An. albimanus* and *An. triannulatus* Neiva and Pinto. A rate of 1 fl. oz./acre of 93% fenthion was dispersed at 350-ft. altitude during the first application and 150–200 ft. altitude for the second spray. Based on man-biting collections and collections from horse-baited traps, these sprays provided successful control (initial reduction of 95 and >81% overall) of the adult anopheline mosquito population for 31 days following the second application.

Haile et al. (1982b) obtained only 55% kill of caged *Ae. taeniorhynchus* with either 0.125 or 0.25 fl. oz./acre of naled (85% naled diluted 1:5 in heavy aromatic naphtha and undiluted 85% naled, respectively) dispersed at altitudes of 240 and 270 ft., respectively. However, these unsatisfactory results are likely due more to insufficient dose than to excessive horizontal transport caused by high-altitude dispersal.

In a high-altitude nighttime test, Weathersbee et al. (1986) applied 80% naled to ricefields of 4 mi.² surrounding Stuttgart, Arkansas for adult mosquito control (Table 3). A rate of 0.72 fl. oz./acre of 80% naled applied at 200–300-ft. altitude produced reductions of 48 and 68% of *An. quadrimaculatus* and *Psorophora columbiae* (Dyar and Knab) populations, respectively, at 24 h posttreatment. Because of high application altitudes and surface wind velocities of 5–10 mph during application, some of the naled was likely transported downwind of the target area. Furthermore, the 24-h reductions may reflect some reinfestation of the target area.

EFFICACY AGAINST MOSQUITO LARVAE

The advantages of the ULV aerial spray method for mosquito adulticiding cannot universally be applied to mosquito larviciding. The ULV method is well suited to large-scale operations whereas most mosquito larviciding is done on a relatively small scale. Nevertheless, knowledge of ULV aerial

Table 3. Extended.

Altitude (ft.)	Swath (ft.)	Area (mi.^{2})	Volume (fl. oz./acre)	Percentage control[1]	Reference(s)
			Malathion, 95%		
500	2.112	25	1.5	74 c	Mount et al. (1970a)
500	1.056	25	3.0	100 c	Mount et al. (1970a)
1.000	1.056	25	3.0	97 c	Mount et al. (1970a)
3.000	1.056	25	3.0	33[2] c	Mount et al. (1970a)
300	1.056	6	6.0	87 n	Mount et al. (1970d)
			Naled, 85% (14 lb. AI/gal)		
500	1.000	>12	1.0	85 n	Machado et al. (1969b)
600–1.000	500	4–28	0.55–0.80	87–100 n	Taylor and Rathburn (1970)
600–1.000	500	4–28	0.55–0.80	14–80 n	Taylor and Rathburn (1970)
600	500	28	0.55	72 n	Taylor and Rathburn (1970)
600	500	>4	0.80	95 n	Taylor and Rathburn (1970)
240	2.112	6	0.125[3]	55 c	Haile et al. (1982b)
270	2.112	6	0.25	55 c	Haile et al. (1982b)
			Naled, 80%		
200–300	Unlisted	4	0.72	48[2] n	Weathersbee et al. (1986)
200–300	Unlisted	4	0.72	68[2] n	Weathersbee et al. (1986)
			Fenthion, 8 lb. AI/gal (Baytex®)		
300	2.112	6	1.2	45[4] n	Mount et al. (1970d)
500	4,224	6	1.2	57[4] n	Mount et al. (1970d)
			Fenthion, 93% (Baytex®)		
150–350	2.112	20	1.0	95 n	Lofgren et al. (1972)

sprays of insecticides was needed to predict their effect on larval populations. Thus, bioassays with mosquito larvae were included in some tests designed primarily for adulticiding. In California, where larviciding has been a mainstay of mosquito control operations, ULV aerial sprays of insecticides were tested against mosquito larvae in pastures and rice fields. However, insecticide formulations were somewhat diluted with various oils in most of the California trials. Furthermore, several investigators tested the ULV aerial spray method for large-scale larvicide applications against *Ae. aegypti* during the previous eradication effort in the USA during the 1960s. All larvicide tests were done with small, single-engine, fixed-wing or rotary-wing aircraft except those by Eliason et al. (1970), Lofgren et al. (1972), and Mount et al. (1970d), which were done with relatively large, twin-engine, fixed-wing aircraft. Most insecticides were dispersed with flat-fan or hollow-cone nozzles. However, a few tests were done by applying insecticides with rotary atomizers. Tests of ULV aerial sprays of insecticides against mosquito larvae are summarized in Table 4.

Although the test results against mosquito larvae shown in Table 4 are not comprehensive enough to determine minimum effective larvicide rates, they indicate expected larval mortality at normal adulticide rates. Results from 8 studies with 95% malathion at 2–3 and 6–6.8 fl. oz./acre indicated 38–100% ($\bar{x}$ = 71%) and 67–100% ($\bar{x}$ = 85%) control of *Aedes* and *Culex* sp. larvae, respectively. Also, 13.6 fl. oz./acre of 50% malathion killed 97% of *Ae. aegypti* larvae in open glass beakers (Knudsen et al. 1980). In tests with midge larvae, *Chironomus fulvipilus* Rempel, Patterson et al. (1966) obtained 95% mortality with 2 fl. oz./acre of 95% malathion. In 5 different studies including *Aedes*, *Anopheles*, and *Culex* larvae, 93–100% control was obtained with doses of 0.047–0.12 lb. AI/acre of fenthion which is equivalent to 0.6–1.6 fl. oz./acre of 93% fenthion. A wide dose range of chlorpyrifos (0.011–0.125 lb. AI/acre = 0.35–3.8 fl. oz./acre of 4 lb. AI/gal formulation) was used to obtain 74–100% control of *Aedes*, *Anopheles*, and *Culex* larvae in 4 different studies. Temephos, which is not used as an adulticide, produced 79–100% control of *Ae. aegypti* larvae at a dose of 0.0625 lb. AI/acre of temephos (= 2.33 fl. oz./acre of 4 lb. AI/gal formulation) (Kilpatrick et al. 1970a, Eliason et al. 1970). Finally, Mount et al. (1970e) obtained 86–100% control of *Cx. quinquefasciatus* Say larvae with 0.75–1.5 fl. oz./acre of 8.34 lb. AI/gal fenitrothion.

DROPLET SIZE

Droplet size is an important factor affecting the efficacy of insecticides applied aerially for mosquito control. The size of droplets governs their air transport as well as subsequent impingement and coverage on target insects and their habitat. For

Table 4. ULV aerial sprays of insecticides against mosquito larvae.

Species	Location	Habitat
	Malathion, 95%	
Aedes nigromaculis	California	Pasture
Culex tarsalis	California	Pasture
Cx quinquefasciatus	Florida	Open pans
Chironomus fulvipilus Rempel (midges)	Florida	Open pans
Cx quinquefasciatus	Florida	Open cups
Ae aegypti	Florida	Urban
	Thailand	Open cups
	Thailand	Open cups
Cx quinquefasciatus	Thailand	Open cups
	Thailand	Open cups
Ae aegypti	Thailand	Open cups
	Thailand	Open cups
Cx. quinquefasciatus	Thailand	Open cups
	Angola	Open dishes
	Malathion, 50%	
Ae. aegypti	Nigeria	Open glass beakers
	Fenthion, diluted (Baytex®)	
Ae. nigromaculis	California	Pasture
	Fenthion, 8 lb. AI/gal (Baytex®)	
Ae. stimulans	Michigan	Open cartons
Cx. quinquefasciatus	Florida	Open cups
	Florida	Open cups
An. albimanus	Panama	Open cups
	Fenthion, 93% (Baytex®)	
An. albimanus, An. triannulatus	Panama	Aquatic
	Chlorpyrifos, diluted (Dursban®)	
Anopheles sp. *Culex* sp.	California	Rice field
An. freeborni Aitken, *Cx. tarsalis*	California	Rice field
	Chlorpyrifos, 4 lb. AI/gal (Dursban®)	
Cx. quinquefasciatus	Florida	Open cups
Ae. aegypti	Florida	Open metal cans
	Temephos, 4 lb. AI/gal (Abate®)	
	Florida	Open metal cans
	Florida	Urban
	Fenitrothion, 8.34 lb AI/gal (Accothion®)	
Cx. quinquefasciatus	Florida	Open cups
	Florida	Open cups

[1] Reduction of the natural population or kill of containerized mosquito larvae as indicated in "Habitat" column within 48 h posttreatment.

economical and rapid application. ULV aerial sprays for adult mosquito control rely on air transport of droplets by crosswinds to obtain wide swaths. Important aspects of spray droplet size include measurement methods, optimum size, factors affecting atomization, and effect of droplet size on paint.

Measurement methods: Generally, measurements are made to estimate the initial droplet spectrum as dispersed from the spray system instead of droplets that impinge on mosquitoes or their habitat. Determination of the initial droplet spectrum is difficult to achieve because droplet collection is usually some distance removed from the flight path of the aircraft. With most methods of droplet sampling, size parameters can be biased by the collection method or placement of collection devices. The volume median diameter (VMD) is the most commonly used parameter to describe a droplet spectrum. The VMD is the droplet diameter where 50% of the spray volume is in larger drops and 50% is in smaller drops. Several methods are available for droplet size determination of insecticidal sprays, including microscopic reading of droplets on slides and optical or laser measurement systems. However, all of these methods involve one or more

Table 4. Extended.

Volume (fl. oz./acre)	Dose (lb. AI/acre)	Percentage control[1]	Reference(s)
		Malathion, 95%	
6.0	0.485	67	Mulhern et al. (1965)
6.0	0.485	60	Mulhern et al. (1965)
2.0	0.162	100	Patterson et al. (1966)
2.0	0.162	95	Patterson et al. (1966)
2.6	0.20	63	Mount et al. (1970e)
3.0	0.243	94	Eliason et al. (1970)
3.0	0.243	38	Kilpatrick et al. (1970b)
6.0	0.485	100	Kilpatrick et al. (1970b)
3.0	0.243	61	Kilpatrick et al. (1970b)
6.0	0.485	100	Kilpatrick et al. (1970b)
3.0	0.243	69	Lofgren et al. (1970a)
6.0	0.485	76	Lofgren et al. (1970b)
6.0	0.485	89	Lofgren et al. (1970b)
6.8	0.550	100	Ribeiro (1973)
		Malathion, 50%	
13.6	0.549	97	Knudsen et al. (1980)
		Fenthion, diluted (Baytex®)	
6.4–11.0	0.07–0.12	80–100	Mulhern et al. (1965)
		Fenthion, 8 lb. AI/gal (Baytex®)	
0.75	0.047	100	Stevens and Stroud (1966)
0.65	0.05	93	Mount et al. (1970e)
1.3	0.10	100	Mount et al. (1970e)
1.2	0.094	100	Mount et al. (1970d)
		Fenthion, 93% (Baytex®)	
1.0	0.076	>99	Lofgren et al. (1972)
		Chlorpyrifos, diluted (Dursban®)	
5.0–8.0	0.013–0.050	74–100	Burgoyne et al. (1968)
1.4–1.6	0.011–0.025	97–100	Womeldorf and Whitesell (1972)
		Chlorpyrifos, 4 lb. AI/gal (Dursban®)	
3.2	0.10	100	Mount et al. (1970e)
Unlisted	0.125	98	Kilpatrick et al. (1970a)
		Temephos, 4 lb. AI/gal (Abate®)	
Unlisted	0.0625	100	Kilpatrick et al. (1970a)
2.33	0.0625	79	Eliason et al. (1970)
		Fenitrothion, 8.34 lb. AI/gal (Accothion®)	
0.75	0.05	100	Mount et al. (1970e)
1.5	0.10	86	Mount et al. (1970e)

problems in sampling, measurement, cost, or convenience. A comprehensive review of droplet sampling and size determination methodology was provided by Rathburn (1970).

A low-altitude method was designed by Mount et al. (1970b) to minimize bias in collecting droplets on microscope slides. This method uses multiple passes of the spray aircraft at the minimum safe altitude (usually 25–50 ft., depending on the aircraft) over a level, open area during relatively calm weather. Teflon-coated glass microscope slides attached to electrically driven spinners placed under the flight line were used to collect spray droplets. A spread factor is required to relate the diameter of droplets on slides to the actual droplet diameter. A method developed by Yeomans (1949) that compensates for the higher critical impingement velocities of smaller droplets was used to calculate the VMD. The accuracy of Yeomans' hand wave method for estimating the VMD of ground-applied aerosols was verified by Mount and Pierce (1972), Haile et al. (1978), and Carroll and Bourg (1979). Their studies showed equivalent estimates of VMD with settling, impaction, and Coulter Counter[5] methods. However, the accuracy of Yeomans' method for aircraft application of somewhat larger droplet spectra has not been fully verified. Thus, Yeomans' method may somewhat underestimate the actual VMD when applied to ULV aerial sprays. Also, a simulated method employed by

Mount et al. (1970c) used the airstream of a high-velocity mist blower for droplet size collection. VMD estimates from this simulated method were 20–30% smaller than those obtained from actual aircraft applications (Mount et al. 1970b). Bouse and Carlton (1983) and Yates et al. (1983) also used laser droplet imaging systems to measure droplet size of aerial sprays.

Optimum droplet size spectrum: The optimum size spectrum for the most efficient mosquito control is dependent on type of application (adulticide or larvicide), impingement efficiency, and transport requirement. Decreasing the droplet size to below the optimum spectrum increases air transport and reduces impingement on adult mosquitoes and their associated habitats. Conversely, increasing the droplet size to above the optimum spectrum decreases swath intervals and increases impingement on nontarget surfaces such as canopy above the mosquito habitat.

Adulticiding: The literature on optimum droplet size for adult mosquito control with sprays or aerosols was reviewed previously by Mount (1970). Four separate laboratory studies provide knowledge on the optimum droplet size of insecticidal aerosols for mosquito adulticiding. Based on wind tunnel test results, Weidhaas et al. (1970) calculated that the minimum lethal dose (LD_{100}) of undiluted technical grade formulations of malathion, naled, and fenthion for adult female *Ae. taeniorhynchus* is contained in droplets of 25, 20, and 17.5 µm diameter, respectively. These results suggest that larger droplets of these insecticides applied as ULV aerosols could be wasteful because of overdosing. Also, in a settlement chamber study with still air, Lofgren et al. (1973) used a scanning electron microscope to observe that 2–16-µm-diameter droplets of soybean oil (used to simulate technical insecticides) impinged more efficiently on mosquito wings than smaller or larger droplets. Furthermore, in a wind tunnel study, Haile et al. (1982a) defined the relationship between adult mosquito mortality and droplet size with exposure of *Ae. taeniorhynchus* to uniform size droplets of malathion insecticide transported at 2.3 mph. Their results indicated that the optimum droplet size range for kill of adult mosquitoes is 10–15 µm diameter. An extension of the optimum size range to 4–26 µm diameter resulted in only a ≤1.7-fold reduced kill efficiency compared to the more narrow range. These results are consistent with those reported previously by Latta et al. (1947), who demonstrated that the most effective droplet size range for adult mosquitoes exposed to DDT in a wind tunnel was 12–20 µm diameter. Haile et al. (1982a) also demonstrated that ground-applied aerosols with VMDs of 5–24 µm provided greater percentage kill of adult mosquitoes than an aerosol with a VMD of 39 µm.

In studies with aircraft applications at 95 mph, Mount et al. (1970e, 1971) showed that adult mosquito kill efficiency could be increased about 2-fold by applying ULV insecticides with rotary atomizers (mean VMD = 31 µm) instead of flat-fan nozzles (mean VMD = 43 µm). This difference in efficiency was consistent with 2 species of mosquitoes, caged adult female *Ae. taeniorhynchus* and *Cx. quinquefasciatus*, as well as natural populations of salt-marsh mosquitoes, predominantly *Ae. taeniorhynchus*, in citrus groves with dense foliage. The increased efficiency was attributed to the smaller and more uniform droplets emitted from the rotary atomizers. The rotary atomizers emitted 83% ($\bar{x}$ of all droplet size estimates) of the spray volume in droplets of <5–50 µm diameter and only 0.1% of the volume in droplets of >100 µm diameter. Comparatively, 61% of the spray volume from flat-fan nozzles was in droplets of <5–50 µm diameter with 18% of the volume in droplets of >100 µm diameter. These tests indicate that the optimum size for aerial sprays is close to that reported for ground and laboratory tests. However, comparative tests with aerial sprays using smaller droplets have not been done because increased atomization is difficult to achieve. Depending on atmospheric conditions, the optimum size for aerial sprays may be somewhat larger than for ground aerosols because sprays must move downward from release altitude to mosquito habitats near the ground.

Mount et al. (1970d) tested ULV spray droplet penetration in the dense jungle canopy of Panama. This test was done when surface winds were calm to minimize loss of droplets by horizontal transport. Droplets collected in the open on a road and under the dense jungle canopy were compared by "flooding" a small target area with 5 swaths of technical malathion at 50-ft intervals and at 75–100 ft. altitude. Droplets were collected on silicone-treated glass microscope slides rotated in a vertical plane with a battery-operated spinning device at a velocity of 5 mph to enhance impingement of the malathion droplets. Approximately 50% of the total spray volume penetrated the jungle canopy. The VMD of the initial spray was 52 µm, as sampled on the open road, while the VMD of the spray that was collected under the canopy was only 32 µm. The maximum droplet size that penetrated the jungle canopy was 68 µm diameter. Taylor et al. (1975) obtained similar results with ULV aerial sprays of technical malathion in Haiti with average VMDs of 46 µm and 28 µm for open and protected sites, respectively. Moreover, Perich et al. (1992) showed that droplet size (VMD) of ULV aerial sprays of a resmethrin formulated in mineral oil was ≈10–20 µm smaller inside than outside of houses in the Dominican Republic.

Larviciding: No definitive studies on optimum droplet size for mosquito larviciding have been reported in the literature. Logically, factors such as drift, foliage penetration, and coverage that influence the optimum size range for adulticiding also influence the droplet size needed for effective and efficient larviciding. Larviciding is usually done in small target areas. Thus, relatively large droplets must be used to avoid excessive air transport. If target areas are also covered by dense vegetation, relatively small droplets are required to penetrate the vegetation and reach the larval habitat. An exception to small droplets for penetration would be the use of large droplets in a high-volume, water-based spray that would create runoff. The contradiction in droplet size requirements for little or no horizontal transport and foliage penetration argues against using ULV aerial sprays for larviciding of small target areas covered by dense vegetation. However, ULV sprays have been used successfully to larvicide small areas with dense vegetation (Burgoyne et al. 1968) and large areas with heavy vegetation where horizontal transport can be tolerated and is even desirable for foliage penetration and wide swath coverage (Lofgren et al. 1972, Womeldorf and Whitesell 1972).

Factors affecting atomization: A wide variety of factors affect the atomization of liquid insecticide formulations dispersed as aerial sprays. These factors include the type of nozzle, orientation of nozzles to the airstream, shearing force created by the airstream during flight, physical characteristics of the insecticide formulation, and flow rate. An understanding of the relationship between these factors and droplet size will influence the choice of aircraft and application equipment for an operational program.

Mount et al. (1970e, 1971) showed that droplet sizes (VMD) of malathion and fenthion sprays were 28% less with rotary atomizers than with flat-fan nozzles when dispersed in an air-blast velocity of 95 mph. Moreover, the percentage of volume atomized into droplets within the <5–50 μm range was much greater with rotary atomizers ($\bar{x}$ = 88) than with flat-fan nozzles ($\bar{x}$ = 51) (Mount et al. 1971).

Various investigators have demonstrated that orientation to the airstream affects the atomization characteristics of flat-fan nozzles. At an air speed of 95 mph, Mount et al. (1970c) showed that a nozzle orientation down and 45° forward provided maximum atomization of technical malathion while positions of straight down and down and 45° back produced VMDs that were 17 and 50% larger, respectively, than the former. Similarly, Bouse and Carlton (1983) and Yates et al. (1983) reported average decreases of 16 and 21% for vegetable oil and water-based sprays, respectively, dispersed at 90–118 mph by nozzles oriented down and 30–45° forward compared to nozzles oriented straight down.

The effect of airstream velocity on atomization of liquids dispersed by flat-fan nozzles was studied by several investigators. Mount et al. (1970c) showed that a relatively slow airstream velocity of only 50 mph produced a VMD 25% larger than the VMD produced by a velocity of 95 mph. Also, Mount et al. (1970b) demonstrated that the VMDs of aerial sprays of naled dispersed at 110 mph were 63% larger than those dispersed at 150 mph. Moreover, Yates et al. (1983) and Bouse and Carlton (1983) showed that even small differences in airstream velocity, such as 90 versus 110 mph and 100 versus 118 mph, produced VMDs 15 and 6% larger at the slower velocities with aqueous and oil sprays, respectively.

Important physical characteristics of ULV insecticide formulations that affect atomization are density, viscosity, and surface tension. These characteristics are inherent with technical or highly concentrated formulations and, without dilution, cannot be altered to change droplet size. Data from Mount et al. (1970e, 1971) indicated that VMDs for 93% fenthion were 31% larger than VMDs for 95% malathion when atomized with the same type of nozzles and about equal flow rates. Also, Mount et al. (1970b) showed that the VMD for 85% naled was 53% greater than for 95% malathion dispersed from the same flat-fan nozzles at equal pressure and aircraft speed. However, the lower flow rate requirements for fenthion and naled, because of higher toxicities than malathion, tend to offset their physical characteristics that resist atomization.

In general, an increasing flat-fan nozzle flow capacity resulted in an increase in VMD. With simulated aerial sprays, Mount et al. (1970c) showed that the VMD increased 47% from a rated capacity (water at 40 psi) of 0.023 gal/min to 1 gal/min. Greater differences in droplet size due to nozzle capacity were shown with an Air Force C-123 aircraft flown at 150 mph. Mount et al. (1970b) indicated 32 and 43% decreases in VMD when flat-fan nozzle capacities were decreased 2- and 3-fold with applications of 95% malathion and 85% naled, respectively. With rotary atomizers, Mount et al. (1970e, 1971) showed −3 to 14% ($\bar{x}$ = 9%) increases in VMD related to 30–100% ($\bar{x}$ = 55%) increases in flow rate of 95% malathion and 93% fenthion.

Effect on paint: A potential side effect of ULV aerial spraying over urban areas is spotting of painted surfaces, particularly automotive paint. However, this effect can be avoided or minimized by dispersing aerial sprays in the optimum or near optimum size range. In tests with aerial sprays, Kilpatrick et al. (1970a) indicated that technical malathion at rates >4 fl oz/acre and sprays >75 μm VMD would cause damage to painted surfaces. In tests with ground-applied aerosols, Rathburn and Boike (1977) demonstrated no visible damage on automotive paint panels under 3× magnification or by unaided eye from exposure to ground-applied aerosols of technical malathion with VMDs of 11–17 μm. Furthermore, Tietze et al. (1992) indicated a positive correlation between malathion droplet VMD and damage spot size on automotive paints.

Tietze et al. (1992) reported size thresholds of droplets too small to cause visible damage of 8 and 11 µm VMD for 2 different types of automotive paint.

Another strategy for avoiding or minimizing the effect of ULV aerial sprays on paint is to decrease swath width over urban areas. With wide swaths, insecticide flow rate must be increased to maintain insecticide dose. Increased flow rate, in turn, increases the potential for deposition of greater numbers of relatively large droplets at a specific site. This is especially the case when prevailing winds decrease in velocity substantially and unexpectedly during an application.

METEOROLOGY

With ULV aerial sprays against adult mosquitoes, the critical meteorological parameters are wind velocity and direction, temperature, and atmospheric stability. In contrast to highly diluted water-based sprays, relative humidity as it relates to droplet evaporation is not critical with ULV sprays because the undiluted insecticide formulations are essentially nonvolatile. Although research reviewed in this paper does not directly relate meteorology to mosquito control, some general guidelines can be interpreted.

Wind velocity and direction. Wind velocity data are required prior to spray operations to determine whether or not the average velocity at ground level exceeds a maximum threshold, usually ≈10 mph. The wind velocity ranges at ground level reported in small-scale (Table 1), large-scale (Table 2), and high-altitude (Table 3) tests were <1–10, <1–17, and <1–10 mph, respectively. As noted by Mount et al. (1970a), wind velocity generally increases with an increase in altitude. Thus, winds exceeding ≈10 mph at ground level may cause excessive displacement of swaths when spray is released at altitudes of >200 ft. An example is the 9–15-mph wind velocity reported by Weathersbee et al. (1986) (Table 3) that likely caused excessive air transport of naled sprays released at 200–300 ft altitude during nighttime applications. However, when sprays are released at ≤200 ft altitude, turbulence created by the aircraft vortices can force insecticide droplets down. In this case, wind velocities somewhat in excess of 10 mph can be used to disperse the spray over wide swaths. Swaths of 2,000–2,500 ft were used by Biery (1989: footnote 8, Table 2) and Haile and Kline (1989: footnote 4, Table 2) for good mosquito control with relatively high crosswinds using malathion and naled sprays released at 150 ft altitude from C-130 aircraft. Conversely, calm conditions may require the use of narrower swaths for thorough coverage of the target area. Also, release altitude can be increased to a level where wind currents are present to disperse the spray over a wider swath. For example, Mount et al. (1970a) and Lofgren et al. (1972) used high release altitudes (175–350 ft) to disperse malathion and fenthion sprays during calm ground level conditions in dense jungle habitat in Panama (Table 3).

Regardless of wind velocity and release altitude, wind direction data are needed to establish crosswind swath direction for aerial sprays. If high-altitude sprays are planned, wind direction data are required for both ground level and release altitude.

Temperature. Ambient temperature is important because it influences mosquito activity and the efficacy of insecticides. Ambient temperatures reported for mosquito adulticide trials listed in Tables 1–3 were 57–88°F. Nevertheless, low temperatures can reduce the effectiveness of insecticides, as indicated by Stevens and Stroud (1967). They reported possible recovery of adult *Ae. stimulans* (Walker) 12 h following an application of propoxur spray at ≈60°F in Michigan. In contrast, Mount et al. (1969) obtained satisfactory control of *Aedes* sp. with malathion sprays during ambient temperatures of <60°F in subarctic Alaska where mosquitoes are apparently adapted to host-seeking activity during relatively low temperatures as compared to mosquito species in temperate and tropical climates.

Atmospheric stability. Atmospheric stability is an important factor that influences transport of droplets from release altitude to ground level. Many factors determine air stability, such as wind velocity, temperature gradient, and time of day. In general, the stable or slightly unstable air associated with early morning or evening are considered most suitable for aerial sprays. Of the small-scale studies listed in Table 1 that indicated application times, 73 and 27% were accomplished with early morning and evening sprays, respectively. Most of the morning sprays were applied during 6:00–8:40 a.m. However, a few sprays were applied as early as 5:30 a.m. or as late as 10:30 a.m. with satisfactory results. In Tables 2 and 3, 67, 20, and 13% of the large-scale studies were done with evening, early morning, and night sprays, respectively. With one exception, the evening and early morning sprays were applied during 5:45–10:00 p.m. and 6:00–8:30 a.m. respectively. Biery (1993: footnote 9, Table 2) reported emergency spray applications during 3:46–8:20 p.m. following Hurricane Andrew. The night applications were made during 3:58–5:20 a.m. (Taylor and Rathburn 1970) and 10:00 p.m.–1:00 a.m. (Weathersbee et al. 1986).

The early morning and evening time frames tend to optimize spray efficacy because of increased mosquito activity and probability of adequate atmospheric stability for effective spray dispersion into mosquito habitat with adequate crosswinds. A stable atmosphere is normally characterized by warmer air on top of colder air and usually occurs when insolation intensity is reduced or absent. Conversely, an unstable atmosphere is characterized by colder air on top of warmer air and usually occurs during the middle of the day when insolation intensity is highest. Thermals, which are rising air currents caused by incoming solar radiation falling on the earth, usually occur during an unstable atmosphere. A strong inversion may actually resist the downward air transport of sprays. For example, Biery (1987; footnote 7, Table 2) reported that an inversion layer caused spray to hang in the atmosphere and cause contamination of a C-130 aircraft in a spray mission for dengue control in San Juan, Puerto Rico. However, an inversion can only be detected prior to spray operations by measurement of temperature rise with increasing altitude.

CONCLUSIONS

1. ULV applications of insecticide are as efficacious against adult mosquitoes as water-based, highly-diluted sprays. The degree of adult mosquito kill obtained with any insecticide application is related to the dose of active ingredient and many other application and environmental factors, but not to application volume. Inert diluents such as water and petroleum-based products do not kill mosquitoes and only add cost and inconvenience to aerial spray operations.

2. The increased number of acres that can be sprayed per aircraft load with the ULV method offers a great advantage over highly diluted sprays for large-scale control of adult mosquitoes. Moreover, this advantage is further enhanced by normal-altitude (≤200 ft.), wide-swath applications that benefit from undiluted insecticide droplets that maintain their integrity during air transport to target mosquitoes and associated habitats.

3. High-altitude (>200 ft.) applications of ULV sprays using wide or stacked swaths could be used for mosquito adulticiding in emergencies or unusual situations if wind velocity and direction data at appropriate altitudes are available to accurately predict placement of the insecticide. However, high-altitude methods are not suitable for most adulticiding programs because detailed wind data are usually unavailable.

4. Successful mosquito control in dense foliage or open housing can be achieved with ULV aerial sprays. However, because of the filtration effect of dense foliage or domicile structure, insecticide doses must be increased ≈2-fold compared to normal doses to achieve satisfactory mosquito control. A caveat here is that, in some cases, a 2-fold dose increase may be above the labeled rate.

5. The ULV aerial application method is suitable for mosquito larviciding over large target areas, especially when concurrent adulticiding is required. However, ULV sprays do not offer a substantial advantage over highly diluted sprays for most mosquito larviciding programs because target areas are relatively small, thus reducing the benefit of increased effective payloads. Furthermore, there is the added problem of accurate insecticide placement into small target areas with ULV applications. This placement problem can be overcome more readily with highly diluted sprays than with ULV sprays by increasing droplet size to reduce horizontal transport and by increasing volume to create runoff when foliage penetration is required. Granular formulations of larvicides can also be used instead of ULV sprays to maximize placement and foliage penetration.

6. The efficacy of ULV aerial sprays against adult mosquitoes is directly related to droplet size because it governs air transport and impingement. The optimum size range for mosquito adulticiding is 5–25 μm VMD based on laboratory wind tunnel and ground aerosol research. However, this size range has been only partially confirmed by research with ULV aerial sprays.

7. For mosquito adulticiding, near optimum atomization of ULV aerial sprays is achieved by using flat-fan nozzles on high-speed aircraft (≥150 mph) or rotary atomizers on slow-speed aircraft (<150 mph). Flat-fan nozzles should be oriented straight down or down and 30–45° forward to the airstream for maximum atomization of the insecticide. Also, flat-fan nozzles with the lowest flow rate capacity that does not create plugging problems should be used to minimize droplet size for maximum foliage or domicile penetration and mosquito kill. Rotary atomizers should be operated at maximum recommended rotational speed and low flow rates to achieve near optimum droplet size.

8. Near optimum atomization of ULV aerial sprays is required not only for maximum biological efficacy, but also to avoid or minimize spotting automotive paint in urban and suburban areas.

9. In general, ULV aerial sprays should be applied during the crepuscular periods following sunrise or preceding sunset when mosquitoes are active and atmospheric stability is favorable to achieve maximum levels of adult mosquito control. Prevailing crosswinds of 2–10 mph are also necessary for successful wide-swath applications.

REFERENCES CITED

Akesson, N. B., W. E. Burgoyne, W. E. Yates and K. Aref. 1969. Aerial spray applications of low volatility and fine atomization for mosquito control. Proc. Calif. Mosq. Control Assoc. 37:44–52.

Bourg, J. A., M. K. Carroll and A. J. Blake. 1978. Ag-cat ULV spray system development, calibration, and field tests using naled. Mosq. News 38:36–38.

Bouse, L. F. and J. B. Carlton. 1983. Factors affecting size distribution of vegetable oil spray droplets. ASAE paper no. AA-83-006, p. 17. ASAE, St. Joseph, MI.

Brooks, G. D., P. Neri, N. G. Gratz and D. B. Weathers. 1970. Preliminary studies on the use of ultra-low-volume applications of malathion for control of *Aedes simpsoni*. Bull. W.H.O. 42:37–54.

Burgoyne, W. E. and N. B. Akesson. 1968. Aircraft operations in the Colusa project. Down to Earth 24:7–10.

Burgoyne, W. E., K. G. Whitesell and N. B. Akesson.

1968. Entomological evaluation within the Colusa project. Down to Earth 24:13–15

Carroll, M. K. and J. A. Bourg. 1979. Methods of ULV droplet sampling and analysis: effects on the size and spectrum of the droplets collected. Mosq. News 39: 645–655

Eliason, D. A., V. R. Joseph and J. Karam. 1975. A prospective study of the effects of ultralow volume (ULV) aerial application of malathion on epidemic *Plasmodium falciparum* malaria I. study design and perspective. Am. J. Trop. Med. Hyg. 24:183–187

Eliason, D. A., J. W. Kilpatrick and M. F. Babbitt. 1970. Evaluation of the effectiveness of the ultra low volume aerial application of insecticides against *Aedes aegypti* (L.) in Florida. Mosq. News 30:430–436.

Forcum, D. L. 1976. Aerial control of adult *Aedes* mosquitoes over irrigated Wyoming pastures. Mosq. News 36:137–141

Glancey, B. M., H. R. Ford and C. S. Lofgren. 1970. Evaluation of a fuselage-mounted spray boom for ultra-low volume application of insecticides for mosquito control. Mosq. News 30:174–180

Glancey, B. M., C. S. Lofgren, J. Salmela and A. N. Davis. 1965. Low volume aerial spraying of malathion for control of adult salt-marsh mosquitoes. Mosq. News 25:135–137.

Glancey, B. M., A. C. White, C. N. Husman and J. Salmela. 1966. Low volume applications of insecticides for the control of adult mosquitoes. Mosq. News 26: 356–359

Groves, R. L., J. C. McAllistar, C. L. Meek and M. V. Meisch. 1994. Evaluation of aerial and ground-applied adulticides against mosquito species in Arkansas and Louisiana. J. Am. Mosq. Control Assoc. 10:407–412

Haile, D. G., G. A. Mount and N. W. Pierce. 1978. Automatic measurement of droplet size of insecticide aerosols with a Coulter Counter[8]. Mosq. News 38:1–9.

Haile, D. G., G. A. Mount and N. W. Pierce. 1982a. Effect of droplet size of malathion aerosols on kill of caged adult mosquitoes. Mosq. News 42:576–583.

Haile, D. G., D. L. Kline, J. F. Reinert and T. L. Biery. 1984. Effects of aerial applications of naled on *Culicoides* biting midges, mosquitoes and tabanids on Parris Island, South Carolina. Mosq. News 44:178–183.

Haile, D. G., T. L. Biery, J. F. Reinert and N. W. Pierce. 1982b. Aerial applications of naled diluted in HAN with UC-123-K aircraft for adult mosquito control. Mosq. News 42:41–48

Husted, S. R., J. A. Mulrennan, R. M. Frederick, D. A. Blair and H. J. U'ren. 1975. Volume as a factor in ULV dispersal of equal dosages of chlorpyrifos for adult mosquito control. Mosq. News 35 286–288

Kilpatrick, J. W. and C. T. Adams. 1967. Emergency measures employed in the control of St. Louis encephalitis epidemics in Dallas and Corpus Christi, Texas, 1966. Proc. 35 Annu. Conf. Calif. Mosq. Control Assoc. p. 53

Kilpatrick, J. W., D. A. Eliason and M. F. Babbitt. 1970a. Studies of the potential effectiveness of ultra low volume aerial applications of insecticides against *Aedes aegypti* (L.) larvae. Mosq. News 30:250–258

Kilpatrick, J. W., R. J. Tonn and S. Jatanasen. 1970b. Evaluation of ultra-low-volume insecticide dispensing systems for use in single-engined aircraft and their effectiveness against *Ae. aegypti* populations in south-east Asia. Bull. WHO 42:1–14

Knapp, F. W. and C. H. Gayle. 1967. ULV aerial insecticide application for adult mosquito control in Kentucky. Mosq. News 27:478–482

Knapp, F. W. and B. C. Pass. 1966. Low-volume aerial sprays for mosquito control. Mosq. News 26:22–25

Knapp, F. W. and W. W. Roberts. 1965. Low volume aerial application of technical malathion for adult mosquito control. Mosq. News 25:46–47

Knapp, F. W. and C. E. Rogers. 1968. Low volume aerial insecticide application for the control of *Aedes sollicitans* Walker. Mosq. News 28:535–540

Knudsen, A. B., Y. H. Bang, D. N. Bown and V. Ezike. 1980. Aerial application of 50% malathion for the control of sylvatic vectors of yellow fever in a rural wooded community near Enugu, Nigeria. Mosq. News 40: 551–559

Latta, R., L. D. Anderson, E. E. Rogers, V. K. LaMer, S. Hochberg, H. Lauterbach and I. Johnson. 1947. The effect of particle size and velocity of movement of DDT aerosols in a wind tunnel on the mortality of mosquitoes. J. Wash. Acad. Sci. 37:397–407

Lofgren, C. S. 1970. Ultra-low volume applications of concentrated insecticides in medical and veterinary entomology. Annu. Rev. Entomol. 15:321–342

Lofgren, C. S. 1972. Ultralow volume (ULV) application of insecticides. Am. J. Trop. Med. Hyg. 21:819–824

Lofgren, C. S. 1974. Recent developments in methods of mosquito control. Bull. W.H.O. 50:323–328.

Lofgren, C. S. and G. A. Mount. 1975. ULV aerial sprays for adult mosquito control. Fifth Int. Agric. Aviation Cong., Warwickshire, United Kingdom, p. 109–115.

Lofgren, C. S., D. W. Anthony and G. A. Mount. 1973. Size of aerosol droplets impinging on mosquitoes as determined with a scanning electron microscope. J. Econ. Entomol. 66:1085–1088.

Lofgren, C. S., R. M. Altman and B. M. Glancey. 1968. Control of anopheline species in the Canal Zone with ultra-low volume sprays of malathion and fenthion. Mosq. News 28:353–355

Lofgren, C. S., H. R. Ford, R. J. Tonn and S. Jatanasen. 1970a. The effectiveness of ultra-low-volume applications of malathion at a rate of 6 US fluid ounces per acre in controlling *Aedes aegypti* in a large-scale test at Nakhon Sawan, Thailand. Bull. WHO 42:15–25.

Lofgren, C. S., H. R. Ford, R. J. Tonn, Y. H. Bang and P. Siribodhi. 1970b. The effectiveness of ultra-low-volume applications of malathion at a rate of 3 fluid ounces per acre in controlling *Aedes aegypti* in Thailand. Bull. WHO 42:27–35

Lofgren, C. S., D. A. Dame, L. Johnston, C. T. Adams, N. W. Pierce and K. F. Baldwin. 1972. Control of anophelines in Canal Zone jungles with ULV aerial applications of fenthion. Mosq. News 32:566–573

Machado, W. C., A. J. Blake, E. S. Bordes, Jr. and G. T. Carmichael. 1969a. Evaluation of a multi-engine aircraft in the ULV application of Dibrom. Mosq. News 29:47–52

Machado, W. C., E. S. Bordes, Jr., A. J. Blake and G. T. Carmichael. 1969b. A technique for ULV insecticide application from high altitudes. Mosq. News 29:353–360.

Meisch, M. V. and G. A. Mount. 1978. Ultralow volume aerial applications of insecticides for mosquito control in Arkansas riceland communities. Mosq. News 38: 343–346.

Messenger, K. 1963. Low volume aerial spraying will be boon to applicator. Agric. Chem. 18:63–66

Messenger, K. 1964. Low volume aerial spraying. Agric Chem 19:61–64.

Mitchell, C. J., J. W. Kilpatrick, R. O. Hayes and H. W. Curry. 1970. Effects of ultra-low volume applications of malathion in Hale county, Texas. II. Mosquito populations in treated and untreated areas. J Med Entomol 7:85–91.

Mitchell, C. J., R. O. Hayes, P. Holden, H. R. Hill and T. B. Hughes, Jr. 1969. Effects of ultra-low volume applications of malathion in Hale county, Texas. I. Western encephalitis virus activity in treated and untreated towns. J Med Entomol 6:155–162.

Mount, G. A. 1970. Optimum droplet size for adult mosquito control with sprays or aerosols of insecticides. Mosq News 30:70–75.

Mount, G. A. and C. S. Lofgren. 1967. Ultra-low volume and conventional aerial sprays for control of adult salt-marsh mosquitoes, *Aedes sollicitans* (Walker) and *Aedes taeniorhynchus* (Wiedemann), in Florida. Mosq News 27:473–477.

Mount, G. A. and N. W. Pierce. 1972. Droplet size of ultralow volume ground aerosols as determined by three collection methods. Mosq. News 32:586–589.

Mount, G. A., J. G. McWilliams and C. T. Adams. 1969. Control of adult mosquitoes in Alaska with malathion. Mosq. News 29:84–86.

Mount, G. A., C. T. Adams, C. S. Lofgren and D. E. Weidhaas. 1970a. Altitude and drift of ultralow volume aerial sprays of technical malathion for mosquito control. Mosq. News 30:580–584.

Mount, G. A., C. S. Lofgren, K. F. Baldwin and N. W. Pierce. 1970b. Droplet size and mosquito kill with ultralow volume aerial sprays dispersed from a rotary-disc nozzle. Mosq. News 30:331–334.

Mount, G. A., C. S. Lofgren, N. W. Pierce and K. F. Baldwin. 1970c. Effect of various factors on droplet size of simulated ultra-low volume aerial sprays of technical malathion. Mosq. News 30:48–51.

Mount, G. A., C. S. Lofgren, N. W. Pierce and C. N. Husman. 1968. Ultra-low volume nonthermal aerosols of malathion and naled for adult mosquito control. Mosq. News 28:99–103.

Mount, G. A., N. W. Pierce, C. S. Lofgren and J. Salmela. 1971. Droplet size and kill of adult mosquitoes with ultralow volume aerial sprays dispersed from a rotary-cylinder atomizer. Mosq. News 31:326–330.

Mount, G. A., C. T. Adams, W. G. Pearson, C. S. Lofgren and D. E. Weidhaas. 1970d. Ultralow volume aerial sprays of malathion and fenthion for anopheline mosquito control in Panama Canal Zone jungle. Mosq. News 30:604–610.

Mount, G. A., R. E. Lowe, K. F. Baldwin, N. W. Pierce and K. E. Savage. 1970e. Ultra-low volume aerial sprays of promising insecticides for mosquito control. Mosq. News 30:342–346.

Mount, G. A., C. S. Lofgren, N. W. Pierce, K. F. Baldwin, H. R. Ford and C. T. Adams. 1970f. Droplet size, density, distribution, and effectiveness in ultra-low volume aerial sprays dispersed with TeeJet® nozzles. Mosq. News 30:589–599.

Mulhern, T. D., C. M. Gjullin, O. V. Lopp, D. Ramke, R. F. Frolli, D. E. Reed and W. D. Murray. 1965. Low volume airplane sprays for the control of mosquito larvae. Mosq. News 25:442–447.

Patterson, R. S., D. L. von Windeguth, B. M. Glancey and F. L. Wilson. 1966. Control of the midge *Glyptotendipes paripes* with low-volume aerial sprays of malathion. J. Econ. Entomol. 59:864–866.

Perich, M. J., B. L. Bunner, M. A. Tidwell, D. C. Williams, C. D. Mara and T. Carvalhe. 1992. Penetration of ultra-low volume applied insecticide into dwellings for dengue vector control. J. Am. Mosq. Control Assoc. 8:137–142.

Pinkovsky, D. D. 1972. United States Air Force aerial spray activities in Operation Combat VEE. Mosq. News 32:332–334.

Rathburn, C. B., Jr. 1970. Methods of assessing droplet size of insecticidal sprays and fogs. Mosq. News 30:501–513.

Rathburn, C. B., Jr. and A. H. Boike, Jr. 1977. Bioassay and droplet size determinations of six ULV aerosol generators. Mosq. News 37:31–34.

Rathburn, C. B., Jr. and A. J. Rogers, A. H. Boike, Jr. and R. M. Lee. 1969. Evaluation of the ultra-low volume aerial spray technique by use of caged adult mosquitoes. Mosq. News 29:376–381.

Ribeiro, H. 1973. The control of *Aedes aegypti* during the yellow fever epidemic in Luanda, Angola, in 1971. Bull. W.H.O. 48:504–505.

Self, L. S., H. I. Ree, C. S. Lofgren, J. C. Shim, C. Y. Chow, H. K. Shin and K. H. Kim. 1973. Aerial applications of ultra-low-volume insecticides to control the vector of Japanese encephalitis in Korea. Bull. W.H.O. 49:353–357.

Skoog, F. E., F. T. Cowan and K. Messenger. 1965. Ultra-low volume aerial spraying of dieldrin and malathion for rangeland grasshopper control. J. Econ. Entomol. 58:559–565.

Stevens, L. F. and R. F. Stroud. 1966. Control of mosquito adults and larvae with ultra-low volume aerial applications of Baytex and Baytex-Baygon mixture. Mosq. News 26:124–128.

Stevens, L. F. and R. F. Stroud. 1967. Control of mosquito adults and larvae with ultra-low-volume aerial applications of Baygon® and Baygon-Baytex® mixture. Mosq. News 27:482–485.

Taylor, D. J. and C. B. Rathburn, Jr. 1970. Large area tests of ultra low volume naled for control of adult mosquitoes. Mosq. News 30:383–387.

Taylor, R. T., M. Solis, D. B. Weathers and J. W. Taylor. 1975. A prospective study of the effects of ultralow volume (ULV) aerial application of malathion on epidemic *Plasmodium falciparum* malaria. II. entomological and operational aspects. Am. J. Trop. Med. Hyg. 24:188–192.

Tietze, N. S., J. P. Ruff, C. F. Hallmon, P. G. Hester and K. R. Shaffer. 1992. Effect of ULV malathion on automotive paint finishes. J. Am. Mosq. Control Assoc. 8:241–246.

Uribe, L. J., G. C. Garrido, M. Nelson, M. E. Tinker and J. Moquillaza. 1980. Aerial ULV application trial of malathion against *Aedes aegypti* in a city of Colombia. World Health Organization, Vector Biology and Control Series 80:768.

Weathersbee, A. A., III, M. V. Meisch, C. A. Sandoski, M. F. Finch, D. A. Dame, J. K. Olson and A. Inman. 1986. Combination ground and aerial adulticide applications against mosquitoes in an Arkansas riceland community. J. Am. Mosq. Control Assoc. 2:456–460.

Weidhaas, D. E., M. C. Bowman, G. A. Mount, C. S. Lofgren and H. R. Ford. 1970. Relationship of minimum lethal dose to the optimum size of droplets of insecticides for mosquito control. Mosq. News 30:195–200.

Wilson, C. M., R. F. Ruppel and R. E. Treece. 1965. Low-volume concentrate sprays applied by aircraft for control of the cereal leaf beetle. J. Econ. Entomol. 58:11–14.

Womeldorf, D. J. and K. G. Whitesell. 1972. Rice field mosquito control studies with low volume Dursban® sprays in Colusa County, California. I. Introduction. Mosq. News 32:364–368.

Yates, W. E., R. E. Cowden and N. B. Akesson. 1983. Nozzle orientation, air speed and spray formulation affects on drop size spectrums. Trans. ASAE (Am. Soc. Agric. Eng.) 26:1638–1643.

Yeomans, A. H. 1949. Directions for determining particle size of aerosols and fine sprays. U.S. Dept. Agric. Bur. Plant Quarant. ET 267.

1993 Tietze, N. S., E. T. Schreiber, P. G. Hester, C. F. Hallmon, M. A. Olson, and K. R. Shaffer
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1414

SUSCEPTIBILITY OF FIRST INSTAR *TOXORHYNCHITES SPLENDENS* TO MALATHION, NALED AND RESMETHRIN

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ABSTRACT. Acute toxicity tests were conducted to measure the response of first instar *Toxorhynchites splendens* to commonly used mosquito adulticides: malathion, naled and resmethrin. The concentrations of pesticide causing 50% mortality (LC_{50}) after 24 h was 2.87, 69.1 and 623 ppb for resmethrin, malathion and naled, respectively. Naled was determined to be the least toxic of the 3 compounds tested for integrated use with *Tx. splendens*. The latter assessments were based on comparisons between laboratory-derived dose-response curves and maximum concentrations reached in standing water calculated using standard application rates.

Interest in using *Toxorhynchites* mosquitoes as biological control agents has hinged upon the possibility of reducing populations of container-developing mosquitoes. In the proper setting, *Toxorhynchites* species may be efficacious control agents for mosquitoes (Focks 1985, Focks et al. 1986). *Toxorhynchites amboinensis* (Theobald) was successfully employed for integrated control of *Aedes aegypti* (Linn.) in New Orleans in conjunction with ULV malathion treatments (Focks et al. 1986). Other species, such as *Tx. splendens* (Wiedemann), have received interest for use in low-income areas of Florida (E. T. Schreiber, unpublished data). *Toxorhynchites splendens* is of particular interest due to its preference to oviposit into ground-level containers (Yap and Foo 1984), as typically found in urban environments.

As true for many biological control agents, *Toxorhynchites*-induced reductions of pestiferous mosquitoes are not expected to reach 95%, but instead are based on establishment of equilibrium between predator and prey (Focks 1985). For this reason, *Toxorhynchites* must be integrated into existing mosquito abatement programs as demonstrated by Focks et al. (1986). However, before further integration is attempted, an evaluation of this Toxorhynchite predator's susceptibility to commonly used toxicants is warranted. This study investigates the acute toxicity of 3 mosquito adulticides to immature *Tx. splendens*.

The *Toxorhynchites splendens* used were reared at the John A. Mulrennan Sr. Research Laboratory (JAMSRL), but were originally obtained from the New Orleans Mosquito Control District, New Orleans, Louisiana. Colony maintenance was described in Focks and Boston (1979). Eggs were oviposited by *Tx. splendens* into black cups (150 ml) and upon hatching, individually placed into 10 ml cells on a plastic multicell sheet to avoid injury or loss due to cannibalism.

Bioassays were conducted in accordance with the American Society for Testing and Materials (ASTM 1980). The compounds tested were malathion (Cythion®), naled (Dibrom® 14) and resmethrin (Scourge®: 18% resmethrin + 54% piperonyl butoxide). Standard methods and equipment developed at JAMSRL (Tietze et al. 1991) were employed for the conduct of bioassays. Deviations from these methods are described below. Larvae were singly transferred from the cells into 50-ml Pyrex beakers containing 40 ml of aged well water. Each test consisted of 30 beakers per concentration and 6 or 7 concentrations in addition to controls. The results of 3 "valid" tests (i.e., control mortality < 5%; dissolved oxygen > 40%; and chi-square test for homogeneity result in $P > 0.01$), were combined

Table 1. Toxicity of mosquito adulticides to <24 h old *Toxorhynchites splendens*.

Compound	Test length (hours)	No. tests	Lethal concentration ng AI/ml	
			LC_{50}	95% CL
Malathion	24	3	69.1	63.2–76.5
(Cythion®)	48	3	49.8	44.8–55.9
Naled	24	3	623	554–696
(Dibrom® 14)	48	3	488	431–548
Resmethrin	24	3	2.87	2.65–3.15
(Scourge®)	48	3	2.07	1.95–2.20

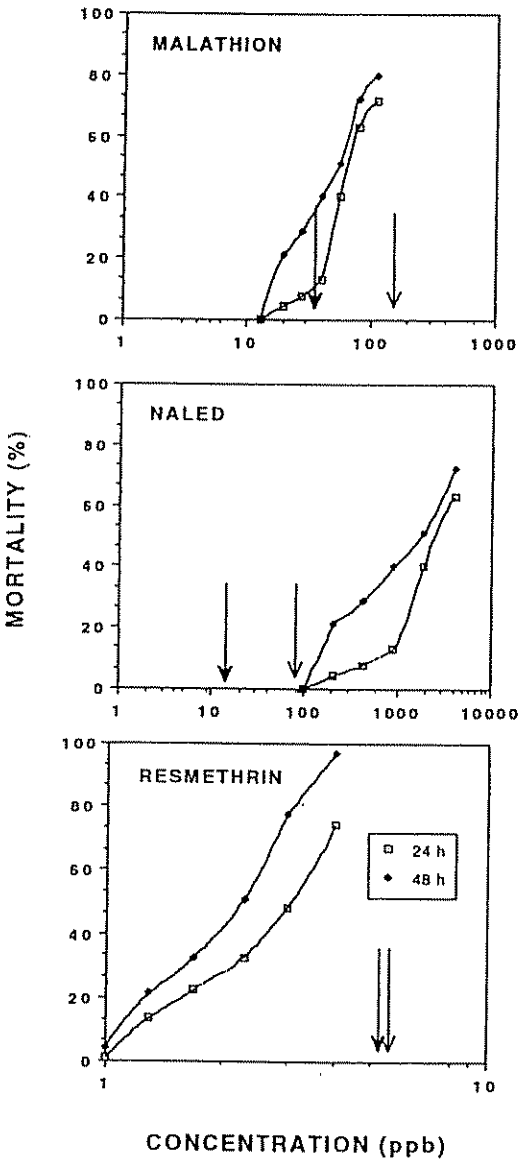

Fig. 1. Dose-response curves of first instar *Toxorhynchites splendens* to adulticides, malathion, naled and resmethrin after 24 and 48 h of exposure. Arrows denote theoretical concentrations in 15.2 cm of water based on maximum ground application rate (solid arrow) and maximum aerial application rate (open arrow). Theoretical aerial and ground rates for resmethrin are equal.

and analyzed using probit and chi-square tests to determine LC_{50} and percent mortality. Mortalities were corrected using Abbott's formula (Abbott 1925).

Resmethrin was the most toxic compound to first instar *Tx. splendens*, followed by malathion and naled (Table 1). Theoretical concentrations were based on maximum labeled ground and aerial application rates (volume per acre) assuming 100% of the material deposited on water 15.2 cm (6 in) in depth. In contrast to malathion and naled, labeled rates for ground and aerial application of resmethrin were the same. These worst-case-scenario concentrations predicted for ground and aerial ultra-low volume sprays indicated resmethrin and malathion to exceed levels deemed toxic to *Tx. splendens* (Fig. 1). This was not the case for naled, where both theoretical exposures were below the dose-response curve (Fig. 1) Naled quickly hydrolyzes in water (Chen 1984) which may be the reason for its relatively low toxicity there.

Rawlins and Ragoonansingh (1990) compared the susceptibilities of fourth instar *Tx. moctezuma* (Dyar and Knab) and *Ae. aegypti* to organophosphates. They found that, while *Tx. moctezuma* was more tolerant to temephos than *Ae. aegypti*, both species had similar susceptibilities to malathion, fenthion, fenitrothion and chlorpyrifos. They concluded that temephos was the only organophosphate tested that would be useful in an integrated management program against these species. In comparison to the reported value for *Tx. moctezuma*, we found the toxicity of malathion to *Tx. splendens* to be 5× greater (Table 1). This discrepancy may largely be caused by differences in larval instars tested (i.e., fourth vs. first instars), which is directly related to differences in larval size and esterase content (M. S. Mulla, unpublished data) or due to species differences.

Further testing in the field is warranted to assess *Tx. splendens* mortality in their natural habitat. Such studies should focus on whether field populations of larval and adult *Tx. splendens* are affected by these adulticides. These studies should simulate operational application techniques in typical urban environments and determine what concentration of adulticide in water results from such applications.

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REFERENCES CITED

Abbott, W. S. 1925. A method for computing the effectiveness of an insecticide. J. Econ. Entomol. 18:265–267.

ASTM. 1980. Standard practice for conducting acute toxicity tests with fishes, macroinvertebrates, and amphibians, pp. 1–24. *In:* Annual book of ASTM standards. Am. Soc. for Testing and Materials, Philadelphia, PA.

Chen, Y. S. 1984. Metabolism and breakdown products of Dibrom 14. J. Fla. Anti-Mosq. Assoc. 55:46–47.

Focks, D. A. and M. D. Boston. 1979. A quantified mass rearing technique for *Toxorhynchites rutilus rutilus* (Coquillett). Mosq. News 39:616–619.

Focks, D. A. 1985. *Toxorhynchites*, pp. 42–45. *In*: H. C. Chapman (ed.), Biological control of mosquitoes. Bull. Am. Mosq. Control Assoc. 6.

Focks, D. A., S. R. Sackett, K. O. Kloter, D. A. Dame and G. T. Carmichael. 1986. The integrated use of *Toxorhynchites amboinensis* and ground-level ULV insecticide application to suppress *Aedes aegypti* (Diptera: Culicidae). J. Med. Entomol. 23:513–519.

Rawlins, S. C. and R. Ragoonansingh. 1990. Comparative organophosphorus insecticide susceptibility in Caribbean populations of *Aedes aegypti* and *Toxorhynchites moctezuma*. J. Am. Mosq. Control Assoc. 6:315–317.

SAS Institute Inc. 1985. SAS user's guide: statistics. Cary, NC.

Sokal, R. R. and F. J. Rohlf. 1981. Biometry. W. H. Freeman and Company, San Francisco, CA.

Tietze, N. S., P. G. Hester, C. F. Hallmon, M. A. Olson and K. R. Shaffer. 1991. Acute toxicity of mosquitocidal compounds to young mosquitofish, *Gambusia affinis*. J. Am. Mosq. Control Assoc. 7:290–293.

Yap, H. H. and A. E. S. Foo. 1984. Laboratory studies on the oviposition site preference of *Toxorhynchites splendens* (Diptera: Culicidae). J. Med. Entomol. 21:183–187.

1992 Linley, J. R. and S. Jordan
Effects of Ultra-Low Volume and Thermal Fog Malathion, Scourge® and Naled Applied Against Caged Adult Culicoides Furens and Culex QuinqueFasciatus in Open and Vegetated Terrain
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EFFECTS OF ULTRA-LOW VOLUME AND THERMAL FOG MALATHION, SCOURGE® AND NALED APPLIED AGAINST CAGED ADULT *CULICOIDES FURENS* AND *CULEX QUINQUEFASCIATUS* IN OPEN AND VEGETATED TERRAIN[1]

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ABSTRACT. The adulticidal effect of ULV and thermal fog malathion, Scourge® and naled was tested at 2× label dosage (1.42, 0.22, 0.39 oz/acre, respectively) against caged *Culicoides furens* and *Culex quinquefasciatus* in open and vegetated (orange grove) terrain. Cages were at 122 cm elevation and positioned at 15.2, 45.7, 76.2, 106.7, 137.2 and 167.6 m from the line of insecticide release. Ultra-low volume applications of all 3 insecticides were markedly more effective than thermal fog under all conditions, especially in vegetated terrain. Of the 3 insecticides, malathion performed the poorest, especially against *Cx. quinquefasciatus* (in which there was some resistance) and particularly when applied as thermal fog. Scourge and naled were about equally effective. The best adulticide against *C. furens* was naled, which was clearly superior applied as ULV. It yielded 75% mortality out to 283 m in the open, and to 38 m in the presence of dense vegetation.

INTRODUCTION

The importance of biting midges (*Culicoides* spp.) as pests of man in many parts of the world has been extensively documented in the literature for many years (Linley and Davies 1971, Linley 1976). Several species, particularly *Culicoides furens* (Poey), *C. barbosai* Wirth and Blanton, *C. hollensis* (Melander and Brues) and *C. mississippiensis* Hoffman are prominent pests in the heavily populated and economically important coastal areas of Florida, where extensive and costly control programs are carried out against biting insects, particularly mosquitoes, by many control agencies. Although it has long been recognized that midges are major pests of man in these areas, very few attempts have been made to determine the most effective insecticides and application methods for control of adult *Culicoides*. Similarly, no information exists on how the presence of vegetation may influence adulticidal measures. Wind tunnel tests, using wild-caught midges, have been used for comparative evaluation of specific insecticides (Kline et al. 1981, Floore 1985), but very few field experiments have been reported. Gigliolí et al. (1980) applied ultra-low volume (ULV) fenitrothion (Sumithion) aerially at 2.7 oz/acre against *C. furens* and obtained better than 99% control. Haile et al. (1984) achieved similar results against *C. hollensis* with 2 consecutive (1 day apart) aerial applications of naled (Dibrom 14) at 1 oz/acre. Most control agencies do not use aerial equipment, however, and instead rely on ground applications at considerably lower dosages, aimed primarily at mosquitoes, but with some expected effect against *Culicoides*. Limited tests of naled applied as thermal fog (Linley et al. 1987) and as ULV spray (Linley et al. 1988) had been completed, but there was no comprehensive information on the effectiveness of ground adulticiding methods against *Culicoides* under field conditions simulating those in most normal operations. The primary aim of our tests was to provide comparative evaluations of 3 insecticides (malathion, Scourge®, naled) applied against adult *Culicoides furens*. The compounds were applied as ULV and thermal fog, in both open and vegetated terrain. The open condition was included as representative of the best result that could be expected, where no vegetation impeded movement of insecticide. Vegetated terrain, with a fairly dense growth of small trees, was selected to reflect quite adverse conditions that might be encountered during some control operations. Parallel tests with *Culex quinquefasciatus* Say served to provide a measure of the control achieved against a mosquito as compared to *Culicoides*, and to provide separate data for this mosquito.

MATERIALS AND METHODS

Adult female *C. furens* used in the tests were collected by aspiration at a number of sites within a few kilometers of the laboratory. Multiple sites had to be used because it proved impossible throughout the 2 year study to find a single site that would consistently yield enough midges for the tests. Once collected, midges were returned to the laboratory and kept with access to 10% sucrose in 473 ml (1-pint) ice cream

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cartons placed in a humidified box. *Culex quinquefasciatus* females were from a laboratory colony originated from collections in the area of Disney World (Orlando, FL). The resistance profile of this colony, when tested against a susceptible strain at the John A. Mulrennan Sr. Research Laboratory, showed some resistance to malathion (resistance ratio of 19.6), but little or none to Scourge (ratio 0.6) or naled (ratio 1.8). Similar tests with the midges were not possible owing to practical difficulties; however, they were more susceptible than the *Culex*, based on our results.

Insects were exposed to insecticide in cages obtained from the World Health Organization and appropriately modified. Each consisted of a cylindrical exposure chamber ca. 12 cm (4.7 inch) long, 4.5 cm (1.8 inch) wide, made almost entirely of stainless steel mesh, separated by a sliding aperture from a postexposure chamber of clear plastic, in which only the top of the end lid had been cut out and covered with mesh. This opening was covered with masking tape during exposure to insecticide, but once tape was removed, it allowed insects to be blown easily from the exposure to postexposure chambers. The mesh (Tetco Inc., Elmsford, NY) was 15.7 mesh/cm (40/inch) for midges and 6.2 mesh/cm (15.7/inch) for mosquitoes.

Prior to test, midges and mosquitoes were loaded into the exposure chambers after carbon dioxide anesthesia. *Culex quinquefasciatus* females were kept torpid on a cold plate and counted into the chambers (15/cage), but this procedure could not be used for *Culicoides* as they became trapped in condensation and were too small and easily damaged to be handled with tweezers. Instead, midges were repeatedly anesthetized in the cartons and loaded, 10–20/cage, by gentle aspiration.

Dosages at which insecticide should be applied were discussed with control district personnel before work began. The consensus was that evaluations should be based on extending control effect beyond the commonly accepted baseline of 91.4 m (300 ft) from the point of insecticide release, to 152.4 m (500 ft), as more appropriate to the larger residential blocks being treated in normal control operations. Preliminary tests in open terrain with ULV malathion against *C. furens* at 2× and 3× label dosages showed that 2× was an acceptable level for the tests envisaged, the primary objective of which was to provide comparative information on application method and the presence or absence of vegetation. Accordingly, the oz/acre dosages of the 3 insecticides were: malathion—1.42, Scourge—0.22, naled—0.39. The ULV applications were done with a Curtis Cyclotronic Dynafog ULV machine yielding droplets in the range 12–17 μm and thermal fog (droplets 1–2 μm) with a Leco HD 120.

The open site was initially an unplanted orange grove. It was planted with small citrus trees 46–76 cm (1.5–2.5 ft) tall, about 3.6 m (12 ft) apart half-way through the study, but this did not affect the open character of the site. The vegetated site was a mature grove with trees 2.4–3.6 m (8–12 ft) high, forming a fairly dense and uniform array of vegetation. Two visits to a test site were required to complete a series of experiments for each insecticide and each application method. At each visit, 3 runs of the vehicle applying insecticide were made. During each of these, a single cage was suspended at 122 cm (4 ft) elevation on each of 12 poles arranged in 2 lines 15.2 m (50 ft) apart, with the first pole of each line at 15.2 m from the line of insecticide release and more distant poles at 45.7, 76.2, 106.7, 137.2 and 167.6 m (150, 250, 350, 450 and 550 ft). Thus, 12 replicate determinations at each pole position were done in each complete experimental series. At the vegetated site, poles were placed close to the planted trees. A single control cage was suspended some distance upwind, where it would not be exposed to insecticide. Tests were run only at wind speeds from 4.8 to 14.5 kph (3–9 mph), in the early morning or late afternoon and early evening, when conditions were similar to those prevailing during normal control operations. Cages were collected after exposure as soon as it was judged that the insecticide had completely cleared the lines, then were quickly returned to the support vehicle, where insects were blown into the postexposure chambers and the cages placed in humidified boxes for return to the laboratory. Collection of cages was done as soon as possible to prevent false, high levels of mortality caused by insects crawling over contaminated mesh. Mortality in each cage was determined 12 h after exposure and adjusted, where appropriate, by Abbott's formula.

Complete data for each test were plotted and evaluated by regression analysis of the untransformed percentage data. Arcsine transformation was not used because: 1) it is of some value only when the percentages are above 90 or below 10 (Sokal and Rohlf 1981), 2) it was considered a confusing element for the primary audience of this paper, and 3) the differences it made to quantitative estimates were negligible. For *Cx. quinquefasciatus* treated with thermal fog malathion in vegetation, for example, where mortality was below 10% in many cages, predicted kill levels at 30.5, 91.4 and 152.4 m (100, 300, 500 ft) were 11, 4 and 1% with untransformed data, 7, 2 and 0.2% with data transformed. The regression analyses for all ULV experiments showed that the linear model provided an appropriate description, but for several of the thermal fog applications, negative logarithmic regression provided a more accurate fit, which was preferentially used in such cases.

RESULTS AND DISCUSSION

The full data for each insecticide, grouped by terrain type and application method, are shown (for *C. furens*) in Figs. 1–4 (M = malathion, S = Scourge, N = naled). The full *Cx. quinquefasciatus* data are not shown. Mortalities at 30.5, 91.4 and 152.4 m (100, 300, 500 ft), calculated from the regression equations, are summarized for easy comparison in histograms, above which the calculated values also are shown (Figs. 5–8).

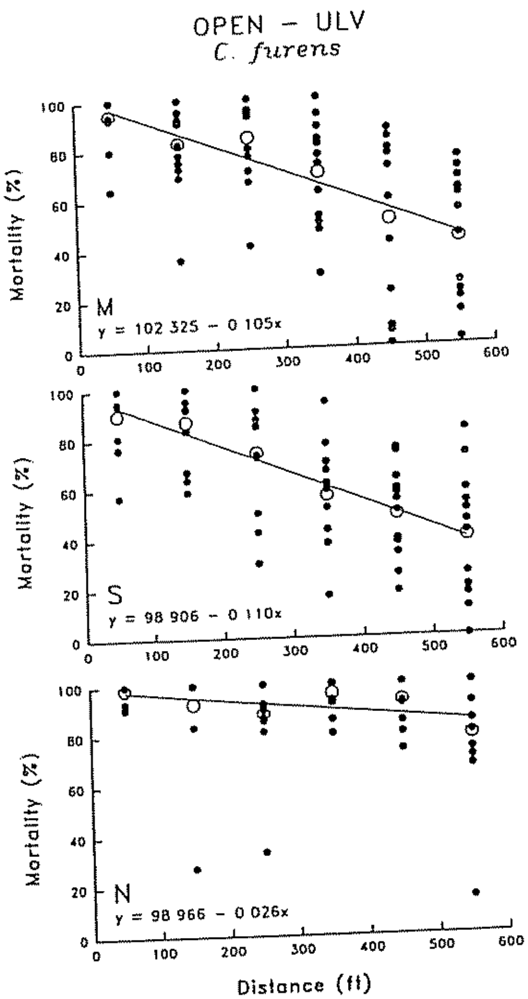

Fig. 1. Results for *Culicoides furens*, open terrain, ULV. Open circles denote mean mortalities.

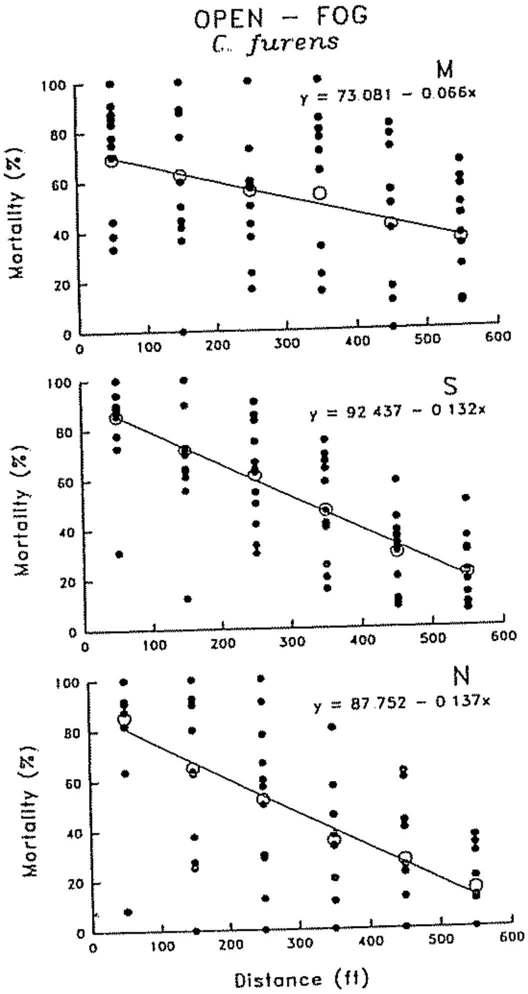

Fig. 2. Results for *Culicoides furens*, open terrain, thermal fog. Open circles denote mean mortalities.

The distances at which 40, 75 and 90% mortality could be expected in each case are given in Table 1.

General comments: In all the tests there was great variation in the mortality observed at any particular distance from the release point (Figs. 1–4), with neither application method obviously more consistent. Less variation was expected in open as opposed to vegetated terrain, but this proved not to be the case. Differences between replicates could have been connected with differences in the distributions of insects within the exposure chambers. There were some places (e.g., close to the sliding aperture) where the solid plastic rim might have provided some shelter from insecticide. This factor was considered unlikely to have accounted for all the variation, however. Pronounced unevenness, augmented by effects of local air currents, apparently exists

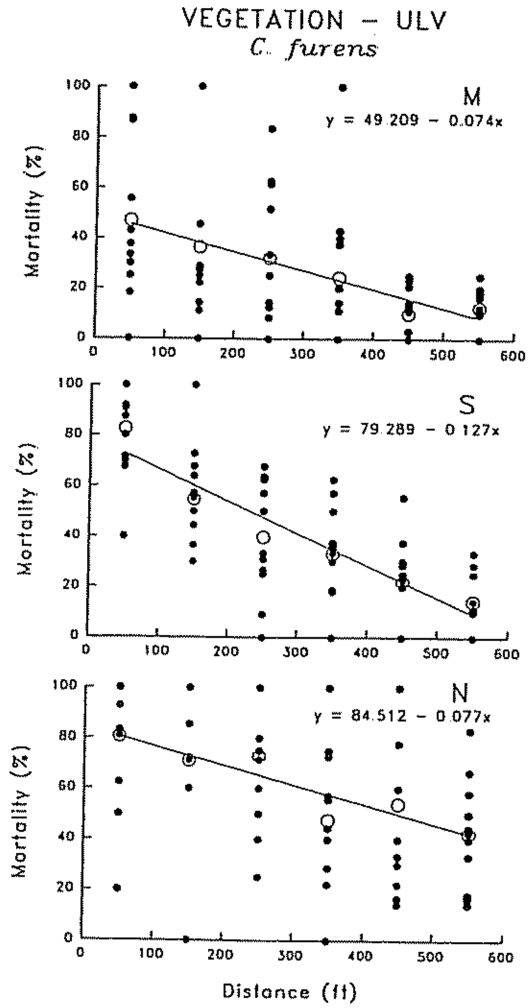

Fig. 3. Results for *Culicoides furens*, vegetated terrain, ULV. Open circles denote mean mortalities.

within the stream of insecticide, even at very short distances from the release point. Many instances were observed where the mortality at 15.2 m (50 ft) varied between less than 40% and 100% (Figs. 2–4), and there were some in which 0% occurred in one replicate, 100% in another (Figs. 3, 4).

Open terrain: Malathion and Scourge applied as ULV in the open performed about equally well with *C. furens* (Fig. 1) and also with *Cx. quinquefasciatus*, with predicted mortalities that were quite similar for the 2 species (Figs. 5, 6). Kill was slightly higher for the *Culicoides* with malathion (the *Culex* were somewhat resistant), somewhat better with Scourge for *Culex* (Figs. 5, 6). However, neither of these materials achieved particularly good levels of control. Ninety percent mortality of *Culicoides* extended only to 35.7 m (117 ft) for malathion and 24.7 m (81 ft) for Scourge (Table 1), with comparable figures for *Culex* of 11.3 m (37 ft) and 46.0 m (151 ft). In contrast, naled as ULV was strikingly more effective against *Culicoides* than the other 2 compounds (Fig. 1), but only about equal to them when used against *Culex*. The relative success of naled against midges is emphasized by the predicted mortalities at 3 distances (Fig. 5), where, even at 152.4 m (500 ft), 86% of the *C. furens* died. In these experiments, 90% mortality was sustained out to 105.8 m (347 ft) and, with the regression coefficient indicating only 2.6% diminution in kill per 30.5 m (100 ft), 75% kill sustained out to 282.9 m (928 ft).

Thermal fog applications in the open were less effective (Fig. 2) than ULV, especially

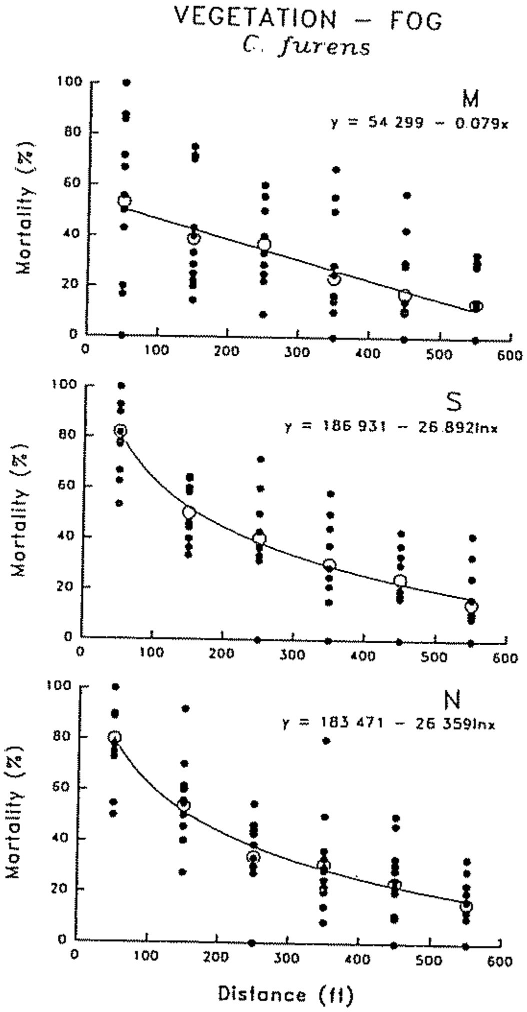

Fig. 4. Results for *Culicoides furens*, vegetated terrain, thermal fog. Open circles denote mean mortalities.

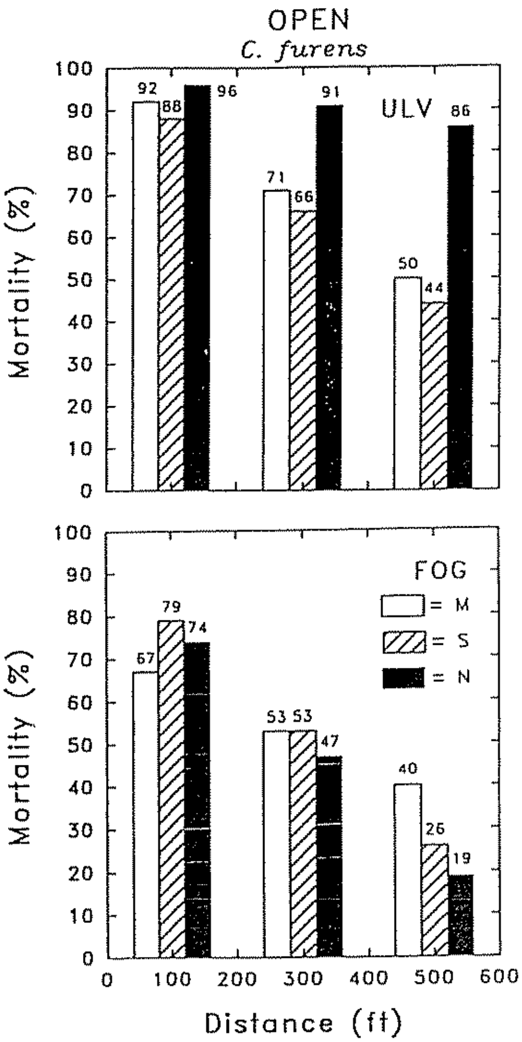

Fig. 5. Predicted mortalities at 30.5, 91.4 and 152.4 m (100, 300, 500 ft) for *Culicoides furens*, open terrain.

Vegetated terrain: With vegetation present, the relative performance of the 3 compounds as ULV against *C. furens* was similar to the pattern observed in the open, except that the level of control with malathion was somewhat depressed compared with Scourge (Figs. 3, 7). Naled again was clearly superior (Fig. 7, Table 1) and maintained better levels of control at all distances from the release point (Fig. 7). However, control was rather poor for all 3 insecticides; none achieved 90% mortality even at 30.5 m (100 ft), and even naled maintained 75% control or better (Table 1) only out to 37.8 m (124 ft). As with the *Culicoides*, ULV applications of malathion against *Cx. quinquefasciatus* performed poorly against *Cx. quinquefasciatus*, as is particularly obvious from the calculated mortalities at 3 distances (Fig. 6). Against *Culicoides*, naled did not maintain its superiority over malathion and Scourge; all 3 performed quite similarly (Figs. 2, 5), giving generally poor levels of control (Table 1). Malathion as thermal fog against *Cx. quinquefasciatus* proved almost totally ineffective (Fig. 6), partially because of resistance, but the other 2 compounds fared only slightly better. In general, control with thermal fog was better compared with ULV against *Culicoides* than against the *Culex*, where ULV was substantially superior (Fig. 6). Overall, however, ULV was clearly the most effective application method, especially so in the case of naled against *Culicoides*.

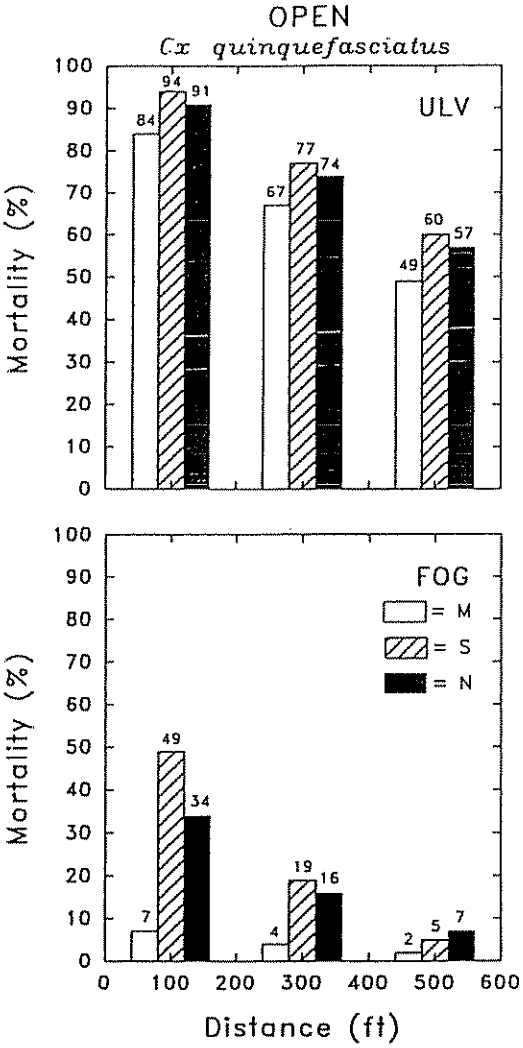

Fig. 6. Predicted mortalities at 30.5, 91.4 and 152.4 m (100, 300, 500 ft) for *Culex quinquefasciatus*, open terrain.

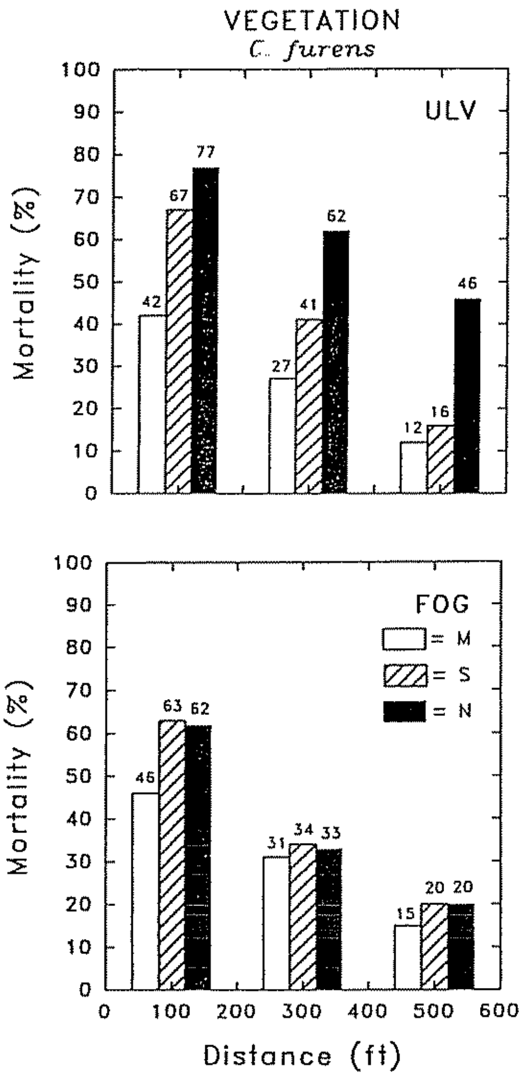

Fig. 7. Predicted mortalities at 30.5, 91.4 and 152.4 m (100, 300, 500 ft) for *Culicoides furens*, vegetated terrain.

relative to the other 2 chemicals in vegetated as compared with open ground (Fig. 8). Scourge, which had given slightly better control than naled as ULV in the open (Fig. 6), showed an increase in this tendency when trees were present (Fig. 8). Overall control of *Cx. quinquefasciatus* by ULV in vegetated terrain was, however, poor with all 3 insecticides, none of which (Table 1) achieved 90% predicted control even at 30.5 m (100 ft), and only rarely did so in individual replicates at 15.2 m (50 ft).

As in the open, all 3 chemicals applied as thermal fog in the presence of vegetation achieved comparable mortalities of *C. furens* (Figs. 4, 7). Predicted mortalities at 30.5 m (100 ft) ranged from only 46 to 62%, however, and at 152.4 m (500 ft) were degraded to 15–20% (Fig. 7). While these results were poor, those with *Cx. quinquefasciatus* were considerably worse. In vegetated terrain, thermal fog applications of all 3 insecticides achieved only minimal kill of the mosquitoes (Fig. 8, Table 1), with predicted mortalities ranging from only 11 to 15% at 30.5 m (100 ft), and with virtually no effect at distances of 91.4 m (300 ft) or greater (Fig. 8). A few replicates exceeded 40% control at 15.2 m (50 ft), but at 45.7 m (150 ft) or beyond, none reached 30%.

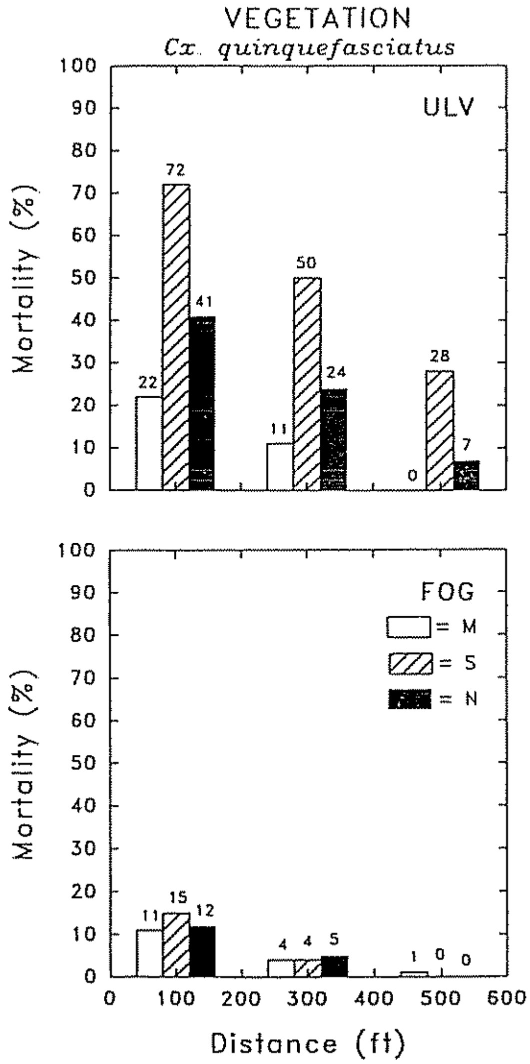

Fig. 8. Predicted mortalities at 30.5, 91.4 and 152.4 m (100, 300, 500 ft) for *Culex quinquefasciatus*, vegetated terrain.

Table 1. Calculated distances (m/(ft)) for mortalities of 40%, 75% and 90% in *Culicoides furens* and *Culex quinquefasciatus* adults exposed to ULV and thermal fog malathion (M), Scourge (S) and naled (N) at 2× label dosage in open and vegetated terrain.

Application method	Mortality (%)	*C. furens* M	*C. furens* S	*C. furens* N	*Cx. quinquefasciatus* M	*Cx. quinquefasciatus* S	*Cx. quinquefasciatus* N
			Open				
ULV	40	180 (591)	164 (537)	696 (2284)	183 (601)	225 (738)	210 (688)
	75	79 (259)	66 (218)	283 (928)	63 (206)	100 (327)	88 (288)
	90	36 (117)	25 (81)	106 (347)	11 (37)	46 (151)	35 (116)
Fog	40	152 (499)	121 (396)	106 (348)	0 (0)	42 (139)	22 (71)
	75	0 (0)	40 (132)	28 (93)	0 (0)	12 (39)	3 (9)
	90	0 (0)	5 (18)	0 (0)	0 (0)	7 (22)	1 (4)
			Vegetation				
ULV	40	38 (124)	94 (309)	177 (581)	0 (0)	119 (389)	35 (114)
	75	0 (0)	10 (34)	38 (124)	0 (0)	23 (74)	0 (0)
	90	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Fog	40	55 (181)	72 (236)	70 (231)	0 (1)	3 (9)	1 (4)
	75	0 (0)	20 (64)	19 (61)	0 (0)	0 (0)	0 (0)
	90	0 (0)	11 (37)	11 (35)	0 (0)	0 (0)	0 (0)

Open versus vegetated terrain: In normal control operations it will be quite rare for the treated area to be completely open and devoid of vegetation. Some trees will almost always be present, together with shrubs and other low plants, particularly in residential areas, and the density of vegetation will vary considerably. In addition to the effects of vegetation, adulticidal treatments will be influenced also by any buildings present. We did not attempt to run the tests in an area with buildings because of the impossibility of repeated treatments in such areas, and because such sites are highly individual, with considerable complexities introduced by the local effects of buildings on insecticide movement, flow and distribution. Within these limitations, we considered it most useful to obtain measures of control in a uniform and quite densely vegetated site, in this case a mature orange grove, that would give an indication of the greatest extent to which vegetation might reduce effect.

As anticipated, the results were consistent in showing diminished mortality in the presence of vegetation for any particular treatment (compare Figs. 5 and 7 for *C. furens*, Figs. 6 and 8 for *Cx. quinquefasciatus*). The extent of reduction can be appreciated from the differences in predicted kill at 30.5 and 91.4 m (100 and 300 ft) in the open as opposed to in vegetation. For *C. furens* (malathion, Scourge, naled applied as ULV), these differences were 50, 21, 19 and 44, 25 and 29%, respectively, and for *Cx. quinquefasciatus* (same treatment) were 62, 22, 50 and 56, 27 and 50%, respectively. These reductions were in the presence of relatively dense vegetation, and some improvement might be expected in most areas since the vegetative cover would be less complete.

As regards the effects of vegetation relative to the 2 methods of application, there was some evidence that thermal fog was less impaired than ULV. With *C. furens*, for example, the predicted kill for thermal fog at 3 distances seems less diminished (compare Figs. 5, 7) than in the case of ULV. The figures bear this out, as open minus vegetation differences at 30.5 and 94.4 m (100 and 300 ft) were 21, 16, 12% and 22, 19, 14%, compared with 50, 21, 19% and 44, 25, 29%, as already cited above. The smaller fog particles remain suspended to a greater degree, as fog flows through foliage, while ULV droplets may tend to impinge more on intervening vegetation. Despite this difference, however, ULV still achieved better results in vegetated terrain, and would remain the method of choice.

CONCLUSIONS

For the many mosquito control agencies that presently use naled in their operations, this study presents an important finding concerning the control of *Culicoides furens*. Of the chemicals tested, naled was by far the most effective against midges, especially in the open (Figs. 1, 5). At 2× label dosage it achieved 90% control out to 105.8 m (347 ft) from the point of release and 75% out to 282.9 m (928 ft). Its performance was diminished in the presence of quite dense vegetation, but it was still the most effective adulticide. Control operations against mosquitoes with naled must certainly have a major simultaneous impact against *Culicoides*. Haile et al. (1984) had previously demonstrated excellent control of *C. hollensis* with aerially applied naled, but at 1 oz/acre, approximately 2.6× the dosage used here. Our study indicates that, if reasonably effective control of midges out to 152.4 m (500 ft) is the desired effect, then the test dosage (2× label, ground application) will suffice, since it achieves 86% mortality at 152.4 m in the open (Fig. 5) and 46% even with heavy vegetation present (Fig. 7). The latter figure does not represent good control, but actual residential and other areas are likely to be less densely vegetated, often considerably so, than the mature grove. Thermal fog applications are not to be recommended as they produced inferior results both in the open and in the grove (Figs. 5, 7), and naled as fog was only about equal in performance to the other 2 compounds.

With *Cx. quinquefasciatus*, ULV again achieved the greatest mortality under both terrain conditions (Figs. 6, 8), but the effect was not as good as against *Culicoides*, and naled was not markedly better than malathion or Scourge. At the experimental dosage, control was rather poor in the open (49–57% at 152.4 m (500 ft)), very poor in the grove (0–28% at this distance). Thermal fog applications, especially of malathion, were ineffective, although this was no doubt caused in some measure by moderate resistance in the strain used.

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REFERENCES CITED

Floore, T. G. 1985. Laboratory wind tunnel tests of nine insecticides against *Culicoides* species (Diptera: Ceratopogonidae). Florida Entomol. 68:678–682.

Giglioli, M. E. C., E. J. Gerberg and R. G. Todd. 1980. Large scale field tests and environmental assessments of Sumithion (fenitrothion) against adult biting midges in Grand Cayman, West Indies. Mosq. News 40:1–5.

Haile, D. G., D. L. Kline, J. F. Reinert and T. L. Biery. 1984. Effects of aerial applications of naled on *Culicoides* biting midges, mosquitoes and tabanids on Parris Island, South Carolina. Mosq. News 44:178–183.

Kline, D. L., D. G. Haile and K. F. Baldwin. 1981. Wind tunnel tests with seven insecticides against adult *Culicoides mississippiensis* Hoffman. Mosq. News 41:745–747.

Linley, J. R. 1976. Biting midges of mangrove swamps and salt-marshes (Diptera: Ceratopogonidae). pp. 335-376, *In*: L. Cheng (ed.), Marine insects. North-Holland Publishing Co. (American Elsevier Publishing Co.), New York.

Linley, J. R. and J. B. Davies. 1971. Sandflies and tourism in Florida and the Bahamas and Caribbean area. J. Econ. Entomol. 64:264–278.

Linley, J. R., R. E. Parsons and R. A. Winner. 1987. Evaluation of naled applied as a thermal fog against *Culicoides furens* (Diptera: Ceratopogonidae). J. Am. Mosq. Control Assoc. 3:387–391.

Linley, J. R., R. E. Parsons and R. A. Winner. 1988. Evaluation of ULV naled applied simultaneously against caged adult *Aedes taeniorhynchus* and *Culicoides furens*. J. Am. Mosq. Control Assoc. 4:326–332.

Sokal, R. R. and F. J. Rohlf. 1981. Biometry. W. H. Freeman and Co., New York.

1990 Curtis, G. A., and D. B. Carlson
Evaluation of Hand Applied Naled Thermal Fog for Wyeomyia Control
J. American Mosquito Control Association 6: 421-424 (Amvac Ref. 1412)

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EVALUATION OF HAND APPLIED NALED THERMAL FOG FOR *WYEOMYIA* CONTROL

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ABSTRACT. Tests on the effect of hand applied naled thermal fog, both as a single treatment on one day/week and a single treatment on 3 successive days, did not control *Wyeomyia vanduzeei* and *Wy. mitchellii*. Five-min landing/biting counts in a native oak/palm woodland demonstrated that single applications produced an average landing rate decrease of 13%. Treatments 3 days in succession did not suppress the landing rate.

INTRODUCTION

Two bromeliads, *Tillandsia utriculata* Linn. and *Billbergia pyramidalis* (Sims) Lindley, are productive *Wyeomyia* habitats in urban areas. *Tillandsia utriculata*, a native arboreal epiphyte, frequently attaches to rough-barked trees such as oak (Frank and Curtis 1981), while *B. pyramidalis*, an exotic, is terrestrial. Rainfall or domestic irrigation contained in the leaf bracts of these bromeliads commonly enables these southern Florida plant species to produce *Wyeomyia vanduzeei* Dyar and Knab and *Wy. mitchellii* (Theobald). Because these 2 bromeliads serve as decorative landscaping plants, *Wyeomyia* mosquitoes are in direct association with humans.

Control of both *Wyeomyia* larvae and adults has eluded the technology of operational mosquito control. Larviciding in *Tillandsia* is difficult because of their abundance and inaccessibility in trees. *Billbergia pyramidalis* are difficult for larviciding because their dense overlapping leaves exclude chemical penetration to the central water-filled cup.

Adults of these 2 mosquitoes are particularly pestiferous in southern Florida in shaded areas where bromeliads are numerous. They exhibit an erratic/wary biting behavior similar to *Aedes aegypti* (Linn). Adults of both *Wy. vanduzeei* and *Wy. mitchellii* are daylight active; therefore, normal crepuscular ultra low volume (ULV) adulticiding is ineffective.

During May-July 1983, the Indian River Mosquito Control District conducted a series of experiments to evaluate the efficiency of thermal fogging for controlling *Wy. vanduzeei* and *Wy. mitchellii* adults. The objective of our study was to develop a functional adulticiding program that could be used by mosquito control agencies or homeowners, by achieving 80-90% reduction of adult *Wyeomyia* with a limited number of chemical applications.

METHODS AND MATERIALS

Study site: Three discrete oak/palm woodlands, separated by about 300 m (900 ft), were selected in Vero Beach, Florida. Each of the sites was approximately 0.3 acres (0.1 ha) in area. Vegetation at each site was dominated by native oak (*Quercus virginiana* P. Mill.) and palm (*Sabal palmetto* (Walt.) Todd) with a dense shrub understory. These 3 sites were selected because their isolation from other possible *Wyeomyia* preadult habitats eliminated the possibility of immigration. *Wyeomyia vanduzeei* has a restricted flight range with the adults dispersing short distances from their emergence site (Frank and Curtis 1977).

Landing rates: All population monitoring was performed by the same 2 individuals taking landing rates at one of several designated locations within each site. For 5 min, the total number of mosquitoes that landed and attempted blood engorgement was counted. This method was selected because trapping techniques using light or bait are not successful for collecting adult *Wy. vanduzeei* and *Wy. mitchellii* (Frank and Curtis 1977). However, they are anthropophilic. Each sampling event included measurement of temperature, wind speed and relative humidity.

For 30 days prior to commencement of the adulticiding tests, daily (Monday-Friday) landing rates were taken at each of the 3 sites between 0800-0900 h. The sequence for sampling was rotated randomly among the 3 sites. This was to establish a baseline estimation of changes in mosquito numbers at each of the selected locations. One site was selected as an untreated control and compared with the 2 insecticide test areas.

Statistical analysis: For statistical purposes, the landing rates of the 2 collectors were averaged. The data were smoothed with a 2-day moving average (Box and Jenkins 1976).

Fogging: In each of the experiments, one or more sites was treated by thermal fogging with Dibrom 14 (naled) diluted with diesel fuel (1:99). The insecticide was applied with a London Turbo Hand Fogger (London Fog Co., Crystal Bay, MN). Treatment was at a rate of 5-6 gal (19-23 liters)/h. The fogger was hand carried at approximately 2 miles/h (55 m/min). This procedure is similar to that used by Linley et al.

(1987) for insecticidal testing against *Culicoides furens* (Poey). Evaluation was on the effect of either the single treatment on one day or a treatment on 3 consecutive days. Landing/biting counts were taken before the treatment. Posttreatment landing rates were taken 24 h following the application. If the experiment was for 3 successive daily treatments, the mean of the 3 pretreatment and 3 posttreatment landing rates were computed. This produced a single smoothed value for comparison.

RESULTS

Figure 1 shows the results of the preliminary adult sampling used to establish baseline population levels. Graphically, Fig. 1 illustrates the percent change from one daily sampling event to the next. This summary of the pretreatment data illustrates the dissimilarity among the landing rates at the 3 sites. Clearly, on consecutive days the individual percent changes differed at each site. To evaluate site stability in relation to mosquito population fluctuation, we employed the methodology of Bidlingmayer (1985). This involves the conversion of the data to standard normal deviates (Sokal and Rohlf 1981). Comparability was tested by Pearson product-moment correlation. The probability matrix generated by this test demonstrated there was no association among all 3 sites ($n = 18$, $P < 0.25$). Although Site 1 and Site 2 exhibited some statistical similarity ($n = 18$, $P < 0.08$), a change in one was not necessarily indicative of a change in the other. This made it impossible to use the original experimental design, which had anticipated a traditional "control" vs. "treated" comparison. Instead we used moving average smoothing technique, which is discussed later.

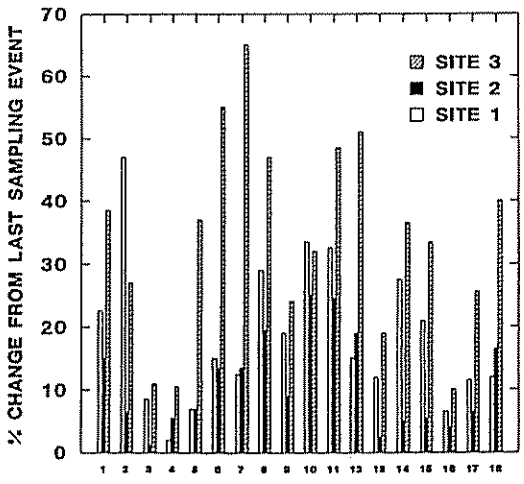

Fig. 1. Preliminary *Wyeomyia* landing rates (mean of 2 samples). Percent change from last daily sampling event.

Sites 1 and 3 were selected for treatment because they had the highest landing rates. Eleven insecticidal treatments were applied between these 2 sites. Figure 2 shows pretreatment and posttreatment landing rates. Statistically, the percent change between the pretreatment and the posttreatment landing rates ranged between a decrease of 48% and an increase of 66% with a mean decrease of 13% (Fig. 3).

Six tests were conducted with naled applied 3 days in succession. Figure 4 shows the results of both pretreatment and posttreatment landing

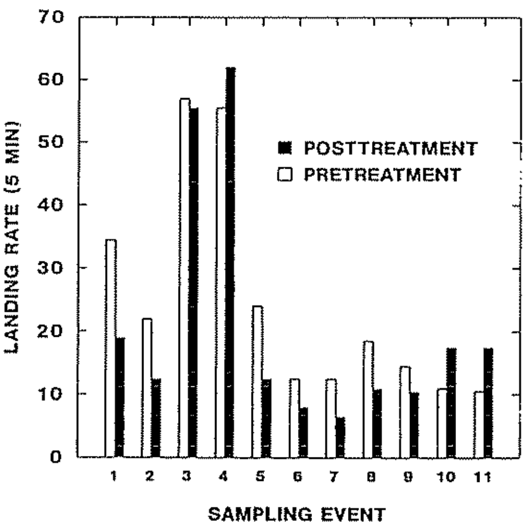

Fig. 2. Efficiency of thermal naled fog in a single application. Pretreatment and posttreatment landing rates are 2 day averages.

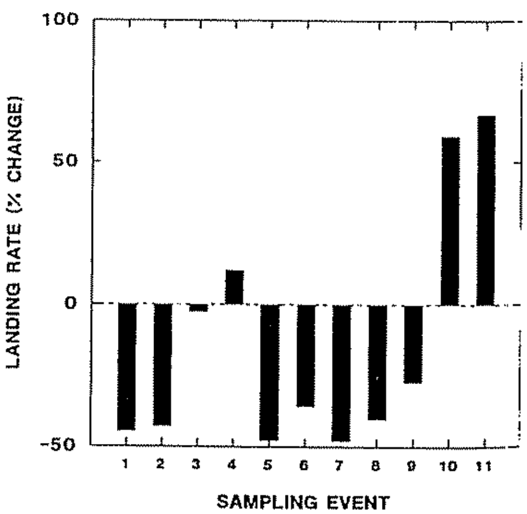

Fig. 3. Percent change in *Wyeomyia* landing rates following a single treatment with thermal naled fog.

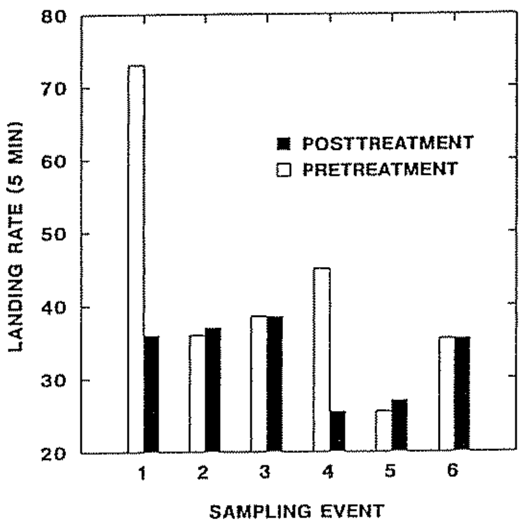

Fig. 4. Efficiency of thermal naled fog in 3 successive daily treatments. Pretreatment and posttreatment landing rates are 2 day averages.

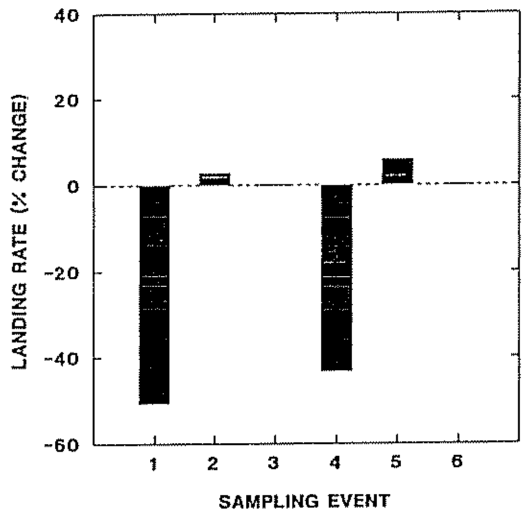

Fig. 5. Percent change in *Wyeomyia* landing rates following 3 successive daily treatments with thermal naled fog.

rates for this series of tests. Percent changes of *Wyeomyia* landing rates ranged from a decrease of 50.7% to an increase of 5.9% with a mean decrease of 14.3% (Fig. 5).

DISCUSSION

The idea of selecting several sites for the study with the intent of one serving as a control was educational. It demonstrated a concern all researchers on this subject should consider. In many adulticiding studies, an isolated control site is selected that presumably will mimic the same population fluctuations as the test site. It is often assumed that even if there is a numerical disparity between sites, the same environmental and biological factors are driving the sites and the percent changes in mosquito abundance will be comparable. If true, this allows statistically valid comparisons to be made between treatment and control sites.

However, in this study a comparison of the standard normal deviates of the pretreatment samples demonstrated that there was insufficient consistency among *Wyeomyia* populations to allow any of the 3 sites to serve as a control. For statistical purposes, we turned instead to a 2-day moving average of landing rates. This commonly used data processing method minimized the normal landing rate variation while retaining the natural trend in the data, and presented the smoothest numeric data ensemble for analysis. Additionally, we were most interested in whether there was a real reduction in mosquito numbers resulting from insecticide treatment.

The single treatment experiments with thermal naled resulted in an average 13% reduction, which was well below the 80–90% target. Figure 3 demonstrates that in 7 of the 11 tests, there was a > 36% reduction in *Wyeomyia* landing rates. The 4 other tests showed a small reduction or an increase from the 2-day mean pretreatment *Wyeomyia* landing rate.

Thermal naled treatments on 3 successive days also proved ineffective in providing adequate control (Fig. 5). The largest observed reduction in *Wyeomyia* numbers in any of the tests (50.7%) occurred in this series of experiments. However, in 4 of the 6 three successive day treatments, there was either no change or a slight increase in mosquito abundance.

Reasons for the failure of hand fogging with naled to control adult *Wyeomyia* are unclear. *Wyeomyia* adults normally exhibit extensive vertical flight distribution along tree trunks (Frank and Curtis 1977). Therefore, the majority of the adults may be avoiding the low-lying fog by being above it, although with each test, we observed the fog dispersing up into the canopy. Also, bromeliads positioned in the tree canopy as well as the canopy itself, may provide harborage for resting mosquitoes. We have no reason to question the susceptibility of *Wyeomyia* to thermal naled. In a series of preliminary trials conducted immediately prior to this study using caged *Wyeomyia*, we achieved > 90% control.

Biologically, the nonsynchronous emergence of *Wyeomyia* supplies a steady daily recruitment that may mask any benefits of hand fogging for adults. Initially, it was hoped we would find that a single fogging treatment would provide effective localized *Wyeomyia* control. However, even with the pressure of 3 successive daily treatments, there was not adequate *Wyeomyia* control to justify using naled thermal fogging for even specialized applications. We believe from these results that physical (e.g., removal of plants) and perhaps biological (e.g., introduction of predators or competitors for resources), rather than chemical, will prove to be the superior control strategies for *Wyeomyia* mosquitoes.

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REFERENCES CITED

Bidlingmayer, W. L. 1985. Adult mosquito surveillance for control programs. J. Fla. Anti-Mosq. Assoc. 56:8–13.

Box, G. E. P. and G. M. Jenkins. 1976. Time series analysis: forecasting and control. Holden-Day, Oakland.

Frank, J. H. and G. A. Curtis. 1977. On the bionomics of bromeliad-inhabiting mosquitoes. V. A mark-release-recapture technique for estimation of population size of *Wyeomyia vanduzeei*. Mosq. News 37:444–452.

Frank, J. H. and G. A. Curtis. 1981. Bionomics of the bromeliad-inhabiting mosquito *Wyeomyia vanduzeei* and its nursery plant *Tillandsia utriculata*. Fla. Entomol. 64:491–506.

Linley, J. R., R. E. Parsons and R. A. Winner. 1987. Evaluation of naled applied as a thermal fog against *Culicoides furens* (Diptera: Ceratopogonidae). J. Am. Mosq. Control Assoc. 3:387–391.

Sokal, R. R. and F. J. Rohlf. 1981. Biometry. 2nd ed., W. H. Freeman and Sons, San Francisco.

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INSECTICIDE TOLERANCE OF *CULEX NIGRIPALPUS* IN FLORIDA

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ABSTRACT. Larval susceptibility tests of *Culex nigripalpus* populations from various areas of Florida have shown resistance to several organophosphorus insecticides since 1984. Although the degree of resistance is low (2 to 7 times), it can be termed tolerance and appears to be the greatest for fenthion, followed by temephos, naled and malathion. It is suggested that pesticide runoff from lawns, golf courses and agricultural and urban areas may play a role in developing resistance in Florida mosquito populations.

INTRODUCTION

Culex nigripalpus Theobald is regarded as one of the main mosquito species in Florida against which control efforts are directed. It was incriminated as the vector of St. Louis encephalitis (SLE) during the 1959, 1961 and 1962 epidemics in the Tampa Bay area (Florida State Board of Health 1969). During these periods, 315 cases were reported with 55 fatalities (Florida State Board of Health 1963) The next SLE epidemic occurred in central Florida during 1977. *Culex nigripalpus* was also incriminated as the vector with 110 cases and 8 deaths recorded (Nelson et al. 1983).

Since 1964, the John A. Mulrennan, Sr., Research Laboratory (JAMSRL), formerly the West Florida Arthropod Research Laboratory (WFARL), has been monitoring the insecticide susceptibility of this species from various areas in the state. From 1965 to 1967, area populations were primarily tested against malathion and naled (Rogers and Rathburn 1964, Rathburn and Boike 1967, Boike and Rathburn 1968) During 1968–71, baseline data were established for the laboratory susceptible colonies with temephos, fenthion and chlorpyrifos (Boike and Rathburn 1969, 1972). From 1972 to 1978, *Cx. nigripalpus* larval populations were tested for malathion, naled and fenthion resistance (Boike and Rathburn. 1975, Boike et al. 1978, 1979) and beginning in 1979 for susceptibility to temephos (Boike et al. 1980) In anticipation of possible resistance and cross resistance to the other currently used insecticides, a program was initiated in 1980 to monitor the susceptibility of mosquito populations from selected areas of the state in which temephos was used (Boike et al. 1982). In 1984, results of the temephos (Abate) monitoring program indicated that some populations of *Cx. nigripalpus* were showing some tolerance to fenthion, temephos and naled (Boike et al. 1985).

In California a similar need to identify resistance trends over a period of several years was reported by Thompson (1986) who showed that, after testing *Cx. tarsalis* Coquillett larvae from throughout the state from 1983 to 1985, most populations were susceptible to malathion and fenthion but resistant to parathion and chlorpyrifos.

MATERIALS AND METHODS

Ideally, the variations of susceptibility of a mosquito population can best be shown when a population is sampled and tested from the same area or locality over a period of several consecutive years (Brown 1986). Many of the areas sampled during the earlier years of the susceptibility testing program (1965–70) were from several localities within a county and tested against several insecticides. Therefore, few mosquito populations from one locality were tested against the same insecticide for several consecutive years. Around 1980, when the Abate monitoring program was initiated, testing of populations from the same area against the same insecticide for consecutive years was realized. It was also around this time (1980–84) that an increase in tolerance to some insecticides was noted in some populations of *Cx. nigripalpus* around the state. All area mosquito populations were compared to the standard susceptible *Cx nigripalpus* strain of the JAMSRL. This strain was colonized since 1964 from adults from Indian River County and has not been exposed to insecticides since then.

Most wild *Cx. nigripalpus* were collected for testing from various areas using CDC portable light traps baited with dry ice (Newhouse et al. 1966) In addition, chicken-baited lard can traps, (Bellamy and Reeves 1952) were used and on several occasions sweep nets were employed when adults were numerous. An average of 500 to 1,000 specimens were collected with the light trap method, while several hundred specimens were captured using lard cans and sweep nets. Specimens were shipped by bus or auto to the laboratory in cages placed inside styrofoam chests and chilled with plastic freezer containers. Adult mosquitoes were transferred to 46 cm^2 screened cages in the laboratory, blood fed on anesthetized chicks, and offered a 10% sugar solution on cotton pads as a carbohydrate source. Egg rafts were collected on infusion water prepared from dried oak leaves and forest floor detritis, hatched, and the F_1 larvae tested.

Larvae were tested for susceptibility to fenthion, malathion, naled and temephos during 1966-86 using the following protocol: 1 ml of insecticide diluted in ACS acetone was pipetted into test beakers containing 200 ml of tap water. Then 25 3rd instar larvae in 49 ml of tap water were added to the beakers, giving a total of 250 ml of solution.

Initially, 600 ml Pyrex glass beakers were used; however, to eliminate breakage, 400 ml polypropylene beakers were used during most of the testing period. From 1986 to the present, 420 ml styrofoam cups were employed and discarded after usage. Since a considerable reduction in larval mortality occurred when plastic beakers were used for the temephos bioassay (Rathburn and Boike 1969) glass was employed throughout the testing period for this insecticide.

A replicate consisted of a control and 5 to 7 serial dilutions of the test insecticide. An average of 12 replications were performed on each insecticide and all tests were performed in water baths at 27 ± 1° C. Mortality counts were made at 24 h posttreatment. A *Cx. nigripalpus* larval bioassay of the susceptible colony from the JAMSRL was performed with each bioassay from the locality.

The resistance ratio is a comparison of the susceptibility of the field-collected mosquitoes to that of the susceptible strain and is defined as the LC_{50} or LC_{90} values of the field collected strain divided by the LC_{50} or LC_{90}, respectively, of the susceptible strain.

The LC_{50} and LC_{90} values were calculated by probit analysis using a Sharp programmable calculator during 1974-82. From 1983 to the present, the values were obtained with the SAS program through the facilities of the Northeast Regional Data Center (NERDC) located in Gainesville, FL and were expressed in μg AI/ml (ppm)

RESULTS

Results of the *Cx. nigripalpus* larval bioassays are presented for each insecticide in Tables 1 to 4. Similar localities sampled for 2 or more years and showing an increase in tolerance, were arranged chronologically. Some localities within the same county were sampled only once and are included for comparison either to localities with little or no tolerance or to localities showing significant tolerance (usually those sampled 1984-86). All resistant ratios (RR) were less than 10×, indicating tolerance as defined by Brown and Pal (1971): "For mosquito larvae, a 10-fold increase in LC_{50} is necessary to indicate resistance, whereas for adult mosquitoes a 4-fold increase is sufficient. In cases where the increase in LC_{50} is less than these indicated minima for the tests, but is nevertheless statistically significant, the word 'tolerance' has proved useful. This usually coincides with a degree of change in susceptibility level that has not resulted in a detectable loss of control by the insecticide." Tables 1 to 4 record the bioassays of *Cx. nigripalpus* with fenthion, temephos, naled and malathion, respectively.

Bioassays of *Cx. nigripalpus* from Gibsonton, FL, during 1981-86 indicated an increase in tolerance to fenthion with LC_{50} and LC_{90} resistance ratios from 0.9× during 1981 to 3.8× and 7.2×, respectively, in 1986 (Table 1). Since the LC_{50} and LC_{90} of the JAMSRL susceptible colony varied little during the time period, the increased resistance ratios were thought to be a result of true increases in the LC_{50} and LC_{90} values of the populations tested. Somewhat similar results were obtained for Marco Island. During 1982, the *Cx. nigripalpus* population and the JAMSRL colony were almost equally susceptible to fenthion. When tested in 1985, the wild population was 4.2× (LC_{50}) and 5.4× (LC_{90}) more tolerant than the JAMSRL strain. Larvae from wild populations from 3 localities (Chapman Road, Port Manatee and Tallevast) in Manatee County tested during 1985 and 1986 were 3.6 to 5.4× more tolerant at the LC_{50} level and 5.7 to 6.7× more tolerant at the LC_{90} level than the JAMSRL colony. Additional localities indicating an increase in tolerance to fenthion during 1985 and 1987 were: Temple Terrace in Hillsborough County, New Port Richey in Pasco County and Daytona Beach and Deltona in Volusia County.

Larval bioassays of *Cx. nigripalpus* from Gibsonton, Hillsborough County, indicated an increase in tolerance to temephos over a 6-year period (Table 2). During 1980, 1981 and 1982, the larvae were almost as susceptible as the JAMSRL strain. From 1984 to 1986, an increase in tolerance was noted with resistance ratios of 2.5× and 5.6× at the LC_{50} and LC_{90} levels, respectively. Larval bioassays conducted during 1984 and 1986 from the Treesweet processing plant in St. Lucie County indicated a 2-fold and 2.3-fold increase in the LC_{50} and LC_{90} resistance ratio, respectively compared to the JAMSRL strain. The 1979 larval bioassays from Ponce Inlet, Volusia County, were almost as susceptible as the JAMSRL strain. Larvae collected from Deltona and Daytona Beach (Volusia County) showed an increase in tolerance to temephos.

Table 1. Susceptibility of *Culex nigripalpus* larvae against fenthion from various localities in Florida for indicated years.

County	Locality	Year	Lethal concentration in μg AI/ml (ppm)				Resistance ratio	
			LC_{50}	95% C.L.	LC_{90}	95% C.L.	LC_{50}	LC_{90}
Collier Bay	Marco Island	1982	0.00353	(0.00348–0.00359)	0.00530	(0.00510–0.00621)	1.1	1.3
	JAMSRL	1982	0.00317	(0.00310–0.00324)	0.00406	(0.00393–0.00418)	—	—
	Marco Island	1985	0.01304	(0.01272–0.01338)	0.02123	(0.02021–0.02248)	4.2	5.4
	JAMSRL	1985	0.00309	(0.00286–0.00331)	0.00395	(0.00363–0.00462)	—	—
	Naples	1986	0.00693	(0.00413–0.00939)	0.02297	(0.01475–0.10412)	2.4	6.4
	JAMSRL	1986	0.00284	(0.00278–0.00291)	0.00360	(0.00350–0.00373)	—	—
Hillsborough Bay	Gibsonton	1981	0.00302	(0.00295–0.00309)	0.00417	(0.00402–0.00434)	0.9	0.9
	JAMSRL	1981	0.00350	(0.00344–0.00356)	0.00452	(0.00437–0.00467)	—	—
	Gibsonton	1984	0.00732	(0.00646–0.00827)	0.01932	(0.01580–0.02582)	2.7	5.6
	JAMSRL	1984	0.00269	(0.00264–0.00273)	0.00343	(0.00336–0.00351)	—	—
	Gibsonton	1985	0.00964	(0.00797–0.01235)	0.02724	(0.01863–0.06346)	3.0	6.5
	JAMSRL	1985	0.00322	(0.00304–0.00340)	0.00416	(0.00385–0.00472)	—	—
	Gibsonton	1986	0.00996	(0.00824–0.01237)	0.02470	(0.01757–0.06017)	3.8	7.2
	JAMSRL	1986	0.00264	(0.00255–0.00273)	0.00345	(0.00332–0.00363)	—	—
	Temple Terrace	1985	0.01081	(0.00896–0.01321)	0.02339	(0.01765–0.04372)	3.4	5.6
	JAMSRL	1985	0.00322	(0.00304–0.00340)	0.00416	(0.00385–0.00472)	—	—
Indian River Bay	Vero Beach	1986	0.00999	(0.00899–0.01101)	0.01463	(0.01291–0.01832)	3.5	4.1
	JAMSRL	1986	0.00284	(0.00278–0.00291)	0.00360	(0.00350–0.00373)	—	—
Manatee Bay	Chapman Rd	1985	0.01134	(0.00944–0.01486)	0.02299	(0.01677–0.05176)	4.1	6.7
	JAMSRL	1985	0.00274	(0.00245–0.00298)	0.00343	(0.00313–0.00431)	—	—
	Chapman Rd	1986	0.01540	(0.01344–0.01668)	0.02057	(0.01816–0.03027)	5.4	5.7
	JAMSRL	1986	0.00284	(0.00278–0.00291)	0.00360	(0.00350–0.00373)	—	—
	Tallevast	1986	0.01295	(0.01140–0.01545)	0.02328	(0.01845–0.03898)	4.6	6.5
	JAMSRL	1986	0.00284	(0.00278–0.00291)	0.00360	(0.00350–0.00373)	—	—
	Port Manatee	1986	0.01054	(0.00352–0.01303)	0.01971	(0.01533–0.09521)	3.6	5.7
	JAMSRL	1986	0.00290	(0.00265–0.00313)	0.00347	(0.00320–0.00412)	—	—
Pasco Bay	N. Pt. Richey	1985	0.00854	(0.00623–0.01949)	0.02465	(0.01314–0.01780)	2.8	6.2
	JAMSRL	1985	0.00309	(0.00286–0.00331)	0.00395	(0.00363–0.00462)	—	—
Volusia Bay	Ponce Inlet	1979	0.00291	(0.00270–0.00507)	0.00457	(0.00412–0.00507)	0.9	1.0
	JAMSRL	1979	0.00331	(0.00326–0.00336)	0.00444	(0.00432–0.00455)	—	—
	Tomoka Marsh	1981	0.00288	(0.00279–0.00298)	0.00421	(0.00403–0.00440)	0.8	0.9
	JAMSRL	1981	0.00350	(0.00344–0.00356)	0.00452	(0.00437–0.00467)	—	—
	Daytona Beach	1987	0.00819	(0.00731–0.00921)	0.01603	(0.01324–0.02264	2.9	4.5
	JAMSRL	1987	0.00282	(0.00266–0.00297)	0.00353	(0.00332–0.00388)	—	—
	Deltona	1987	0.00859	(0.00767–0.00950)	0.01765	(0.01527–0.02178)	3.2	5.0
	JAMSRL	1987	0.00270	(0.00249–0.00287)	0.00355	(0.00330–0.00401)	—	—

$$\text{Resistance ratio} = \frac{LC_{50} \text{ or } LC_{90} \text{ of area strain}}{LC_{50} \text{ or } LC_{90} \text{ of susceptible strain}}$$

Most *Cx. nigripalpus* naled bioassays prior to 1984 indicated that wild populations tested were similar in susceptibility as the JAMSRL strain (Table 3). Populations from Manatee County sampled in 1973 (Bradenton) and 1976 (Perico Island) showed similar susceptibility when compared with the JAMSRL colony; however, from 1985 to 1987 populations from Chapman Road, Port Manatee and Tallevast (located approximately 8 to 13 km from Bradenton and Perico Island) were 2.8 to 3.0× more tolerant to naled at the LC_{50} level and 3.8 to 4.9× more tolerant at the LC_{90} level. Populations from New Smyrna, Oak Hill, Ponce Inlet and Tomoka Marsh (Volusia County) tested during 1966–81 were almost as tolerant as the JAMSRL colony, while larval bioassays from Daytona Beach and Deltona conducted during 1987 indicated an increase in tolerance of 2.2× and 2.7× at the LC_{50} level and 3.7× and 4.3× at the LC_{90} level, respectively.

Malathion is the most widely used insecticide for mosquito control in the state. Susceptibility tests were performed from more locations at more time intervals than for the 3 previous insecticides (Table 4). Results from 1985–87 larval bioassays from Naples, Collier County; Gibsonton, Hillsborough County; Vero Beach, Indian River County; Chapman Road, Port Manatee, and Tallevast, Manatee County; New

Table 2. Susceptibility of *Culex nigripalpus* larvae against temephos from various localities in Florida for indicated years.

County	Locality	Year	Lethal concentration in µg AI/ml (ppm)				Resistance ratio	
			LC_{50}	95% C.L.	LC_{90}	95% C.L.	LC_{50}	LC_{90}
Collier Bay	Naples	1980	0.000291	(0.000278–0.000304)	0.000547	(0.000513–0.000583)	0.9	0.9
	JAMSRL	1980	0.000327	(0.000313–0.000340)	0.000608	(0.000581–0.000635)	—	—
	Marco Island	1982	0.000478	(0.000469–0.000488)	0.000645	(0.000626–0.000665)	0.8	0.8
	JAMSRL	1982	0.000574	(0.000562–0.000585)	0.000824	(0.000792–0.000857)	—	—
	Marco Island	1984	0.000792	(0.000647–0.000948)	0.001252	(0.001016–0.002852)	1.2	1.4
	JAMSRL	1984	0.000637	(0.000626–0.000648)	0.000898	(0.000872–0.000929)	—	—
Hillsborough Bay	Gibsonton	1980	0.000296	(0.000283–0.000309)	0.000609	(0.000564–0.000658)	0.6	0.8
	JAMSRL	1980	0.000470	(0.000354–0.000560)	0.000730	(0.000609–0.001160)	—	—
	Gibsonton	1981	0.000327	(0.000315–0.000340)	0.000700	(0.000651–0.000754)	0.5	0.5
	JAMSRL	1981	0.000600	(0.000588–0.000612)	0.000915	(0.000875–0.000957)	—	—
	Gibsonton	1982	0.000389	(0.000377–0.000402)	0.000626	(0.000605–0.000648)	0.7	0.7
	JAMSRL	1982	0.000524	(0.000511–0.000537)	0.000844	(0.000802–0.000888)	—	—
	Gibsonton	1984	0.001313	(0.001192–0.001464)	0.004031	(0.003244–0.005491)	2.1	4.5
	JAMSRL	1984	0.000637	(0.000626–0.000648)	0.000898	(0.000872–0.000929)	—	—
	Gibsonton	1984	0.001115	(0.000877–0.001348)	0.003402	(0.002490–0.006450)	1.7	3.9
	JAMSRL	1984	0.000651	(0.000636–0.000665)	0.000876	(0.000845–0.000915)	—	—
	Gibsonton	1985	0.001200	(0.001061–0.001344)	0.002640	(0.002219–0.003427)	2.4	3.4
	JAMSRL	1985	0.000506	(0.000384–0.000568)	0.000766	(0.000675–0.001055)	—	—
	Gibsonton	1986	0.001451	(0.000852–1.544009)	0.004469	(0.002146–1.677432)	2.5	5.6
	JAMSRL	1986	0.000583	(0.000502–0.000640)	0.000792	(0.000711–0.001016)	—	—
	Temple Terrace	1985	0.000797	(0.000745–0.000847)	0.002230	(0.001978–0.002622)	1.4	2.8
	JAMSRL	1985	0.000552	(0.000461–0.000611)	0.000796	(0.000706–0.001064)	—	—
Manatee Bay	Tallevast	1986	0.001654	(0.001092–0.002781)	0.003397	(0.002271–0.004195)	3.0	4.2
	JAMSRL	1986	0.000551	(0.000475–0.000604)	0.000810	(0.000724–0.001031)	—	—
	Chapman Rd.	1986	0.002033	(0.001534–0.003719)	0.005089	(0.003089–0.045879)	3.7	6.3
	JAMSRL	1986	0.000551	(0.000475–0.000604)	0.000810	(0.000724–0.001031)	—	—
St. Lucie Bay	Treesweet	1984	0.001072	(0.000947–0.001244)	0.002099	(0.001704–0.002954)	1.6	2.3
	JAMSRL	1984	0.000656	(0.000627–0.000689)	0.000905	(0.000835–0.001019)	—	—
	Treesweet	1986	0.001869	(0.001628–0.002288)	0.004276	(0.003190–0.007468)	3.2	5.4
	JAMSRL	1986	0.000583	(0.000502–0.000640)	0.000792	(0.000711–0.001016)	—	—
	Tropicana	1984	0.001115	(0.000914–0.000163)	0.001905	(0.001396–0.004851)	1.7	2.1
	JAMSRL	1984	0.000656	(0.000627–0.000689)	0.000904	(0.000835–0.001019)	—	—
Volusia Bay	Ponce Inlet	1979	0.000542	(0.000529–0.000555)	0.000859	(0.000815–0.000905)	1.2	1.1
	JAMSRL	1979	0.000468	(0.000458–0.000479)	0.000795	(0.000760–0.000832)	—	—
	Deltona	1987	0.001526	(0.001294–0.001818)	0.003272	(0.002477–0.006615)	2.3	3.4
	JAMSRL	1987	0.000669	(0.000646–0.000694)	0.000967	(0.000908–0.001051)	—	—
	Daytona Beach	1987	0.001622	(0.001318–0.002340)	0.004391	(0.002780–0.025535)	2.4	4.5
	JAMSRL	1987	0.000669	(0.000646–0.000694)	0.000967	(0.000908–0.001051)	—	—

Port Richey, Pasco County; Daytona Beach and Deltona, Volusia County, indicate a resistance ratio range of 1.7 to 2.5× to malathion at the LC_{50} level and a resistance ratio range of 1.9 to 2.9× at the LC_{90} level when compared to the JAMSRL strain. Only 3 locations, Tallevast, New Port Richey and Naples, had an LC_{90} resistance ratio approaching 3× that of the JAMSRL strain.

DISCUSSION

The increase in tolerance of *Cx. nigripalpus* larvae from different areas of the state to 4 commonly used insecticides can readily be documented for such localities as Gibsonton, Marco Island, Naples, Chapman Road and Tallevast, where populations were sampled from the same localities over a period of several years. Within the past 3 years, populations of *Cx. nigripalpus* from certain localities began showing tolerance. Some counties contained localities which showed tolerance while in other localities, tolerance could not be detrmined because no data was available to compare with the earlier data. *Culex nigripalpus* is considered a nonmigrating species with a dispersal range of 1.5 to 3 km (Nayar 1982). Those localities within a county showing tolerance should not be considered with the localities sampled earlier which showed very

Table 3. Susceptibility of *Culex nigripalpus* larvae against naled from various localities in Florida for indicated years.

County	Locality	Year	Lethal concentration in µg AI/ml (ppm)				Resistance ratio	
			LC_{50}	95% C.L.	LC_{90}	95% C.L.	LC_{50}	LC_{90}
Collier Bay	Naples	1981	0.0416	(0.0404–0.0429)	0.0583	(0.0554–0.0614)	1.1	1.1
	JAMSRL	1981	0.0385	(0.0376–0.0395)	0.0512	(0.0496–0.0528)	—	—
	Naples	1985	0.1402	(0.1239–0.1649)	0.2816	(0.2201–0.4560)	3.0	4.8
	JAMSRL	1985	0.0467	(0.0460–0.0474)	0.0583	(0.0570–0.0598)	—	—
	Naples	1986	0.1135	(0.0991–0.1325)	0.1875	(0.1539–0.2919)	2.8	3.2
	JAMSRL	1986	0.0402	(0.0384–0.0418)	0.0584	(0.0553–0.0630)	—	—
Hillsborough Bay	Gibsonton	1981	0.0528	(0.0512–0.0544)	0.0895	(0.0810–0.0990)	1.4	1.7
	JAMSRL	1981	0.0385	(0.0376–0.0395)	0.0512	(0.0496–0.0528)	—	—
	Gibsonton	1984	0.0722	(0.0659–0.0851)	0.1820	(0.1336–0.3371)	2.0	4.2
	JAMSRL	1984	0.0355	(0.0342–0.0365)	0.0436	(0.0422–0.0455)	—	—
	Gibsonton	1985	0.0730	(0.0663–0.0793)	0.1420	(0.1263–0.1659)	1.7	2.1
	JAMSRL	1985	0.0422	(0.0367–0.0465)	0.0667	(0.0575–0.0980)	—	—
	Gibsonton	1986	0.0902	(0.0866–0.0937)	0.1744	(0.1643–0.1870)	2.4	3.0
	JAMSRL	1986	0.0382	(0.0361–0.0399)	0.0575	(0.0542–0.0623)	—	—
Indian River Bay	Vero Beach	1967	0.0670	(0.0655–0.0698)	0.0800	(0.0761–0.0848)	0.9	0.8
	JAMSRL	1967	0.0756	(0.0677–0.0841)	0.0967	(0.0861–0.1470)	—	—
	Vero Beach	1968	0.0775	(0.0730–0.0830)	0.0946	(0.0875–0.1102)	1.1	1.1
	JAMSRL	1968	0.0680	(0.0611–0.0712)	0.0870	(0.0815–0.1049)	—	—
	Vero Beach	1986	0.1141	(0.1096–0.1188)	0.2398	(0.2214–0.2637)	2.4	3.7
	JAMSRL	1986	0.0467	(0.0421–0.0512)	0.0645	(0.0571–0.0869)	—	—
Manatee Bay	Bradenton	1973	0.0463	(0.0128–0.0805)	0.0815	(0.0577–0.5248)	1.1	1.4
	JAMSRL	1973	0.0419	(0.0409–0.0428)	0.0586	(0.0564–0.0616)	—	—
	Perico Island	1976	0.0593	(0.0580–0.0606)	0.0750	(0.0723–0.0776)	1.1	1.1
	JAMSRL	1976	0.0521	(0.0514–0.0529)	0.0713	(0.0692–0.0736)	—	—
	Chapman Rd	1985	0.1249	(0.1006–0.1624)	0.2568	(0.1863–0.7495)	3.0	3.9
	JAMSRL	1985	0.0422	(0.0367–0.0465)	0.0667	(0.0575–0.0980)	—	—
	Chapman Rd	1986	0.1304	(0.1062–0.1840)	0.2675	(0.1879–0.7472)	3.0	4.8
	JAMSRL	1986	0.0434	(0.0422–0.0446)	0.0558	(0.0538–0.0585)	—	—
	Port Manatee	1986	0.1221	(0.0986–0.1496)	0.2756	(0.2036–0.6168)	2.8	4.9
	JAMSRL	1986	0.0434	(0.0422–0.0446)	0.0558	(0.0538–0.0585)	—	—
	Tallevast	1986	0.1225	(0.1022–0.1556)	0.2100	(0.1628–0.4002)	2.8	3.8
	JAMSRL	1986	0.0434	(0.0422–0.0446)	0.0558	(0.0538–0.0585)	—	—
	Tallevast	1987	0.0847	(0.0805–0.887)	0.1674	(0.1572–0.1801)	1.7	2.4
	JAMSRL	1987	0.0510	(0.0487–0.0536)	0.0685	(0.0631–0.0784)	—	—
Pasco Bay	N.P. Richey	1974	0.0684	(0.0672–0.0696)	0.0911	(0.0878–0.0944)	1.8	1.7
	JAMSRL	1974	0.0371	(0.0362–0.0381)	0.0537	(0.0515–0.0559)	—	—
	N.P. Richey	1985	0.0901	(0.0801–0.1049)	0.2091	(0.1620–0.3286)	2.1	3.1
	JAMSRL	1985	0.0422	(0.0367–0.0465)	0.0667	(0.0575–0.0980)	—	—
Polk Bay	Mulberry	1981	0.0420	(0.0412–0.0427)	0.0627	(0.0603–0.0653)	1.1	1.2
	JAMSRL	1981	0.0385	(0.0376–0.0395)	0.0512	(0.0496–0.0528)	—	—
	Bartow AB	1986	0.0828	(0.0781–0.0871)	0.1467	(0.1387–0.1568)	1.8	2.3
	JAMSRL	1986	0.0467	(0.0421–0.0152)	0.0645	(0.0571–0.0869)	—	—
Volusia Bay	New Smyrna	1966	0.0777	(0.0766–0.0790)	0.0968	(0.0938–0.1008)	1.5	1.4
	JAMSRL	1966	0.0517	(0.0477–0.0548)	0.0690	(0.0649–0.0755)	—	—
	Oak Hill	1975	0.0612	(0.0593–0.0631)	0.0818	(0.0776–0.0863)	1.1	1.1
	JAMSRL	1975	0.0543	(0.0521–0.0567)	0.0726	(0.0663–0.0795)	—	—
	Ponce Inlet	1979	0.0525	(0.0510–0.0540)	0.0707	(0.0663–0.0753)	1.1	1.1
	JAMSRL	1979	0.0487	(0.0470–0.0505)	0.0621	(0.0582–0.0662)	—	—
	Tomoka Marsh	1981	0.0509	(0.0500–0.0519)	0.0740	(0.0711–0.0771)	1.3	1.4
	JAMSRL	1981	0.0385	(0.0376–0.0395)	0.0512	(0.0496–0.0528)	—	—
	Daytona Beach	1987	0.1192	(0.1016–0.1425)	0.2532	(0.1963–0.4127)	2.7	4.3
	JAMSRL	1987	0.0444	(0.0434–0.0453)	0.0595	(0.0576–0.0619)	—	—
	Deltona	1987	0.1005	(0.0964–0.1049)	0.2084	(0.1921–0.2296)	2.2	3.7
	JAMSRL	1987	0.0458	(0.0425–0.0488)	0.0562	(0.0520–0.0654)	—	—

Table 4. Susceptibility of *Culex nigripalpus* larvae against malathion from various localities in Florida for indicated years.

County	Locality	Year	Lethal concentration in µg AI/ml (ppm)				Resistance ratio	
			LC_{50}	95% C.L.	LC_{90}	95% C.L.	LC_{50}	LC_{90}
Collier Bay	Naples	1980	0.0242	(0.0231–0.0253)	0.0452	(0.0422–0.0484)	0.8	1.2
	JAMSRL	1980	0.0312	(0.0306–0.0318)	0.0393	(0.0382–0.0405)	—	—
	Naples	1985	0.0626	(0.0596–0.0658)	0.1188	(0.1090–0.1318)	2.4	3.0
	JAMSRL	1985	0.0258	(0.0183–0.0296)	0.0397	(0.0337–0.0722)	—	—
	Naples	1986	0.0470	(0.0402–0.0546)	0.0737	(0.0617–0.1067)	1.9	1.9
	JAMSRL	1986	0.0242	(0.0191–0.0282)	0.0387	(0.0318–0.0805)	—	—
	Marco Island	1982	0.0330	(0.0322–0.0337)	0.0470	(0.0450–0.0490)	1.1	1.2
	JAMSRL	1982	0.0300	(0.0292–0.0307)	0.0392	(0.0372–0.0410)	—	—
Hillsborough Bay	Gibsonton	1980	0.0242	(0.0237–0.0247)	0.0357	(0.0343–0.0372)	0.8	0.9
	JAMSRL	1980	0.0312	(0.0306–0.0318)	0.0393	(0.0382–0.0405)	—	—
	Gibsonton	1985	0.0461	(0.0414–0.0504)	0.0804	(0.0715–0.0948)	1.7	2.2
	JAMSRL	1985	0.0276	(0.0271–0.0280)	0.0371	(0.0362–0.0381)	—	—
	Gibsonton	1986	0.0375	(0.0284–0.0448)	0.0764	(0.0621–0.0112)	1.5	2.0
	JAMSRL	1986	0.0242	(0.0191–0.0282)	0.0387	(0.0318–0.0805)	—	—
Indian River Bay	Vero Beach	1967	0.0376	(0.0339–0.0424)	0.0508	(0.0445–0.0675)	1.3	1.1
	JAMSRL	1967	0.0300	(0.0269–0.0337)	0.0450	(0.0389–0.0572)	—	—
	Vero Beach	1968	0.0380	(0.0318–0.0442)	0.0540	(0.0436–0.0822)	1.4	1.5
	JAMSRL	1968	0.0267	(0.0263–0.0271)	0.0353	(0.0345–0.0362)	—	—
	Vero Beach	1987	0.0580	(0.0536–0.0636)	0.0921	(0.0807–0.1124)	2.4	2.7
	JAMSRL	1987	0.0243	(0.0203–0.0280)	0.0337	(0.0290–0.0554)	—	—
Manatee Bay	Bradenton	1973	0.0413	(0.0369–0.0456)	0.0739	(0.0638–0.0927)	1.3	1.7
	JAMSRL	1973	0.0315	(0.0301–0.0329)	0.0447	(0.0418–0.0491)	—	—
	Perico Island	1976	0.0451	(0.0436–0.0466)	0.0670	(0.0631–0.0712)	1.3	1.4
	JAMSRL	1976	0.0340	(0.0333–0.0346)	0.0485	(0.0466–0.0504)	—	—
	Chapman Road	1985	0.0459	(0.0442–0.0476)	0.0856	(0.0815–0.0905)	1.7	2.3
	JAMSRL	1985	0.0276	(0.0271–0.0280)	0.0371	(0.0362–0.0381)	—	—
	Port Manatee	1986	0.0511	(0.0477–0.0551)	0.0841	(0.0752–0.0981)	2.0	2.5
	JAMSRL	1986	0.0260	(0.0230–0.0282)	0.0342	(0.0310–0.0434)	—	—
	Tallevast	1986	0.0462	(0.0401–0.0523)	0.0715	(0.0619–0.0918)	1.8	2.1
	JAMSRL	1986	0.0260	(0.0230–0.0282)	0.0342	(0.0310–0.0434)	—	—
	Tallevast	1987	0.0545	(0.0529–0.0563)	0.0822	(0.0799–0.0875)	2.5	2.9
	JAMSRL	1987	0.0217	(0.0196–0.0230)	0.0285	(0.0209–0.0333)	—	—
Pasco Bay	N. Pt. Richey	1974	0.0330	(0.0320–0.0340)	0.0550	(0.0530–0.0570)	1.4	1.2
	JAMSRL	1974	0.0230	(0.0220–0.0240)	0.0470	(0.0450–0.0490)	—	—
	N. Pt. Richey	1985	0.0608	(0.0526–0.0693)	0.1035	(0.0876–0.0138)	2.2	2.8
	JAMSRL	1985	0.0276	(0.0271–0.0280)	0.0371	(0.0362–0.0381)	—	—
Volusia Bay	Daytona Beach	1967	0.0349	(0.0322–0.0368)	0.0445	(0.0414–0.0498)	1.1	1.0
	JAMSRL	1967	0.0304	(0.0269–0.0337)	0.0443	(0.0389–0.0572)	—	—
	Oak Hill	1975	0.0482	(0.0470–0.0494)	0.0719	(0.0684–0.0758)	1.7	1.5
	JAMSRL	1975	0.0288	(0.0280–0.0297)	0.0471	(0.0436–0.0509)	—	—
	Ponce Inlet	1979	0.0282	(0.0273–0.0292)	0.0481	(0.0458–0.0506)	1.1	1.3
	JAMSRL	1979	0.0264	(0.0253–0.0275)	0.0381	(0.0359–0.0404)	—	—
	Deltona	1987	0.0389	(0.0376–0.0402)	0.0619	(0.0591–0.0656)	1.7	2.1
	JAMSRL	1987	0.0228	(0.0216–0.0239)	0.0290	(0.0273–0.0316)	—	—
	Daytona Beach	1987	0.0532	(0.0481–0.0583)	0.0864	(0.0763–0.1053)	1.7	1.7
	JAMSRL	1987	0.0321	(0.0284–0.0414)	0.0506	(0.0399–0.1152)	—	—

little tolerance, because, in most cases, collections were made more than 3 km from the tolerant population. The increase in tolerance of all 4 insecticides appears to have started prior to 1984 with fenthion exhibiting the highest degree, followed by temephos, naled and malathion. Although fewer areas were sampled for fenthion before 1984 than after 1984, those sampled before 1984 were almost as susceptible as the JAMSRL strain. Although used since 1979, there was no tolerance to fenthion until after the widespread use of temephos in 1984 (W. R. Opp, personal communication).

Since cross resistance between fenthion and temephos has been shown with *Aedes nigromaculis* (Ludlow) in California (Gillies et al 1968), it is possible that the use of temephos could have contributed to fenthion tolerance in *Cx. nigripalpus*. In view of the data presented here and the fact that malathion has been the most widely used adulticide in Florida, it appears that its continued use for the control of *Cx. nigripalpus* should be continued since the compound exhibited the least tolerance of all insecticides tested, while the use of fenthion and temephos should be curtailed. The future monitoring of certain localities should be accomplished to ascertain whether tolerances are increasing.

The increased use of agricultural insecticides has been associated with the development of resistance in mosquito populations worldwide (Georghiou 1982). We concur with this and also suggest that exposure to pesticide runoff from lawns, golf courses, agricultural areas and other urban sites may play a role in developing resistance in mosquito populations in Florida.

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REFERENCES CITED

Bellamy, R. E. and W. C. Reeves. 1952. A portable mosquito bait-trap. Mosq. News 12:256–258.

Boike, A. H., Jr. and C. B. Rathburn, Jr. 1968. Tests of the susceptibility of Florida mosquitoes to insecticides, 1967. Mosq. News 28:313–316.

Boike, A. H., Jr. and C. B. Rathburn, Jr. 1969. Laboratory tests of the susceptibility of mosquito larvae to insecticides in Florida, 1968. Mosq. News 29:392–395.

Boike, A. H., Jr and C. B. Rathburn, Jr. 1972. The susceptibility of mosquito larvae to insecticides in Florida, 1969–1971. Mosq. News 32:328–331.

Boike, A. H Jr. and C. B. Rathburn, Jr. 1975. Laboratory susceptibility tests of some Florida strains of *Aedes taeniorhynchus* (Wied.) and *Culex nigripalpus* Theob. to malathion and naled, 1972–1974. Mosq. News 35:137–140.

Boike, A. H. Jr., C. B. Rathburn, Jr., T. G. Floore, K. L. Lang and H. M. Masters. 1985. Current status on the Florida Abate monitoring program-susceptibility levels of three species of mosquitoes during 1984. J. Am. Mosq. Control Assoc. 1:498–501.

Boike, A. H. Jr., C. B. Rathburn, Jr., C. F. Hallmon and S. G. Cotterman. 1978. Insecticide susceptibility tests of *Aedes taeniorhynchus* and *Culex nigripalpus* in Florida, 1974–1976. Mosq. News 38:210–217.

Boike, A. H. Jr., C. B. Rathburn, Jr., C. F. Hallmon and S. G. Cotterman. 1979. Insecticide susceptibility levels of some Florida mosquitoes for 1977–1978. Journal of the Florida Anti-Mosquito Association 50:62–67.

Boike, A. H. Jr., C. B. Rathburn, Jr., C. F. Hallmon and R. L. Wells. 1980. Monitoring for resistance in mosquitoes from several selected areas in Florida for 1979. Journal of the Florida Anti-Mosquito Association 51:48–51.

Boike, A. H. Jr., C. B. Rathburn, Jr., L. A. Sizemore and M. W. Peters. 1982. Results of the Florida program for monitoring mosquito susceptibility to temephos, 1980–1982. Journal of the Florida Anti-Mosquito Association 53:84–92.

Brown, A. W. A. 1986. Insecticide resistance in mosquitoes: a pragmatic review. J. Am. Mosq. Control Assoc. 2:123–140.

Brown, A. W. A. and R. Pal. 1971. Insecticide resistance in arthropods. 2nd ed. WHO Monogr. Ser. 38, 791 pp.

Florida State Board of Health. 1963. Tampa Bay area arbovirus investigations 1959–1961. Florida State Board of Health, Jacksonville, FL. Monogr. No. 5, 79 p.

Florida State Board of Health. 1969. St. Louis Encephalitis in Florida. Florida State Board of Health, Jacksonville, FL. Monogr. 12, 125 p.

Georghiou, G. P. 1982. The implication of agricultural insecticides in the development of resistance by mosquitoes with emphasis on Central America, pp. 95–121. *In:* Resistance to insecticides used in public health and agriculture. Proceedings of an international workshop held at the Sri Lanka Foundation Institute, Colombo, Sri Lanka; National Science Council of Sri Lanka (1982) Univ. of California, Riverside.

Gillies, P. A., D. J. Womeldorf and K. E. White. 1968. Cross-tolerance of California *Aedes nigromaculis* (Ludlow) larvae to EPN, Abate, and Dursban. Proc. Calif. Mosq. Vector Control Assoc. 36:85.

Nayar, J. K. 1982. Bionomics and physiology of *Culex nigripalpus* (Diptera: Culicidae) of Florida: an important vector of diseases. pp. 33–34. *In:* IFAS Bul 827, University of Florida, FL.

Nelson, D. B., K. D. Kappus, H. T. Janowski, E. Buff, F. M. Wellings and N. J. Schneider. 1983. St. Louis encephalitis—Florida, 1977. Patterns of a widespread outbreak. Am. J. Trop. Med. Hyg. 32:412–416.

Newhouse, V. F., R. W. Chamberlain, J. B. Johnston and W. D. Sudia. 1966. Use of dry ice to increase mosquito catches of the CDC miniature light trap. Mosq. News 26:126–129.

Rathburn, C. B., Jr. and A. H. Boike, Jr. 1967. Studies of insecticide resistance in Florida mosquitoes. Mosq. News 27:377–382.

Rathburn, C. B., Jr. and A. H. Boike, Jr. 1969. A study of factors affecting the susceptibility of mosquito larvae to insecticides in laboratory resistance tests. Mosq. News 29:395–401.

Rogers, A. J. and C. B. Rathburn, Jr. 1964. Present status of insecticides for mosquito control in Florida. Mosq. News 24:286–291.

Thompson, M. A. 1986. Insecticide susceptibility of mosquitoes in California: status of oraganophosphorus resistance in larval *Culex tarsalis* through 1985. Proc. Calif. Mosq. Vector Control Assoc. 54:60–63.

1989 Brown, J. R., R. O. Melson, and G. E. Tetreault. United States Navy Pesticide Aerial Unit
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1411

United States Navy Pesticide Aerial Unit[1]

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ABSTRACT

A detailed description of a rotary head modification to the US Navy's Pesticide Aerial Unit Dash Nine is provided. Droplet analysis and bioassay results from a 1988 field test are also discussed. The modified aerial unit meets label specifications for both Malathion 91% and Dibrom 14 and performs to US Navy Air Systems Command engineering standards.

INTRODUCTION

Chemical insecticides appear to be the most efficient means for controlling large populations of mosquitoes and aircraft, rotary or fixed-wing, are the most effective tools by which insecticides are applied (Akesson and Gates 1982). Essentially all ground and air insecticide delivery efforts in the U.S. mosquito control industry for the past two decades have been directed towards ultra-low volume methods (ULV). During this time the United States Navy Disease Vector Ecology and Control Center (USN DVECC), Naval Air Station, Jacksonville, Florida, has focused its efforts on routine, disaster relief, and combat insect control applications for DVECC'S mission of supporting the Fleet Marine Force.

The Pesticide Aerial Unit Dash Nine (PAU-9) maintained at USN DVECC, was developed in the late 1960's at the Jacksonville, FL, facility and described by Hayden et al. (1973). That system utilized 10 TeeJet nozzles (8001 and 8002) in a configuration common to all rotary or fixed wing aircraft with a boom support system. In the decade following development of the PAU-9 system, the malathion label also underwent modifications. One of the requirements included the use of a "Rotary nozzle equipment similiar to the Beecomist Spray Head Assembly Model No. 350. . . ." Given that label requirement, the USN DVECC staff modified the PAU-9 system to support a rotary head system.

It is the purpose of this study to provide a detailed description of the rotary head modified Navy PAU-9 dispersal system and to provide results of an operational test performed at the Florida Army National Guard's Camp Blanding, Starke, FL facility during July 1988. This study is an interim report as modifications to the PAU-9 are an ongoing process.

METHODS AND MATERIALS

A US Navy PAU-9 was modified by installing an electrically powered Beecomist rotary nozzle Model 360 (Beecomist Products Company, Ft. Washington, PA 19034) on a 3.8 cm aluminum boom and outboard 222.6 cm. A 0.5 HP electric motor (Beeco Products Company) was used to drive a Zero-Max transmission model E-1 (Zero-Max, Minneapolis, MN 55408-2291) which in turn drove an Oberdofer model 2146 SS pump (Oberdofer Pump Division, Syracuse, NY 13221). The range of insecticide delivery was 0-2 gpm.

A field test of the above modifications was conducted at Camp Blanding, Florida during June, 1988. Three to six day old *Aedes aegypti* (L.) were provided by the Insects Affecting Man and Animals Laboratory, USDA-ARS, Gainesville, Florida 32604. Mosquitoes were immobilized with CO_2 and placed in #18 wire mesh cages (5x7.8 cm) for exposure to the insecticide treatment. Cages were hung from 1.3 m stands and placed in a row 15.2, 30.5, 45.7,

[1]The opinons and assertions contained herein are those of the authors and are not to be construed as official or reflecting the views of the Navy Department or the Naval Service at large.

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60.9, 76.2, and 91.4 m perpendicular to the flight path. The test was replicated 6 times. After exposure, cages were placed in trays and held in an air conditioned vehicle for the return trip to USN DVECC, Jax, FL. A cotton pad moistened with 10% sugar water solution was placed on each cage before returning to the laboratory. The experimental design called for cages to be changed in the laboratory and mortality readings taken at 2 and 24 hours after insecticide exposure. However, 100% mortality occurred within 2 hours in all bioassay cages except 1 (85%). That one cage was changed and the mortality reading taken at 24 hours (100%).

Bioassays were conducted using 1 fl oz per acre of Dibrom 14 (Chevron Chemical Company, San Francisco, CA 94104) and 3 fl oz of Malathion 91% (American Cyanamid Company, Wayne, NJ 07470). Initial calibrations were made using a 91.4 m swath width. Applications were made with an HD-1 helicopter (FLANG 1st BN 111th AV) equiped ith the modified PAU-9. The helicopter flight path was 50 m upwind and perpendicular to the forward line of mosquito cage stands at 15.2, 30.5, and 45.7 m above ground level and 70 kts delivery speed. Wind speed ranged 0-3 kts during the tests.

The first of two controls (#1) was held in the laboratory at USN DVECC. The second control (#2) was held in an air conditioned vehicle at the test site and upwind from the point of insecticide release. Both

Table 1. Droplet analysis (mmd in microns and range) for the USN pesticide aerial unit (PAU-9, rotary nozzle) utilizing Malathion 91 and Dibrom 14.[1]

Impinger distance (m)	Insectidide	Height of aircraft above ground level (m)		
		15.2	30.5	45.7
15.2	Malathion	26.7 (4.7-63.5)	27.1 (4.7-56.4)	0[2]
	Dibrom	10.6 (2.1-27.6)	0	0
30.5	Malathion	28.7 (7.1-68.2)	26.4 (2.4-56.4)	0
	Dibrom	13.9 (4.7-32.9)	0 (2.1-27.6)	12.7
45.7	Malathion	28.4 (4.7-70.5)	17.3 0 (4.7-23.5)	0
	Dibrom	10.7 (4.2-25.4)	12.1 (2.1-33.9)	9.2 (2.1-25.4)
60.9	Malathion	24.9 (4.7-58.8)	27.3 (2.4-54.1)	33.0 (4.7-68.2)
	Dibrom	0	12.6 (2.1 29.7)	10.9 (2.1-23.3)
76.2	Malathion	24.8 (2.4-58.8)	28.5 (2.4-63.5)	25.9 (2.4-56.4)
	Dibrom	18.7 (4.2-27.6)	11.1 (2.1-27.6)	11.4 (2.1-27.6)
91.4	Malathion	28.9 (4.7-58.8)	24.9 (2.4-58.8)	28.8 (2.4-56.4)
	Dibrom	0	13.6	11.4
121.9	Malathion	24.6 (7.1-51.7)	28.1 (2.4-58.8)	26.1 (2.4-65.8)
	Dibrom	0	11.8 (2.1-29.7)	13.4 (2.1-29.7)
152.4	Malathion	30.3 (2.4-51.7)	33.9 (2.4-63.5)	28.8 (2.4-65.8)
	Dibrom	0	0	8.4 (2.1-19.1)

[1]Means of six replications.

[2]Helicopter altitude and erratic wind conditions (0-3 kts) carried droplets beyond or over some impingers

controls were handled in the same manner except for exposure to the insecticide.

A droplet analysis was performed with each bioassay. Droplet samples were collected on Teflon coated slides by impaction with an impinger (Carroll and Bourg 1979). Impingers and slides were placed at 15.2, 30.5, 45.7, 60.9, 76.2, 91.4, 121.9, and 152.4 m downwind and perpendicular to the flight path. The droplet analysis was calculated utilizing VECTEC Particle Analysis Program (VECTEC, Orlando, FL 32807).

RESULTS AND DISCUSSION

Droplet analysis results of the 1988 field trial using the rotary nozzle are shown in Table 1. Results from the unmodified PAU-9 utilizing 8001 and 8002 flat fan nozzles are included in Table 2 (modified from Hayden et al. 1973). Mass median diameters generated by the rotary head modification were within label specifications (≤50 microns) for Malathion (Table 1) ranging from 17.3 microns at an impinger distance of 45.7 m and a helicopter altitude of 30.5 m to 33.9 microns at an impinger distance of 152.4 m and 30.5 m in helicopter altitude.

100% mortality occurred within 2 hours in all bioassay cages except 1 (85%). 100% mortality occurred in that one cage within 24 hrs. 0% mortality occurred in the field control at 24 hrs. 10% mortality occurred in the laboratory control within 24 hrs.

Mass median diameters generated by the rotary head modification were generally smaller than the label specifications for Dibrom 14 (30-80 microns) ranging from 8.4 microns at an impinger distance of 152.4 m and a flight altitude of 45.7 m to 13.9 microns at an impinger distance of 30.5 m and an altitude of 15.2 m (Table 1). No droplets were observed which exceeded the maximum size specified on the insecticide label. 67% mortality occurred within 2 hrs averaged over all bioassay cages. 100 % mortality occurred in all cages in 24 hours.

No significant defects were noted in any of the system components during operations. MMD's generated by both systems met label specifications for Malathion. The rotary head met label specifications for Dibrom. Additional swath and droplet testing is planned for both systems. Operating parameters (flow rate, droplet size, air speed, and altitude) and insecticides utilized will be periodically evaluated. In operations with the FLANG and using the HD-1 helicopters the unit has conformed to US Navy Air Systems Command engineering standards and no adverse flight characteristics were reported by pilots involved. As determined by bioassay cages, the mosquito test population was reduced 100% within 24 hrs using the rotary head modification dispersing Malathion and Dibrom at the recommended rates.

REFERENCES CITED

Akesson, N. B. and W. E. Gates. 1982. The use of aircraft for mosquito control. Am. Mosq. Control Bull. 1:92 p.

Carroll, M. K. and J. A. Bourg. 1979. Methods of ULV droplet sampling and analysis effects on size and spectrum of the droplets collected. Mosquito News 39:645-655.

Hayden, D. L., J. A. Mulrennan, W. V. Weeks, and F. M. Ulmer. 1973. Ultra low volume dispersal equipment for military helicopters. Mosquito News 33:387-391.

Table 2. Droplet analysis for the unmodified US Navy pesticide aerial unit (pau-9)[1,2]

Aircraft	Number of nozzles and tip type	Mass median diameter	Frequency median diameter	Range of particle sizes
H-1	5-8002 and 5-8001 flat fan	48	28	12-69
H-1	4-8002 and 6-8001 flat fan	47	23	5-75

[1]Modified from Hayden et al. (1973)
[2]Aircraft speed 65 kts, altitude 50 ft. Malathion 91, flow rate 1.3 gpm. Measurements were made directly under the line of flight.

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Susceptibility of Female Aedes Albopictus from Texas to Commonly Used Adulticides
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1409

OPERATIONAL AND SCIENTIFIC NOTES

SUSPECTIBILITY OF FEMALE *AEDES ALBOPICTUS* FROM TEXAS TO COMMONLY USED ADULTICIDES[1]

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Since the discovery of an established population of *Aedes albopictus* (Skuse) in Houston, TX, in August 1985 (Sprenger and Wuithiranyagool 1986), there have arisen a number of important questions about this exotic mosquito species. Mosquito control practitioners and public health officials along the Texas Gulf coast are particularly concerned about the susceptibility of *Ae. albopictus* to currently labeled insecticides and the virtual lack of insecticide susceptibility data involving this recently introduced species. These concerns have been intensified by a newspaper report indicating that this species is resistant to common insecticides such as malathion (Falda 1986), the most commonly used mosquito adulticide in Texas. The Centers for Disease Control (1986) and the Pan American Health Organization (1987) have indicated that repetitive monitoring of *Ae. albopictus* populations susceptibility to insecticides is essential.

Data that are currently available involving *Ae. albopictus* susceptibility to insecticides are almost exclusively Asian in origin (World Health Organization 1986). Since the exact origin and insecticide exposure history of *Ae. albopictus* populations introduced into the United States is unknown, it is impossible to use insecticide susceptibility data from particular Asian localities. Most mosquito susceptibility research in Asia has involved the larval stage (Herbert and Perkins 1973, Takahashi et al. 1985). Various Asian populations of *Ae. albopictus* larvae have been shown to be resistant to a wide variety of insecticides (World Health Organization 1986). In contrast, populations from other Asian areas are susceptible to cyclodienes (Herbert and Perkins 1973) and organophosphates (Gould et al. 1971).

Despite the numerous reports of resistance, control of adult *Ae. albopictus* with insecticides has proven effective on several occasions. Gould et al. (1971) reported short-term control of this species in villages in an insular region of Thailand, using ground applied malathion fogs. During outbreaks of dengue in China, this species was effectively controlled with ULV applications of malathion (0.45 liter/ha) and fenitrothion (0.30–0.45 liter/ha) (Luh and Zhu 1983). *Aedes albopictus* and *Ae. aegypti* (Linn.) populations were substantially reduced in urban areas of Malaysia when a mixture of pyrethrins (1.2 gm/ha) and a synergist (1.9 gm/ha) were applied from the ground using a Leco HD ULV cold aerosol generator (Pant 1983).

Preliminary data from Houston and New Orleans indicate that adult *Ae. albopictus* populations in these areas are relatively resistant to malathion. However, they are susceptible to resmethrin (Centers for Disease Control 1986, Khoo et al. 1988).

This study was undertaken to further clarify the degree of susceptibility of Texas adult *Ae. albopictus* populations to 4 currently labeled insecticides: bendiocarb, malathion, naled and resmethrin. Two Texas *Ae. albopictus* populations were used in the study, one collected from Houston and the other from Liberty County. Sufficient eggs of the Houston population were collected in the field so that the adults developing from these eggs were used in the susceptibility tests. Few eggs of the Liberty County population were collected; subsequently, this population was reared in the laboratory through 4 generations in order to obtain sufficient numbers of adult females.

The mosquito susceptibility values for *Ae. albopictus* were compared with 2 laboratory strains of *Ae. aegypti*: the UTMB strain, in colony for ca. 25 years, obtained from D. W. Micks, University of Texas Medical Branch, Galveston, TX, and the TAMU strain, which has been in colony for ca. 12 years at Texas A&M University. The 2 strains of *Ae. aegypti* were chosen because they represent long-established, insecticide-susceptible laboratory colonies. In addition, this species may also be a target for control in the case of a vector-borne disease outbreak.

All mosquitoes were reared using techniques developed at the TAMU Mosquito Research Laboratory for maintenance of *Aedes* (*Stego-*

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myia) species. Mosquito susceptibility tests were conducted using 3–4-day-old females. A vial bioassay procedure modified from Plapp (1971) was used to test mosquito susceptibility. Each technical grade insecticide was serially diluted to the appropriate concentration using acetone. Insecticides were pipetted into 20-ml glass vials (6 replicates/concentration), then acetone was added to attain a final volume of 0.5 ml. Control vials were treated with 0.5 ml of acetone only. All vials were manually rotated on their side until the solvent evaporated. A small cotton pad (ca. 0.75 cm^2) soaked with 10% sucrose solution was placed in the bottom of each vial. Mosquitoes were lightly anesthetized with carbon dioxide and placed on a chill table for counting. Ten females were placed in each vial, and the vials were plugged with cotton. Mortality was recorded after 24 hours.

The data were analyzed using the SAS Probit Program (SAS 1985). The analyses yielded LC_{50}, LC_{95} and 95% confidence interval values in micrograms of insecticide per vial. Slope (a measure of the homogeneity of the population response to each insecticide) was also provided.

There were no significant differences in insecticide susceptibility when comparing strains of the same species; however, there were significant differences between the 2 species. The 4 mosquito strains did not significantly differ in their susceptibility to bendiocarb and resmethrin and are therefore considered susceptible to these chemicals. The 2 *Ae. albopictus* strains were significantly different ($P < 0.05$, nonoverlapping 95% confidence limits) from the 2 *Ae. aegypti* strains in their response to naled at the LC_{95} level.

The 2 strains of each species did not significantly differ in their response to malathion; however, there was a significant difference in susceptibility between the 2 species. The responses of the 2 field strains of *Ae. albopictus* were significantly different ($P < 0.05$) compared to the responses of the *Ae. aegypti* strains (Table 1). As is indicated by the slopes of the dose/mortality lines and LC_{95}, the difference in insecticide susceptibility between the 2 species became greater as the insecticidal concentration increased.

The malathion resistance observed in the Houston and Liberty strains of *Ae. albopictus* used in this study is consistent with that previously reported for the Houston and New Orleans populations of this species (Centers for Disease Control 1986, Khoo et al. 1988). *Aedes albopictus* resistance to malathion and other insecticides has been extensively reported in Asia (Herbert and Perkins 1973, World Health Organization 1986). Adult *Ae. albopictus* populations were found to be partially resistant to malathion in Thailand (Gould et al. 1971) and resistant to organophosphates and carbamates in Sri Lanka (World Health Organization 1986).

Table 1. Insecticide susceptibility of adult females of 2 wild Texas strains of *Aedes albopictus* and 2 laboratory strains of *Aedes aegypti* to 4 commonly used adulticides using a vial bioassay procedure. Lethal concentration (LC) values are reported as micrograms of insecticide per vial.

Species	LC_{50} (μg/vial)	LC_{95} (μg/vial)	Slope
	BENDIOCARB		
Ae. albopictus (Houston)	0.05	0.14	3.5
Ae. albopictus (Liberty)	0.09	0.17	5.1
Ae. aegypti (TAMU)	0.04	0.11	3.6
Ae. aegypti (UTMB)	0.03	0.06	5.0
	MALATHION		
Ae. albopictus (Houston)	0.15	4.65	1.1
Ae. albopictus (Liberty)	0.13	1.61	1.4
Ae. aegypti (TAMU)	0.05	0.16	2.8
Ae. aegypti (UTMB)	0.05	0.14	3.1
	NALED		
Ae. albopictus (Houston)	0.07	0.35	1.9
Ae. albopictus (Liberty)	0.05	0.13	2.8
Ae. aegypti (TAMU)	0.04	0.07	4.0
Ae. aegypti (UTMB)	0.02	0.04	4.0
	RESMETHRIN		
Ae. albopictus (Houston)	0.03	0.12	2.5
Ae. albopictus (Liberty)	0.04	0.13	2.5
Ae. aegypti (TAMU)	0.02	0.04	3.5
Ae. aegypti (UTMB)	0.02	0.07	3.3

As for the current situation in Texas, malathion resistance may be a problem in the event of a disease outbreak for 2 reasons: 1) malathion is the most widely used adulticide along the Gulf coast and mosquito control practitioners may be reluctant to use alternative chemicals, and 2) to break the cycle of transmission during a disease outbreak, a high percentage of vector mortality is required and resistance seems to be a greater problem at higher lethal concentrations.

It should be stressed that the data presented here are from the laboratory and may not reflect the ability to control this species in the field. Although insecticide resistance has been shown in various Asian *Ae. albopictus* populations, excellent adult control has been obtained during disease outbreaks using pyrethrins (Pant 1983), malathion (Gould et al. 1971) and fenitrothion (Luh and Zhu 1983). There is a need for mosquito susceptibility tests to be performed on both larval and adult *Ae. albopictus* populations from around the United States. This will enable mosquito control practitioners and public health officials to choose the most effective control agents and practices.

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REFERENCES CITED

Centers for Disease Control. 1986. *Aedes albopictus* infestation in the United States: background, public health implications, and action plans. Informational Letter, July 1986, 6 pp.

Falda, W. 1986. Asian mosquitoes putting old tires to new use. South Bend Tribune, September 18.

Gould, D. J., G. A. Mount, J. E. Scanlon, M. F. Sullivan and P. E. Winter. 1971. Dengue control on an island in the Gulf of Thailand. I. Results of an *Aedes aegypti* control program. Am. J. Trop. Med. Hyg. 20:705–714.

Herbert, E. W. and P. V. Perkins. 1973. Comparative tests of five insecticides against *Aedes albopictus* larvae from South Vietnam. Mosq. News 33:76–78.

Khoo, B. K., D. V. Sutherland, D. Sprenger, D. Dickerson and H. Nguyen. 1988. Susceptibility status of *Aedes albopictus* to three topically applied adulticides. J. Am. Mosq. Control Assoc. 4:310–313.

Luh, P. and C. Zhu. 1983. Mosquito control in the People's Republic of China, pp. 85–103. *In*: M. Laird and J. Miles (eds.), Integrated mosquito control methodologies, Vol. 1. Academic Press, New York.

Pan American Health Organization. 1987. Control of *Aedes albopictus* in the Americas. PAHO Bull. 21:314–324.

Pant, C. P. 1983. Space sprays used in mosquito vector control, pp. 37–48. *In*: M. Laird and J. Miles (eds.), Integrated mosquito control methodologies, Vol. 1. Academic Press, New York.

Plapp, F. W., Jr. 1971. Insecticide resistance in *Heliothis*: Tolerance in larvae of *H. virescens* as compared with *H. zea* to organophosphate insecticides. J. Econ. Entomol. 64:999–1002.

SAS Institute, Inc. 1985. SAS user's guide statistics, Version 5 Edition. SAS Institute, Inc., Cary, NC. 956 pp.

Sprenger, D. and T. Wuithiranyagool. 1986. The discovery and distribution of *Aedes albopictus* in Harris County, Texas. J. Am. Mosq. Control Assoc. 2:217–219.

Takahashi, M., C. Shudo, Y. Wada and T. Ito. 1985. Insecticide susceptibility in *Aedes albopictus*. Jpn. J. Sanit. Zool. 36: 251–254. (In Japanese.)

World Health Organization. 1986. Resistance of vectors and reservoirs of disease to pesticides. 10th Report of the Expert Committee on Vector Biology and Control. W.H.O. Tech. Rep. Ser. 737, 87 pp.

1988 Curtis, G. A., and J. Mason
Evaluation of Equipment Modifications and Dosage Rates of Ground ULV Applications of Naled Against Aedes Taehniorhynchus in a Florida Citrus Grove
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EVALUATION OF EQUIPMENT MODIFICATIONS AND DOSAGE RATES OF GROUND ULV APPLICATIONS OF NALED AGAINST *AEDES TAENIORHYNCHUS* IN A FLORIDA CITRUS GROVE

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ABSTRACT. Efficiency of ground-applied naled (Dibrom 14), based on caged mosquito bioassays in a moderately vegetated coastal southeastern Florida citrus grove, proved to be significantly associated with downwind distance. However, association analysis between wind speed, temperature or relative humidity revealed no correlation between these meteorological factors and mosquito mortality. Tests conducted with 3 of the commonly used ULV machines demonstrated no significant differences in efficiency. Equipment modifications to simulate aerial application by elevating the spray release point proved ineffective. Increasing the dosage of naled to 3 times the labeled rate for ground treatment resulted in greater than 95% mortality.

INTRODUCTION

Ground ultra low volume (ULV) application of insecticides for adult mosquito control has become the standard of the industry since its introduction by Mount et al. (1968). This method, used by virtually all mosquito control agencies to some extent, is generally considered by the public to be "mosquito control" due to its high visibility. Reluctantly however, it is considered the least effective of the various control methods commonly employed in a progressive mosquito control operation. Operational programs are constantly faced with the erratic results of ground ULV with retreatments to suppress adult mosquito populations being considered the norm. This unpredictability often appears to be most evident when the habitat to be treated is heavily vegetated (Taylor and Schoof 1971), a common condition around salt marshes and agriculturally cultivated locations in coastal southeastern Florida. These areas pose particular problems in that they are prolific producers of mosquitoes, principally floodwater *Aedes* species.

In addition to vegetation, meteorological conditions (e.g., wind speed, wind direction, humidity and temperature) have also been implicated as contributing factors influencing the efficiency of ground ULV treatments (Henderson et al. 1985).

In 1985, we conducted a series of ground ULV tests to identify and quantify some of the important meteorological and physical conditions associated with insecticide induced mosquito mortality in moderate to heavy vegetation. These tests were designed to evaluate the comparative effectiveness of several equipment and technique modifications on the successful insecticide penetration in moderately vegetated areas. Experiments were conducted during what we felt were normal operational situations, those in which spray trucks are commonly deployed for adult mosquito control. The tests were sufficiently replicated to make statistically accurate evaluations of the various parameters believed to influence ULV treatments. This paper is a report on the findings of that investigation.

MATERIALS AND METHODS

Study area. All field tests were conducted in a mature 120 acre (48.6 ha) coastal citrus grove ca 10 miles (16.1 km) north of Vero Beach, Florida, typical to others along coastal southeastern Florida (Curtis 1985). This habitat was selected because it represented the moderate to heavily vegetated areas that are commonly treated. Citrus groves comprise some 65,000 acres of Indian River County.

Test procedures. Three to six day old laboratory reared flamingo strain *Aedes taeniorhynchus* (Wiedemann) females were caged (25/cage) in modified WHO cages (Haile et al. 1982). Prior to testing, caged mosquitoes were placed in styrofoam ice chests and provided 10% sucrose. Immediately following insecticide exposure, mosquitoes were mechanically transferred to clean plastic holding cages where the sucrose solution was also available. Additionally, control cages were identically handled but not exposed to the insecticide. These control mosquitoes were used for mortality adjustment. If control mosquitoes exhibited greater than 10% mortality in any test, that particular test was discarded from the data set. Mosquito mortality was assessed 12 hr. posttreatment. Generally, 4 separate tests were conducted nightly with weather conditions usually being the determining factor.

The test plot consisted of 2 parallel transects 50 ft (15.2 m) apart. Mosquito cages were hung at the top of 4 ft (1.2 m) polyvinylchloride stakes spaced at 100 ft (30.5 m) intervals from the application point to 500 ft (152.4 m). Both sets of cages were positioned in the mid-section of the test site. This allowed the spray truck to make a 0.25 mi (0.46 km) pass by the test cages which was sufficient to allow insecticidal drift to the most distant cages even with quartering wind directions. Perimeter roads permitted ground treatments under all wind directions so that insecticidal applications were made nearly perpendicular to the test plot and wind direction.

Meteorological data collection. Meteorological data was collected at 1 sec intervals and stored with a recording anemometer (Weather Measure #2010) and recording wind vane (Weather Measure #2005) coupled to a portable IBM PC computer. This data was later analyzed in concert with the mosquito mortality information. Relative humidity was measured at the start of each test and entered into the data storage program. Temperature was measured at 4 and 25 ft (1.2 and 7.6 m) heights for detection of temperature inversions.

Experimental procedures. Tests were divided into 3 groups: 1) standard dosage for base line comparisons, 2) modified equipment, and 3) high dosage tests. Baseline tests were conducted for each of the standard machine configurations using the labeled dosage rate before any modifications were attempted. The 3 machines, LECO, London Aire and Curtis-Dyna, were all standard machines with only a variable insecticide flow rate system added, which accurately delivered the proper dosage with changing vehicle speed. Vehicle speed in all tests was approximately 10 mph. Comparisons among the standard machines was primarily to demonstrate that there were no initial biases. The modifications are as follows: 1) The London Aire was adapted to a Buffalo Turbine with the nozzle injected into the upward air flow of the Buffalo Turbine. Tests using this modification were conducted in two phases, the first using only the London Aire ULV machine with the turbine inoperative. This was to verify that the equipment modification had not changed the performance of the ULV machine. 1b) The London Aire ULV was operated with the turbine functioning. 2) The output of the Curtis-Dyna was elevated using manufacturer supplied extension tubes from 4 ft to 13.5 ft (approximately that of the tree canopy). In the tests involving the Buffalo Turbine, the turbine was directed upwards allowing the prevailing wind to disperse the propelled insecticide droplets into the test plot. Both of the modifications were with the intent of simulating an aerial application from the ground. It was hypothesized that with both modifications, descending droplets would be able to drift greater distances not having to penetrate the citrus vegetation.

Calibration and dosage. Prior to each test all ULV machines were calibrated to insure proper insecticide output. Droplet analysis (Beidler 1974) was conducted on all 3 machines to assure that they all functioned similarly. Naled (Dibrom 14) was applied at 3.6 fluid oz/min in all but the triple dose tests (10.8 fluid oz/min). The 10.8 fluid oz/min rate was selected as a reference point, we wanted to pick a rate that was sufficiently high to insure optimal lethality, yet one that was operationally possible.

Statistical methods. Comparisons between tests were evaluated using a Kruskal-Wallis Multiple Comparison technique (Dunn 1964).

RESULTS

From May 1985 through December 1985 110 individual tests were conducted. Meteorological conditions varied, as expected, during the course of the investigation. Ambient temperature ranged between 23 and 35°C (mean = 26.5 ± 4.0°), relative humidity between 74 and 100% (mean = 89.0 ± 6.9%) with wind speed between 0.2 and 8.6 mph (mean = 4.1 ± 1.7 mph). Association analysis revealed that mosquito mortality and changes in the various meteorological parameters were independent.

Figures 1, 2 and 3 illustrate the absence of correlation between the various meteorological elements measured and mosquito mortality at the standard Dibrom 14 rate. Figure 1 shows that there was no relationship between wind speed and percent mortality ($r^2 = 0.021$, $P > 0.63$, df = 37). Similarly, temperature and relative humidity (Figs. 2 and 3) demonstrate no significant ($r^2 = 0.002$, $P > 0.1$, df = 37, and $r^2 = 0.002$, $P > 0.22$, df = 37, respectively) trends with increases or decreases in these two meterological parameters.

Data adjustment. The test plots were set up so that treatments could be made with any wind direction. However, it is obvious that the spray traveled greater distances to reach a particular cage whenever the wind angle was not exactly perpendicular to the direction of the application truck. For example, for cages at 500 ft; if the wind is exactly parallel to the test plots then the functional distance the droplets travels is 500 ft. However, if the wind is at 45° to the test plot the distance traveled is 707 ft. Figure 4 shows the significant negative relationship ($r^2 = 0.45$, $P < 0.001$, df = 194) between mosquito mortality and the test cage distance from the insecticide output (standard Dibrom 14 rate). To adjust for this condition of varying wind angle, which affects the distance the spray travels, an average angle of wind direction ($V\Theta$) was determined by vector analysis from the continuous meteorological record, velocity (V) and direction (Θ) were used in the following equation:

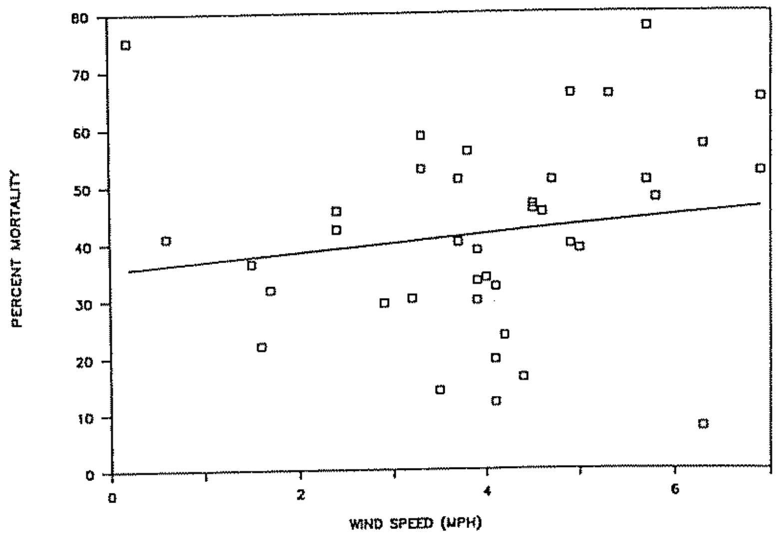

Fig. 1. Relationship between wind speed and caged mosquito mortality evaluated at the labeled dosage rate of Dibrom 14.

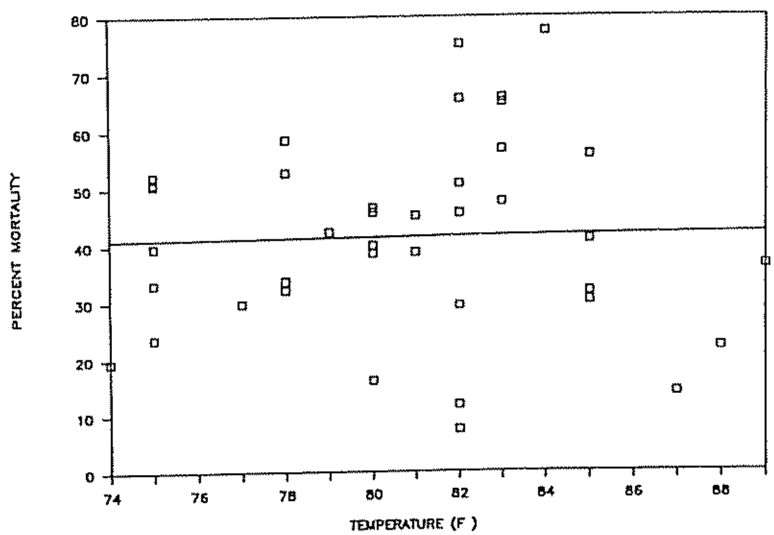

Fig. 2. Relationship between temperature and caged mosquito mortality evaluated at the labeled dosage rate of Dibrom 14.

Where average direction during test = $V\Theta$, X = horizontal vector component and Y = vertical vector component.

$$\Sigma X = V_1 \cos(\Theta_1) + V_2 \cos(\Theta_2) \cdots V_n \cos(\Theta_n)$$

$$\Sigma Y = V_1 \sin(\Theta_1) + V_2 \sin(\Theta_2) \cdots V_n \sin(\Theta_n)$$

$$V\Theta = \tan^{-1}(\Theta) = (\Sigma X)/(\Sigma Y)$$

$V\Theta$ allowed estimation of the actual distance the spray travelled to reach the cages, as follows:

Actual Distance = measured distance/sin($V\Theta$)

Mosquito mortality correction was determined by least squares fitting of the test data for tests where the wind direction was nearly parallel (within 3 degrees) to the test plot. This gave a prediction of what, under the best wind conditions, could be expected given the variances encountered in experimentation. The equation calculated for estimated mortality at a given distance (X) was:

estimated mortality (Y)

$$= 324.65 - 49.25\ (\ln(X))$$

$$r^2 = 0.817,\ n = 80$$

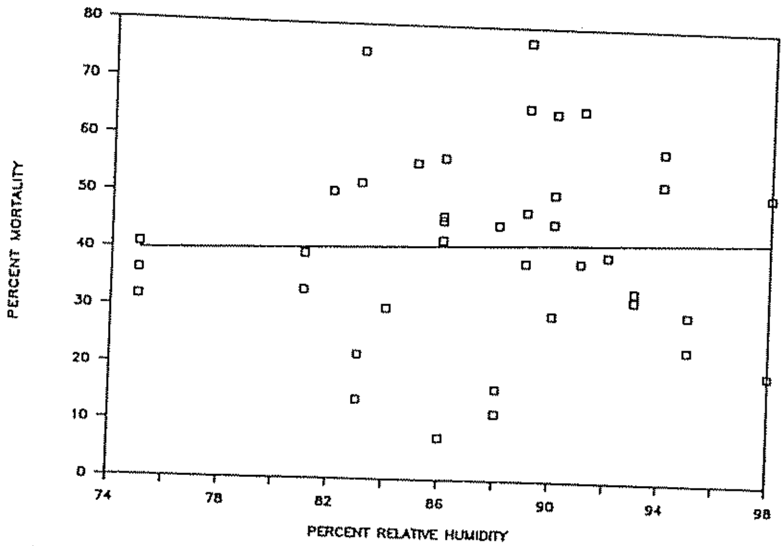

Fig. 3. Relationship between relative humidity and caged mosquito mortality evaluated at the labeled dosage rate of Dibrom 14.

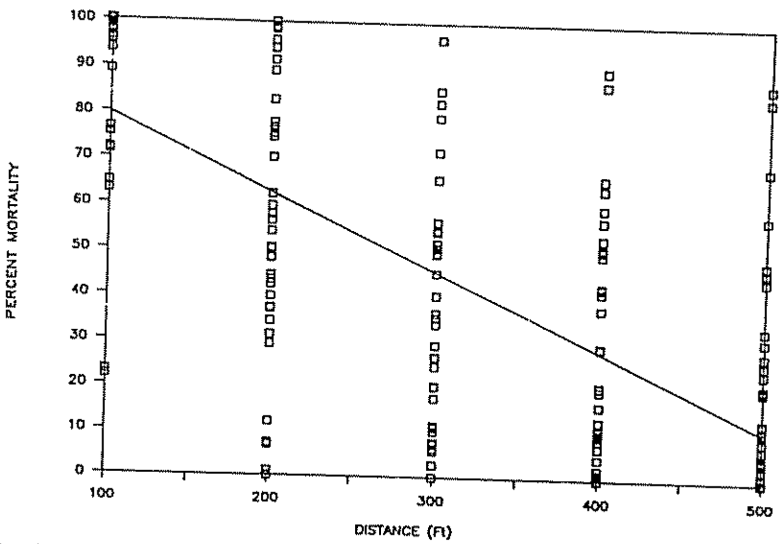

Fig. 4. Relationship between distance and caged mosquito mortality evaluated at the labeled dosage rate of Dibrom 14.

With these equations we could then correct mosquito mortalities at varying wind angles relative to the actual cage placement. This made inter-test comparisons more homogeneous for statistical analysis. Corrections were not necessary for any of the meteorological parameters since they were independent from treatment efficiency. For comparative purposes, all mortality data were adjusted for distance in accordance to the wind direction during that particular experiment. In all cases the adjustment for distance resulted in only a slight increase in percent mortality.

Standard rate tests. The first series of trials were baseline tests using naled at the labeled rate (3.6 fluid oz/min). These were used for both comparing the various ULV machines and the varying techniques. Table 1 illustrates the results of the standard tests with the 3 ULV machines (LECO, Curtis-Dyna and London Aire). There was not a significant overall difference (all distances combined) between any of the machines tested ($P \leq 0.35$, $n = 49$). However, in comparing the various distances, the Curtis-Dyna was significantly better than either of the other 2 machines at 200 ft ($P \leq 0.05$, $n = 245$).

Although the Curtis-Dyna appears to cause better overall mortality than the LECO or the London Aire (56.5% vs 39.6% and 32.8%, respectively), the difference was not statistically significant.

The droplet analysis revealed that the Volume Median Diameters (VMD) of all machines were not significantly different (Kolmogorov-Smirnov, $P \geq 0.45$).

Equipment modifications at standard rates. Table 2 shows the results of elevating the Curtis-Dyna nozzle to tree canopy height. Note that there was only slight improvement at 300–500 ft and a slight deterioration at the 100 and 200 ft placements compared to the standard application. This special configuration resulted in an overall mortality of 32%, not significantly different from the standard procedure. Mortality at individual distances also were not statistically different from the standard.

The London Aire modified Buffalo Turbine, with the turbine inoperative, performed like that of the standard London Aire machine (Table 2). Also in Table 2 are the results of the tests using the turbine assisted ULV. This method killed 33.9% of the mosquitoes, which was not statistically different from conventional methods. This technique resulted in some improvement in mortality at 400 and 500 ft, but not statistically different from the standard. However, there was a marked deterioration in mosquito mortality at 100 ft which was significantly less than normal ($P \leq 0.001$, n = 12).

High dosage rates. Twelve tests were executed at 10.8 fluid oz/min (3 × the labeled rate for Dibrom 14). The results, shown in Table 2 depicts the efficiency of this increased rate above that of the standard rate. Treatments at 10.8 fluid oz/min produced greater than 95% mortality through 500 ft in the test plot. This is a highly significant increase over any of the standard application methods ($P \leq 0.001$, n = 12).

The last series of experiments was a variation on the triple rate tests. Three individual passes were made by the test plot at 3.6 fluid oz/min, each made within 1 min of the previous pass. These results seen in Table 2, indicate that there is no significant overall difference ($P < 0.45$, n = 12) between the triple dose single pass method and the triple pass normal dose treatment. Both produced greater than 95% mortality through the 500 ft cages.

CONCLUSIONS

Results from this investigation indicate that under the conditions of these tests, which included penetration of vegetation in a citrus grove, the standard labeled rate for ground ULV application of naled will only produce about 35%

Table 1. Results of labelled dose rate (3.6 fluid oz/min Dibrom 14) with standard application methods. Mortality is percent mean mortality ± SD.

Application method and (replicates)	Distances (feet)					
	100	200	300	400	500	Total
LECO (n = 21)	94.1 ± 17.1	45.2 ± 26.8	29.7 ± 22.4	14.5 ± 14.5	14.6 ± 25.0	39.6 ± 36.7
Curtis-Dyna (n = 14)	86.5 ± 22.5	71.0 ± 30.3	52.3 ± 29.5	47.7 ± 26.3	30.2 ± 21.2	57.5 ± 32.1
London Aire (n = 12)	88.0 ± 17.5	46.2 ± 30.9	17.2 ± 32.5	11.2 ± 21.0	1.8 ± 3.6	32.9 ± 38.3

Table 2. Results of experimental application methods and dosage rates. Mortality is percent mean mortality ± SD.

Application method, dosage rate and (replicates)	Distances (feet)					
	100	200	300	400	500	Total
Curtis Dyna 3.6 oz/min, nozzle at 13.5′ (n = 15)	73.1 ± 23.5	32.4 ± 21.3	34.4 ± 34.4	35.3 ± 32.8	25.0 ± 25.6	40.0 ± 32.1
Buffalo Turbine London Aire ULV only, 3.6 oz/min (n = 12)	82.5 ± 24.8	37.8 ± 36.8	19.7 ± 27.3	43.2 ± 35.3	10.6 ± 15.4	38.8 ± 36.9
Buffalo Turbine London Aire ULV and turbine, 3.6 oz/min (n = 12)	51.9 ± 41.2	14.0 ± 26.4	30.0 ± 35.7	47.2 ± 46.6	26.5 ± 38.5	33.9 ± 38.2
LECO 10.8 oz/min (n = 12)	100.0 ± 0.0	98.6 ± 4.8	88.4 ± 19.3	93.0 ± 16.0	95.1 ± 11.1	95.0 ± 12.7
LECO 3 passes, 10.8 oz/min (n = 12)	100.0 ± 0.0	99.8 ± 0.6	97.5 ± 5.3	96.0 ± 8.9	90.5 ± 17.4	96.7 ± 9.3

mortality at 500 ft, or 52% at 300 ft. This is inadequate in an operational adulticiding program, especially one directed towards high density mosquito populations. Giglioli et al. (1979) accurately pointed out that if adult mosquito control measures are to be considered effective against high density salt marsh mosquitoes they must provide a higher level of protection (greater than 96% reduction), than that expected for low density or vector mosquitoes. Attempts to overcome the vegetation penetration problem by elevating the spray output either by physically raising the nozzle or propelling the insecticide up in the air with an air blast proved to be futile.

Meteorological conditions were unimportant in this set of tests. No statistical relationship could associate changes in wind speed, wind direction, temperature or humidity and caged mosquito mortality. Mortality was dependent upon dosage rate and the distance the test cages were from the application source.

This study strongly demonstrates that with the methods tried in this study, effective ground adult mosquito control can only be achieved by increasing the dosage rate. This is especially applicable for situations such as coastal southeastern Florida where high density salt marsh mosquitoes (*Ae. taeniorhynchus* and *Ae. sollicitans* (Walker)) and two of the citrus grove mosquitoes *Ae. vexans* (Meigen) and *Psorophora columbiae* (Dyar and Knab) may cause a severe annoyance. The conclusion that increasing the dosage rate is a solution for successful adult mosquito treatment in heavily vegetated habitats has been independently determined by Focks et al. (1987). The highest rate we tested (10.8 fluid oz/min) is still well below that labeled for aerial application.

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REFERENCES CITED

Beidler, E. J. 1975. A new method of sampling ultra low volume droplets. Mosq. News 35:482–488.

Curtis, G. A. 1985. Habitat selection strategies of mosquitoes inhabiting citrus irrigation furrows. J. Am. Mosq. Control Assoc. 1:169–173.

Dunn, O. J. 1964. Multiple comparisons using rank sums. Technometrics (6)3:241–252.

Focks, D. A., K. O. Kloter and G. T. Carmichael. 1987. The impact of sequential ULV aerosol applications of malathion on the population dynamics of *Aedes aegypti* (L.). Am. J. Trop. Med. Hyg. 36:639–647.

Giglioli, M. E. C., E. J. Gerberg and R. G. Todd. 1979. Large scale field tests and environmental assessments of Sumithion (fenitrothion) against adult mosquitoes in Grand Cayman, West Indies. Mosq. News 39:781–792.

Haile, D. G., T. J. Biery, J. F. Reinert and N. W. Pierce. 1982. Aerial applications of naled diluted in HAN with US-123K aircraft for adult mosquito control. Mosq. News 42:41–48.

Henderson, J. M., R. G. Knepper and D. M. Fanara. 1985. Field studies of temperature effects on ULV malathion, chlorpyrifos, and resmethrin. Proc. 72nd Annu. Meet. N.J. Mosq. Control Assoc. pp. 212–219.

Mount, G. A., C. S. Lofgren, N. W. Pierce and C. N. Husman. 1968. Ultra low volume nonthermal aerosols of malathion and naled for adult mosquito control. Mosq. News 28:99–102.

Taylor, R. T. and H. F. Schoof. 1971. The relative effectiveness of malathion thermal aerosols and ground-applied ULV against three species of mosquitoes. Mosq. News 31:346–349.

1988 Linley, J. R., R. E. Parsons, and R. A. Winner
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(1406)

EVALUATION OF ULV NALED APPLIED SIMULTANEOUSLY AGAINST CAGED ADULT *AEDES TAENIORHYNCHUS* AND *CULICOIDES FURENS*[1]

J. R. LINLEY,[2] R. E. PARSONS[3] AND R. A. WINNER[3]

ABSTRACT. Two experiments were conducted to test application of ULV naled against adult *Aedes taeniorhynchus* and *Culicoides furens* exposed simultaneously in cages hung on poles at selected heights and distances from the spray source. ULV spray was released at 0.14 oz active ingredient/acre, droplet size 13.5 µm mmd. In both experiments, insecticide largely carried over the first poles. The greatest mortality occurred at the second pole position, 18.3 and 25.7 m, respectively, from the spray origin, and diminished progressively with increasing distance. Cages at the highest elevation (183 cm) showed the greatest mortality, while those near the ground (15 cm) were substantially less affected. Regression analysis showed that 70% control or better was attained up to a distance (beyond a line 10 m from the release point) of 23 m in the case of *Ae. taeniorhynchus* and 18 m in the case of *C. furens*. ULV naled, applied as described, was not particularly effective for control of *Ae. taeniorhynchus* and *C. furens*, and was poor for insects exposed in low vegetation.

INTRODUCTION

Giglioli et al. (1980) tested the effect of aerially applied ultra low volume (ULV) Sumithion (fenitrothion) for control of *Culicoides* (predominantly *C. furens* (Poey)) in Grand Cayman. Excellent control, better than 99%, was achieved with a dosage of 191.5 gm/ha (2.7 oz/acre) active ingredient. Similarly, Haile et al. (1984) obtained essentially the same level of control of *C. hollensis* (Melander and Brues) after two consecutive (1 day apart) serial applications of naled (Dibrom 14®) at 28.4 gm/acre (1 oz/acre). In Florida, ULV naled applied from vehicle-mounted equipment is used by many mosquito control districts predominantly as a measure against mosquitoes, but also with some anticipated effect in controlling *Culicoides*. Despite the widespread application of this method, no attempt has been made to evaluate the effect of such treatments on biting midge populations. Accordingly, we report here the results of two experiments to test the control effect of ULV naled applied against *Culicoides furens* and *Aedes taeniorhynchus* (Wiedemann) exposed simultaneously. These experiments are complementary to an earlier test to assess the effect of thermal fog naled against *C. furens* (Linley et al. 1987).

MATERIALS AND METHODS

Wild caught female *C. furens* were collected by aspiration from a site on Hutchinson Island, Florida, as previously described (Linley et al. 1987). The *Ae. taeniorhynchus* were obtained from a laboratory colony (Lake Charles strain) obtained from the USDA Insects Affecting Man and Animals Research Laboratory in Gainesville, Florida.

The insects were exposed during test in cages consisting of two compartments, a screen exposure chamber and a closed post-exposure chamber, separated by a sliding barrier. The cage used for the *Culicoides* is described fully by Linley et al. (1987) and one somewhat larger, but otherwise similar in basic design, was used for *Aedes*. Both experiments were conducted at Sarasota, Florida, in an open meadow devoid of bushes or trees and covered predominantly by grass. Grass stems were fairly dense to a height of 16–20 cm (6–8 in) above ground but relatively sparse above this height, with the tallest stems reaching to about 45 cm (18 in).

Cages were hung from hooks attached at heights of 15, 91 and 183 cm (6, 36, 72 in) to wood poles erected in pairs along two parallel lines oriented in the direction of the prevailing wind and perpendicular to the line of spray release (see Linley et al. 1987). In the two experiments, the nearest two poles were respectively 6 and 9.1 m (20, 30 ft) from the line of spray release; the two lines of poles were 6 m apart (both experiments), and pairs of poles were respectively 12.2 and 16.8 m (40, 55 ft) apart. Poles were set further apart in the second experiment in an attempt to obtain more complete coverage of the zone within which the insecticide showed some effect. Two control cages (for both *C. furens* and *Ae. taeniorhynchus*) in each experiment were hung at 91 and 183 cm on a pole set about 1 km from the treatment area, sufficient to assure no exposure to chemical.

Test insects were transferred to the cages under CO_2 anesthesia in the early morning, just prior to being transported to the field site. From

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15–20 *Ae taeniorhynchus* and 10–40 *C. furens*, respectively, were placed in each cage. The *Culicoides* could not be counted into cages as they recover extremely rapidly from CO_2 anesthesia (<20 sec). After cages had been set out at the test site, the ULV naled treatment was applied at approximately sunrise + 1 hr. Application was made with vehicle-mounted Leco Model HD equipment, nozzle angle 45°, at 1.5 m (5 ft) elevation, dispensing 3.7 oz/km (6 oz/mile) 85% active ingredient naled (droplet size 13.5 μm mmd). Cages were left in place for 15 min after application, then insects were transferred to the post-exposure chambers and the cages returned to the laboratory. Mortality was subsequently recorded at 1, 6 and 24 h posttreatment. Conditions during the two experiments were generally very favorable, with fairly constant wind speeds (determined with a hand-held anemometer) of about 2.4 km/hr (1.5 miles/hr) in the first experiment and 6.4 km/hr (4 miles/hr) in the second.

RESULTS

Control mortalities showed no difference related to cage height and the counts were therefore combined. On this basis, at 24 hr after treatment, mortalities for *Ae. taeniorhynchus* and *C. furens* in the two experiments were 0 and 10.7%, and 4.3 and 2.1%, respectively. Where appropriate, Abbott's formula was applied to the data prior to further analysis.

Results from the two pole lines in both experiments were similar and the data for each experiment were combined. Since it is useful to have access to exact mortality figures, conventional tabulations are given in Table 1 (Exp. 1) and Table 2 (Exp. 2). However, the effects of treatment in relation to time, distance from the release point and cage elevation, are more comprehensible from isometric plots (Figs. 1,2). Survival rather than mortality percentages were plotted in these figures because, as argued previously (Linley et al. 1987), concern is more with proportions of insects surviving than with those eliminated.

The overall pattern of effect in the two experiments was similar (Figs. 1,2). Mortality generally tended to be higher in Experiment 1, in which wind speed was lower (2.4 km/hr) than under the somewhat higher wind speed (6.4 km/hr) prevailing during Experiment 2 (Tables 1,2). Mortality in most instances was higher in the caged groups of *Ae. taeniorhynchus* than among the *C. furens* (Tables 1,2; Figs. 1,2), possibly because insecticide was not able to pass as easily through the finer mesh necessary to confine *Culicoides*. Only in Experiment 1, and then only in two groups of *Ae. taeniorhynchus* at higher cage elevations, were all the insects dead after 24 hr (Table 1).

It was obvious from the survival plots, especially in the 24 hr time blocks (Figs. 1,2), that both mosquitoes and midges survived considerably better in cages in the first pair of poles than on the second. Evidently, and especially with higher wind speed (Exp. 2), much of the insecticide carried over the first poles and consequently produced only moderate effect. The highest mortalities for both species were, as expected, in cages of 183 cm (Tables 1,2), but even then, the highest mortality (*Ae. taeniorhynchus*, Exp. 2) was only 51.2%. At the distance of the second pair of poles in the two experiments (18.3 and 25.7 m, respectively), control was substantially better as is especially obvious from the survival data (Figs. 1,2). More than 70% of the *Ae. taeniorhynchus* were dead after 24 hr at all elevations in Experiment 1 (Table 1), and more than 75% at the two highest

Table 1. Percent mortality of adult female *Aedes taeniorhynchus* (not italicized) and *Culicoides furens* (italicized) exposed to ULV naled (Exp. 1).

Distance (m) from release point	Time (hr) after treatment: 1			6			24		
	Height (cm)			Height (cm)			Height (cm)		
	15	91	183	15	91	183	15	91	183
6.1	40.0	25.0	41.0	42.5	40.0	48.7	45.0	45.0	48.7
	14.0	*20.9*	*18.2*	*26.2*	*33.8*	*26.4*	*32.8*	*48.3*	*29.2*
18.3	67.5	94.9	87.2	70.0	100.0	89.7	72.5	100.0	89.7
	35.5	*33.3*	*69.7*	*59.3*	*61.6*	*75.3*	*69.7*	*68.0*	*81.0*
30.5	55.0	97.5	100.0	57.5	97.5	100.0	57.5	97.5	100.0
	27.8	*37.8*	*60.7*	*39.2*	*63.1*	*82.6*	*75.6*	*80.9*	*87.9*
42.7	47.5	82.1	83.8	57.5	87.2	94.6	57.5	89.7	94.6
	8.7	*24.6*	*25.9*	*9.6*	*41.3*	*59.0*	*32.8*	*49.0*	*68.0*
54.9	32.5	57.9	50.0	40.0	68.4	55.0	40.0	73.7	57.5
	0.7	*43.9*	*32.9*	*0.7*	*65.1*	*42.9*	*17.1*	*75.8*	*64.8*

Table 2. Percent mortality of adult female *Aedes taeniorhynchus* (not italicized) and *Culicoides furens* (italicized) exposed to ULV naled (Exp. 2).

Distance (m) from release point	Time (hr) after treatment: 1 — Height (cm) 15	91	183	6 — Height (cm) 15	91	183	24 — Height (cm) 15	91	183
9.1	4.5	13.3	38.7	4.5	19.4	52.2	9.4	17.7	51.2
	2.6	*0.0*	*7.5*	*0.5*	*2.6*	*10.6*	*16.6*	*4.9*	*13.2*
25.9	1.1	45.7	72.7	11.3	77.6	89.8	11.3	77.6	89.8
	5.1	*6.9*	*12.9*	*6.2*	*59.7*	*79.6*	*33.3*	*76.2*	*90.1*
42.7	5.3	29.2	40.6	16.7	45.0	50.5	16.7	47.8	50.5
	0.0	*0.0*	*14.6*	*9.2*	*17.3*	*52.6*	*23.4*	*51.4*	*67.6*
59.4	8.3	18.2	18.2	26.0	38.7	52.2	26.0	40.8	52.2
	9.1	*1.9*	*9.6*	*10.2*	*7.5*	*20.9*	*16.4*	*32.5*	*24.2*
76.2	16.1	12.9	16.8	16.1	12.9	16.8	17.9	12.9	16.8
	0.0	*2.4*	*4.6*	*0.0*	*5.3*	*5.7*	*9.4*	*22.8*	*12.0*

positions in Experiment 2 (Table 2). Results were very similar with the *Culicoides*, except that the mortality levels were somewhat lower, an effect ascribed earlier to reduced penetration of insecticide. Control remained fair out to the third poles in Experiment 1 (Table 1, Fig. 1), with no lower than 57.5% mortality among the test groups of *Ae. taeniorhynchus*, and 75.6% among *C. furens*. There was less effect in Experiment 2 (Fig. 2), with comparable lowest mortalities (Table 2) of 16.7 and 23.4%. As anticipated, the treatment had diminishing effect at progressively greater distances, as seen most clearly on the plotted data (Figs. 1,2). In comparing these figures it should be remembered that poles in Experiment 2 were further apart (e.g., pole pair 4 in Exp. 2 was further from the release point than pair 5 in Exp. 1).

With respect to cage height, a generally consistent pattern (Figs. 1,2) indicated that control effect diminished, or survival increased, at progressively lower elevations. The data demonstrate this effect more clearly if displayed as in Fig. 3, in which it is evident that survival was usually greatest in the lowest cages (15 cm). Since the wind-borne insecticide droplets would not have settled to ground along vertical paths, but rather at an angle, much of the chemical was presumably intercepted by grass stems and other low vegetation. There is some indication in Fig. 3 that cages at 91 cm were somewhat less affected than the highest ones at 183 cm, but the extent to which the lowest cages were least affected is much more obvious.

An important objective was to estimate, for this method of ULV naled application, the distance from the release point at which selected levels of survival occur. The data present some difficulty because survival was relatively high at the first poles, especially in Experiment 2 (Figs. 1,2), and lowest at the second poles, with larger proportions then remaining alive at progressively greater distances. Data for pole position two and beyond can therefore be evaluated by regression analysis, using the combined percentage survival data from all cage heights (at each pole position) and both experiments (Fig. 4). Highly significant linear regressions (slopes not significantly different) are obtained for both *Ae. taeniorhynchus* ($P < 0.02$, $r^2 = 0.666$) and *C. furens* ($P < 0.01$, $r^2 = 0.708$). The distances corresponding to selected survival levels are therefore easily calculated, but must be related to an estimated origin in terms of distance from the release point. Since survival was high at 9.1 m in Experiment 2 (Table 2), 10 m (from the release point) has been chosen as a reasonable estimate of the distance at which the linear survival trends in Fig. 4 originate. Obviously this represents a compromise between the two experiments, since the lowest survival may have been closer than 10 m in Experiment 1 (Fig. 1) and probably beyond it in Experiment 2 (Fig. 2). A matter of a few meters does not, however, affect the broad significance of conclusions that can be reached.

The distances (beyond 10 m) within which survival is equal to or less than 10, 30 and 50% are shown for the two species in Table 3. Since survival was consistently higher in cages at 15 cm elevation as opposed to 91 and 183 cm (Fig. 3), similar calculations were applied to the combined data grouped by cage elevation (Table 3). These figures provide an indication of survival that might be expected among insects resting in grass or other low vegetation, or in flight or at rest in more elevated, open sites. The overall estimate (all cage heights) shows that 10% survival (90% control) of *Ae. taeniorhynchus* was attained to only 5 m (beyond 10 m) and was not achieved at all for *C. furens*. For 30 and 50% survival, representing considerably poorer con-

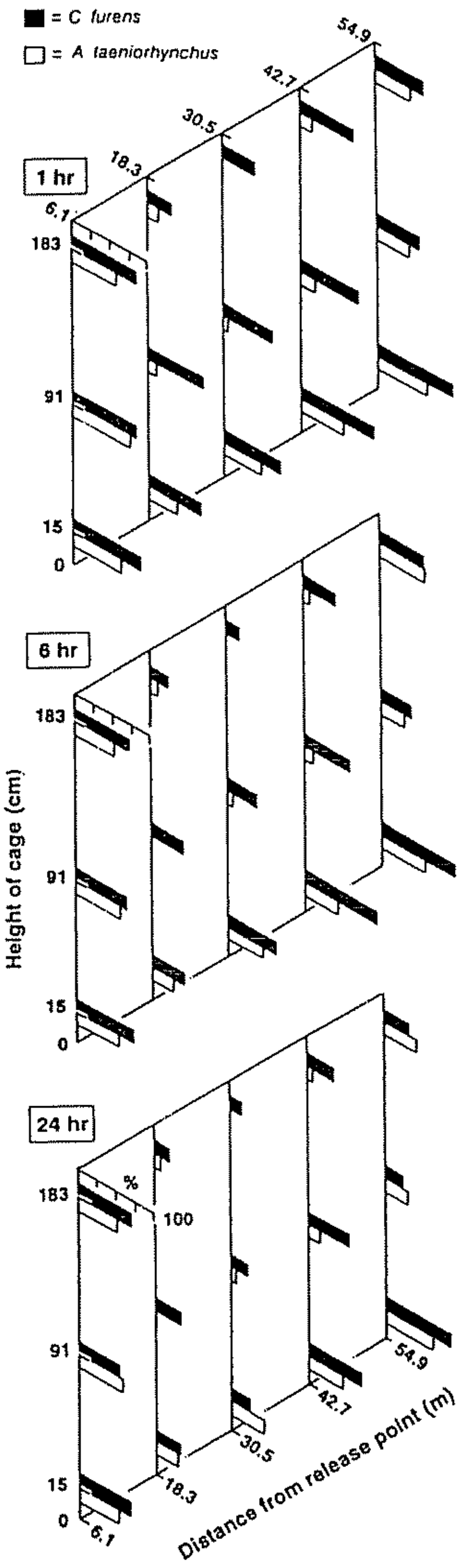

Fig. 1. Experiment 1: isometric plots of percent survival of *Aedes taeniorhynchus* and *Culicoides furens* (data from both pole lines combined) at 1, 6, and 24 hr after treatment.

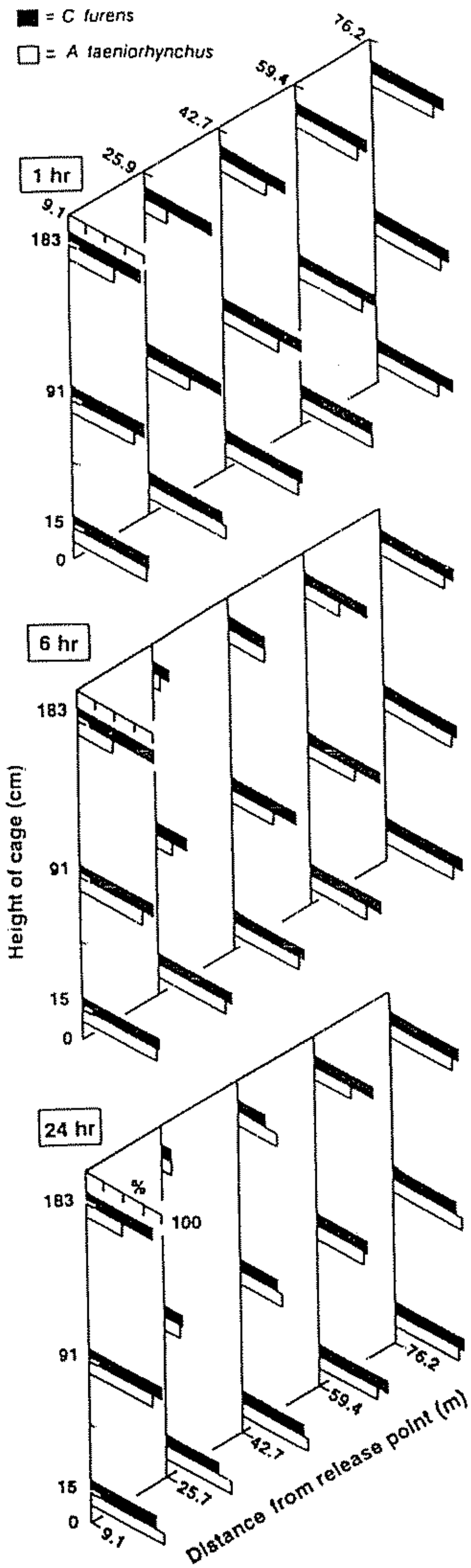

Fig. 2. Experiment 2: isometric plots of percent survival of *Aedes taeniorhynchus* and *Culicoides furens* (data from both pole lines combined) at 1, 6 and 24 hr after treatment.

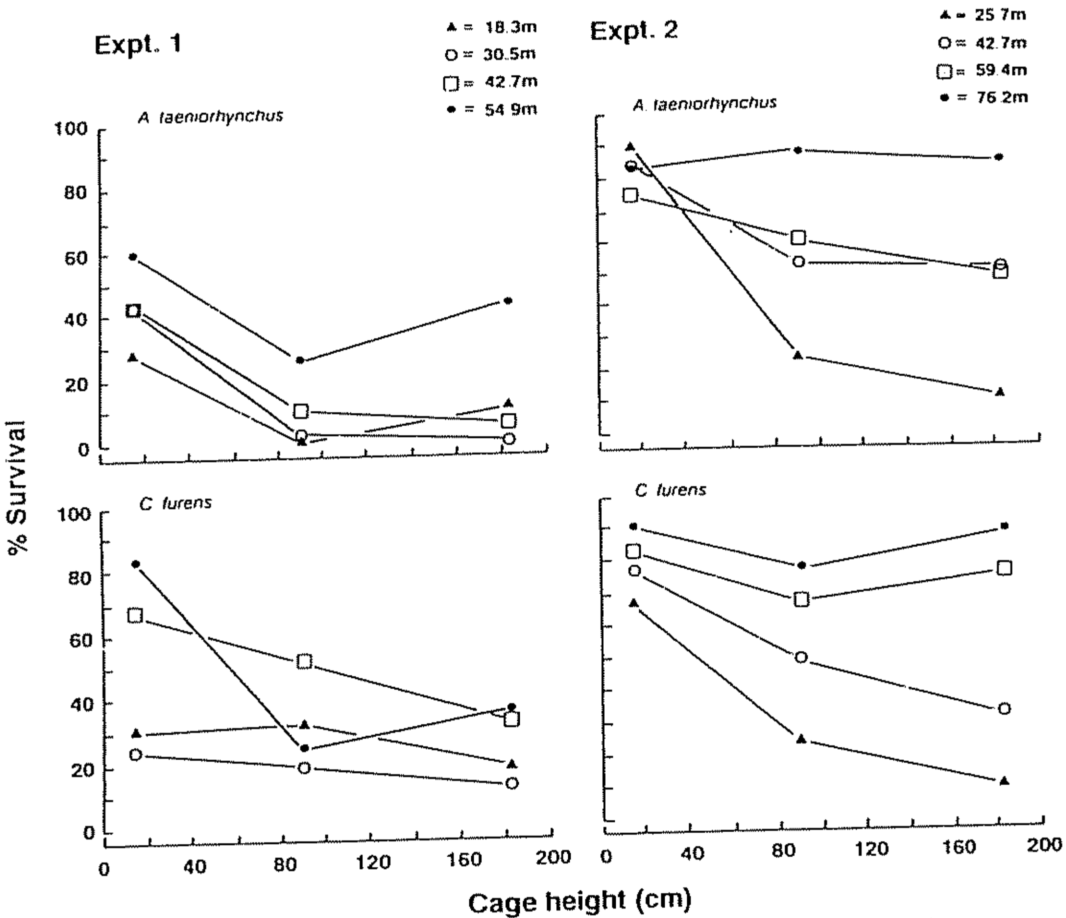

Fig. 3. Percent survival of *Aedes taeniorhynchus* and *Culicoides furens* in relation to cage height.

trol levels, the distances for the two species were 23 and 18 m, and 41 and 36 m, respectively. Considering insects very near the ground (15 cm cage elevation), survival in both species was not reduced below 30% at any distance, and was equal to or less than 50% only out to 12 and 19 m (beyond 10 m), respectively. Survival was considerably lower at 91 to 183 cm, but was equal to or less than 10% only to a distance of 18 m for *Ae. taeniorhynchus* and 8 m for *C. furens* (Table 3). These results can also be visualized more practically as "swaths of control" running parallel to and starting at about 10 m from the line of spray release. Thus, the overall estimate indicates that 70% control, or better, occurred within a swath 23 m (25 yd) wide and 18 m (19.7 yd) wide, respectively, for the two species.

DISCUSSION

At the dosage rate used here, which is that routinely applied in Sarasota County mosquito abatement operations, it is easily calculated that for an assumed swath width of 91.4 m (300 ft), the dosage was 0.14 oz naled/acre (active ingredient) when 85% concentrate is dispensed at 6 oz/linear mile. As shown, this treatment achieves relatively poor control of caged female *Ae. taeniorhynchus* and *C. furens*, with 70% mortality occurring only within a swath 23 and 18 m wide (originating at about 10 m from the release point) for the two species, respectively. Control of 90% or better extended only to 5 m in the case of *Ae. taeniorhynchus*, and was not attained at all in the case of *C. furens*.

In earlier experiments with caged *Ae. taeniorhynchus*, Mount et al. (1968) reported (top line of their Table 3) 76 and 58% mortality (18 hr after treatment) at distances of 45.7 and 91.4 m (150 and 300 ft) from the release point and 24% mortality as far as 182.9 m (600 ft). Since the dosage rate (given as 0.0045 lb/acre) for these particular data was essentially the same as used here, it is apparent that our tests yielded poorer control. Our results imply, for example (Fig. 4), that 58% mortality, recorded by Mount and co-workers at 91.4 m (300 ft), would extend to only 43.4 m (142.5 ft). One factor contributing to the difference may have been droplet size. As compared to the 13.5 μm mmd size dispensed in our tests, Mount et al. (1968), insofar as can be estimated from their paper, were probably working with smaller droplets in the 6–8.5 μm mmd range, which they found to be consistently more effective. Another consideration is that their insects were suspended 1.5 m (5 ft) above ground, equivalent to the higher cage elevations in our work (Table 3), at which wider swaths of control were obtained. Based on the two higher cages, our data project 58% control out to 50.8 m (166.7 ft) compared to 91.4 m (300 ft) reported by Mount and co-workers. Midges and mosquitoes at rest in low vegetation are a significant consideration, however, and they are very poorly controlled by ULV naled applied as described (Table 3). Since our tests were carried out with caged insects (as were those by Mount et al. (1968)), it can be assumed that the cage mesh in each case reduced the amount of insecticide making contact with the insects and thus diminished the apparent effectiveness of the treatment. This factor may also have contributed slightly to the superior survival of *C. furens*, since the mesh in their cages presented 54.8% open area to the passage of insecticide, as opposed to 57.4% for the mosquito cages.

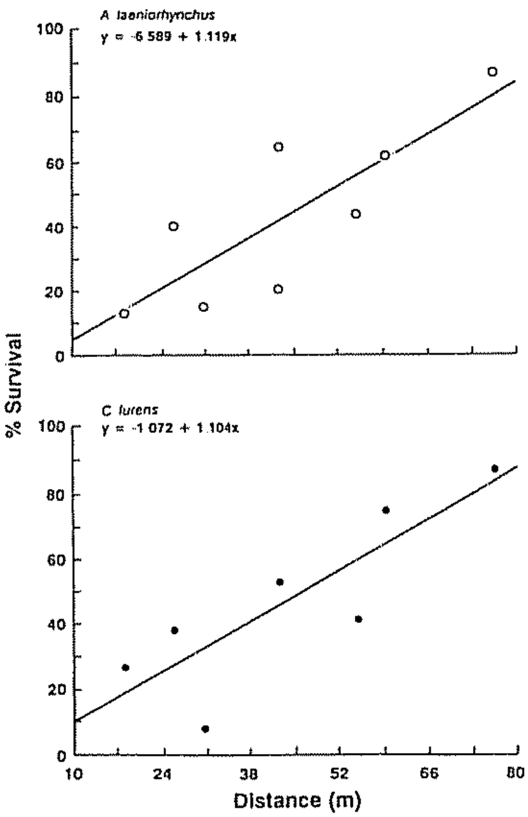

Fig. 4. Regressions of percent survival of *Aedes taeniorhynchus* and *Culicoides furens* on distance (data from all cage heights combined) from an origin 10 m away from the line of spray release. Data from the first pair of poles in each experiment omitted (see text).

In contrast to ground applications, aerial treatments of ULV naled, at appropriate dosages, appear to be extremely effective against both mosquitoes and *Culicoides*. Haile et al. (1984) found that two applications, on successive days, gave extremely effective control of several mosquito species and *C. hollensis* (predominantly) at 1 oz/acre, but relatively poor results at a dosage of 0.25 oz/acre. Similarly, Giglioli et al. (1980) obtained excellent abatement of a mixed population of *C. furens* (primarily) and *C. barbosai* Wirth and Blanton with aerially applied fenitrothion at 2.7 oz/acre. These treatments clearly produced excellent control, but the aerially applied naled (Haile et al. 1984) was dispensed at 7.1 × the dosage per acre compared to the ground applications reported here or by Mount et al. (1968).

In conclusion, the results we have described suggest that ULV naled, applied by vehicle-mounted equipment at 0.14 oz/acre, droplet size

Table 3. Predicted distances (m) beyond 10 m from release point, where survival would be equal to or less than percentage indicated.

Cage heights	Species	Distance (m) beyond 10 m where survival equal to or below percentage indicated		
		10%	30%	50%
1. All heights combined	*Ae. taeniorhynchus*	5	23	41
	C. furens	0	18	36
2. 15 cm only	*Ae. taeniorhynchus*	0	0	12
	C. furens	0	0	19
3. 91 and 183 cm	*Ae. taeniorhynchus*	18	32	47
	C. furens	8	26	45

13.5 μm mmd, does not control *Ae. taeniorhynchus* and *C. furens* particularly effectively. Insects resting in low vegetation close to the ground appear to be very poorly controlled. The disparity of these results with respect to those obtained in similar, previously published tests (Mount et al. 1968) seems most likely to be at least partly due to the smaller droplet size used in the earlier experiments.

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We are grateful to Brian Benner and operations personnel of Sarasota County Mosquito Control District for their cooperation during this study.

REFERENCES CITED

Giglioli, M. E. C., E. J. Gerberg and R. G. Todd. 1980. Large scale field tests and environmental assessments of Sumithion (fenitrothion) against adult biting midges in Grand Cayman, West Indies. Mosq. News 40:1–5.

Haile, D. G., D. L. Kline, J. F. Reinert and T. L. Biery. 1984. Effects of aerial applications of naled on *Culicoides* biting midges, mosquitoes and tabanids on Parris Island, South Carolina. Mosq. News 44:178–183.

Linley, J. R., R. E. Parsons and R. A. Winner. 1987. Evaluation of naled applied as thermal fog against *Culicoides furens* (Diptera: Ceratopogonidae). J. Am. Mosq. Control Assoc. 3:387–391.

Mount, G. A., C. S. Lofgren, N. W. Pierce and C. N. Husman. 1968. Ultra-low volume nonthermal aerosols of malathion and naled for adult mosquito control. Mosq. News 28:99–103.

1987 Linley, J. R., R. E. Parsons, and R. A. Winner
Evaluation of Naled Applied as a Thermal Fog Against Culicoides Furens (Diptera: Ceratopogonidae)
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1408

EVALUATION OF NALED APPLIED AS A THERMAL FOG AGAINST *CULICOIDES FURENS* (DIPTERA: CERATOPOGONIDAE)[1]

J. R. LINLEY[2], R. E. PARSONS[3] AND R. A. WINNER[3]

ABSTRACT. Naled/diesel oil (1:99), applied as a thermal fog, was tested against the biting midge *Culicoides furens*. The insects were confined in small cages suspended at 4 heights on poles at progressively greater distances from the fog release point. In terms of population survival 24 hr after treatment, a parabolic equation accurately described the regression of percent survival on distance from the release point. If 10% survival is considered as the maximum acceptable, then the equation predicts adequate control up to 19.6 m (64.3 ft) from the fog release point.

INTRODUCTION

Biting midges (*Culicoides* spp.), especially *Culicoides furens* (Poey), *C. barbosai* Wirth and Blanton and *C. mississippiensis* Hoffman, are important pests of man in the heavily populated and economically important coastal areas of Florida (Linley and Davies 1971). Other species are the cause of similar problems in many other parts of the world (Linley 1976). For many years, concern for the environment has restricted the direct application of pesticides to the swamps and marshes where these insects breed. Control, where attempted, has been confined to the adult stage, usually in conjunction with concurrent efforts to reduce mosquito populations. Thermal fogging and ultra-low-volume (ULV) spraying have traditionally been the two methods applied, although ULV has, in recent years, almost entirely supplanted thermal fogging as the method of choice for mosquito control.

Despite the annoyance created by midge populations and the interest of control agencies in providing effective relief, relatively few efforts have been made to evaluate adulticidal methods under field conditions. In the laboratory, wild-caught insects have been used for evaluation of various insecticides in wind tunnel experiments (Kline et al. 1981, Floore 1985). Two recent field studies, by Giglioli et al. (1980) and Haile et al. (1984) have tested, respectively, the effectiveness of ULV fenitrothion against *C. furens* and *C. barbosai* in Grand Cayman, and of ULV naled against *C. hollensis* (Melander and Brues) in South Carolina. However, no data obtained to date allow comparison of thermal fogging as opposed to ULV methods for control of *Culicoides* under field conditions. Also, it is of interest to know the degree of midge control obtained from routine adulticidal treatment directed primarily against mosquitoes. Accordingly, this paper reports the first of a series of tests to evaluate the use of different application methods for control of adult biting midge populations.

MATERIALS AND METHODS

Culicoides furens adults (females) were collected by aspiration at a site on Hutchinson Island, about 8 km south of Ft. Pierce, Florida. The insects were kept and transported in 473 ml (1 pt.) ice cream cartons with nylon gauze lids supporting small wads of cotton soaked in 10% sucrose. For exposure during test, midges were placed in specially built cages consisting of an exposure and postexposure chamber separated by a closable (sliding) aperture (Fig. 1A). The exposure end consisted of a 3 cm cubical stainless steel screen cage (15.7 mesh/cm, Tetco Inc., Elmsford, NY) sealed at the edges with paraffin wax and at the bottom to a plastic lid. Between this lid and a similar one capping the postexposure chamber was a rectangular plastic slider (3.5 x 11 cm) adjustable to open or closed positions (Fig. 1A). The slider, fitted at one end with a suspension hook, was retained between small plastic guides contact cemented between the two lids. The postexposure chamber was made from a cylindrical clear plastic container 4.5 cm diam. and 7.5 cm long. A 3 cm diam. hole in the bottom, covered with stainless steel mesh, allowed through passage of air when it was necessary to blow the insects from one chamber to the other. The chambers worked well during the experiment. Their only disadvantage is that they are somewhat delicate and must be handled carefully.

The test was conducted in Sarasota County, at Siesta Public Beach, in an area of predominantly open terrain, with occasional bushes (Fig. 1B). The cages were suspended from hooks (Fig. 2A) set at heights of 15, 46, 91 and 183 cm (6, 18, 36, 72 in.) on poles implanted in the ground. Poles were spaced at intervals of 7.6 m (25 ft) in two lines 3 m (10 ft) apart, with the first two poles 3 m from the line of release of the fog (Fig. 2B). Two control cages were hung from vegeta-

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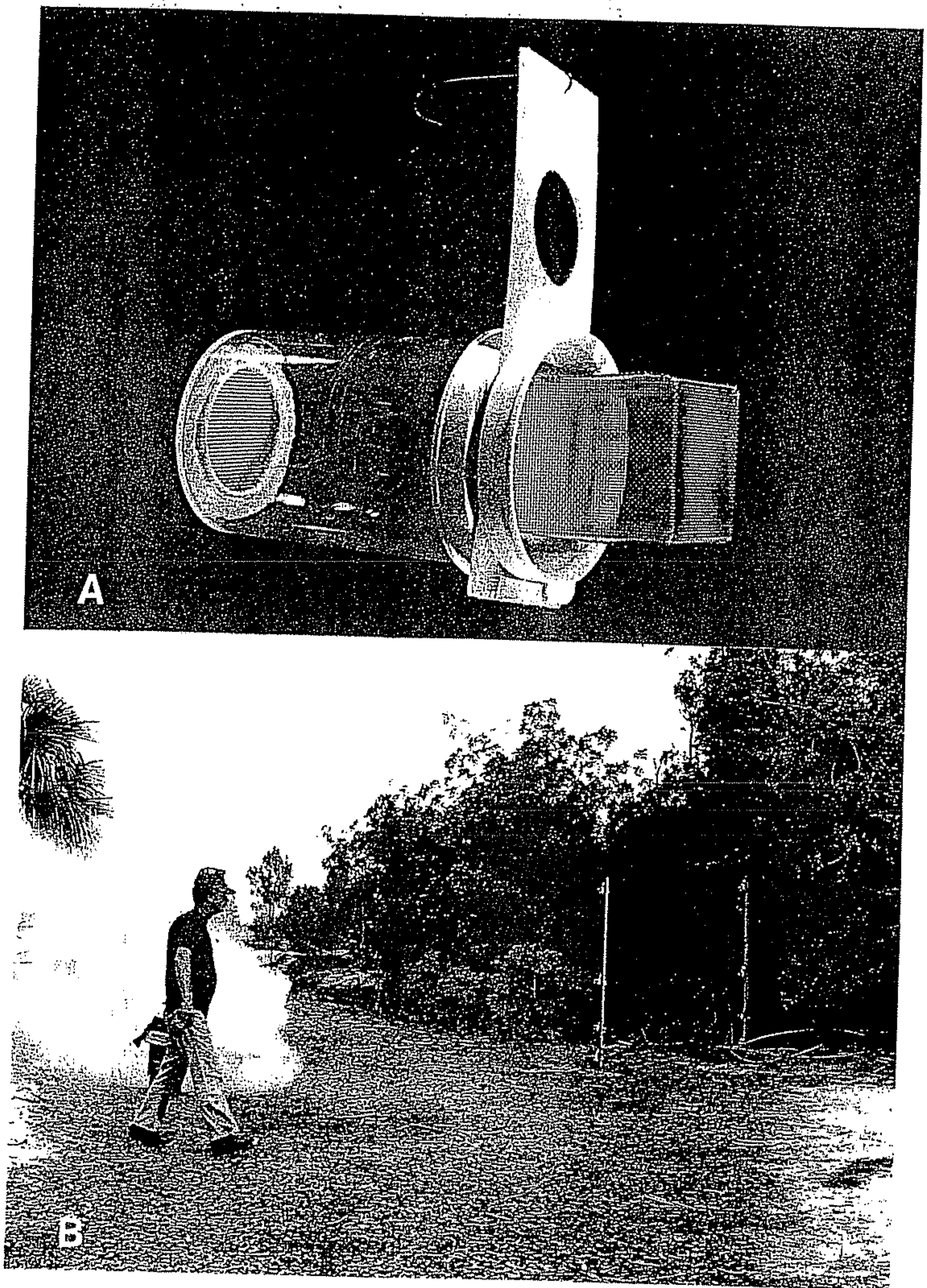

Fig. 1. A, cage used to confine *Culicoides furens* adults during test; exposure chamber to right, postexposure chamber to left. B, method of fog release; first 2 poles with cages in position at right.

tion at a height of about 91 cm, 50 m away and upwind of the fog release point. Beginning at about 0600 hr, in the laboratory, the adult *Culicoides* were anesthetized with CO_2 and transferred quickly (*Culicoides* recover extremely rapidly from CO_2 anesthetization) to the mesh exposure chambers. Chambers received between 6 and 50 insects, the numbers being unequal because of insufficient time to count insects prior to recovery from anesthetization. The cages were then carried out to the field site and suspended from the poles. At 0745 hr (sunrise + 71 min) fog was dispensed (Fig. 2) about 61 cm (2 ft) above ground along a line 30 m (100 ft) long perpendicular to the pole lines. A London Turbo Hand Fogger (London Fog Co., Crystal Bay, MN) was used, held by an operator moving at about 55 m/min (2 miles/hr). The insecticide mixture consisted of naled (Dibron 14) concentrate/diesel fuel 1:99, dispensed at a rate of 19–23 liters (5–6 gallons)/hr. Air movement during the test was almost ideal; fog drifted along the pole lines at about 70 m/min (approximately 2.5 miles/hr).

Cages were left in place for 15 min after fog release, then taken down and the insects blown into and confined in the postexposure chambers. Back at the laboratory, the cages were laid in large Plexiglas® boxes containing damp paper towelling and mortality recorded at 1, 3, 6 and 24 hr posttreatment.

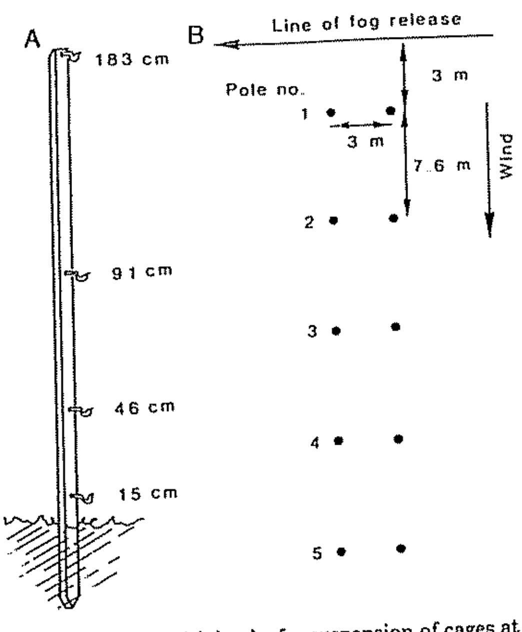

Fig. 2. A, pole with hooks for suspension of cages at 4 heights. B, layout of pole lines relative to line of fog release and prevaling wind direction.

RESULTS

The control cages were very similar, showing (combined data) no mortality at 1 and 3 hr posttreatment, then 5.5% at 6 hr and 14.8% at 24 hr. Where appropriate, Abbott's formula has been used to correct the data prior to further analysis.

With one exception, results from the two pole lines were very similar and data from replicate cages have been combined for analysis. The only inconsistency was that at the 183 cm height on poles 1 and 2 of one of the pole lines (nearest the fog release point, Fig. 2B) mortality was relatively low compared to the other replicate at 1 and 3 hr posttreatment. This inconsistency was caused by unequal upward disperal of fog as it moved down the pole lines. The effect does not alter the main conclusions of the study, but we mention it to emphasize that some "patchiness" may occur in the effect of a given treatment owing to local air currents.

Since the data provided information on the effects of cage height, distance from fog release point and time after release, they have been plotted isometrically in time blocks (Fig. 3). Observations at 3 hr posttreatment have been omitted as superfluous. Percentage survival rather than mortality is depicted because in assessing treatment effect it is more immediately relevant to measure the surviving population, which retains its nuisance potential.

At 1 hr after treatment (Fig. 3) no *C. furens* were alive at the 15 cm cage elevation at 3 and 10.7 m from the release point and very few (<7%) at the 46 and 91 cm elevations. As less fog reached the highest cage, especially in one pole line, survival was considerably greater at this level. Up to 1 hr the greatest effect was noticeable out to 10.7 m; survival was somewhat reduced but still substantial (>62% at all heights) at 18.2 m from the release point, and very high (>85%) at all heights beyond this distance. With the subsequent passage of time, as shown in the time blocks for 6 and 24 hr (Fig. 3), the lethal effect gradually spread both upward and along the pole lines. By 6 hr after treatment very few *C. furens* were still alive out to 18.2 m at all cage elevations except the highest, and almost all were dead at the highest level on the first pole (Fig. 3). Eighteen hours later (24 hr), no insects remained alive on the poles at 3 m and none, except a few (<13%) at the highest elevations, on the poles at 10.6 and 18.2 m. Beyond 18.2 m, some midges survived at all heights, although the maximum at 25.9 m at any level was 27%, with somewhat higher values at 33.5 m, where the maximum survival was 77% at the top cage elevation (Fig. 3).

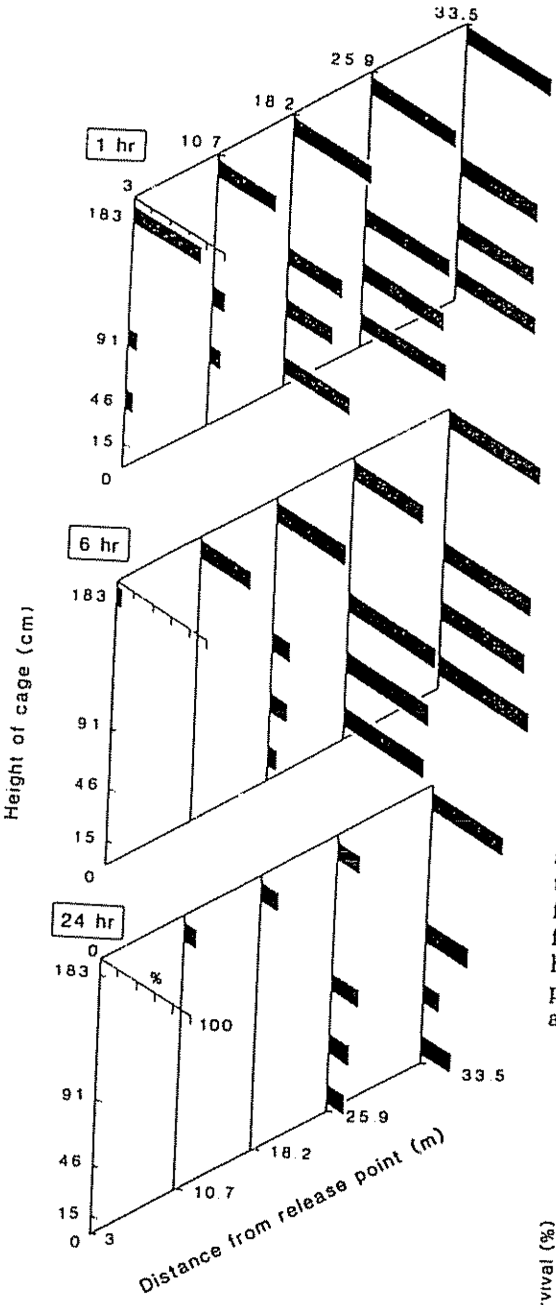

Fig. 3. Isometric plots of percent survival of *Culicoides furens* adults (data from both pole lines combined) at 1, 6, and 24 hr after treatment.

DISCUSSION

It is useful, initially, to consider how the use of caged insects may have affected the results. The steel mesh used to fabricate the exposure chambers presented 54.8% open area to fog droplets, so that a fairly large proportion presumably impinged on the exterior of the mesh and did not enter the cage. Droplets that passed through the first mesh into the cage may, however, have settled on the interior. Thus, chemical could have contacted crawling midges during the 15 min posttreatment period prior to transfer into the postexposure chambers. Increased survival caused by interception of chemical on the mesh exterior was probably offset by its settlement on the interior.

Although a large proportion of the *C. furens* remained alive beyond 10.7 m at 1 hr and beyond 18.2 m at 6 hr after treatment, relatively few survived to 24 hr (Fig. 3). Insects that did not die within a short time had, nonetheless, been lethally affected and their behavior might presumably have been altered for many hours before death. The desired control objective would be achieved if the affected *Culicoides* were deterred from biting until the time of death. Thus, despite the survival of midges for many hours at the greater distances from the release point, good control would be achieved out to 18.2 m and there would be some relief even at 33.5 m. While it is possible that sublethally poisoned midges may cease to seek a host, we have assumed that the behavior of midges still surviving after 24 hr was not significantly affected and that they would remain part of the biting population. On this assumption, the data for 24 hr after treatment can be used to assess the relationship between level of control and distance from the release point. This is a general estimate for which it is best to combine data from all heights (both pole lines) to show the change in percent survival with distance (Fig. 4). The data are accurately ($r^2 = 0.98$) described by the par-

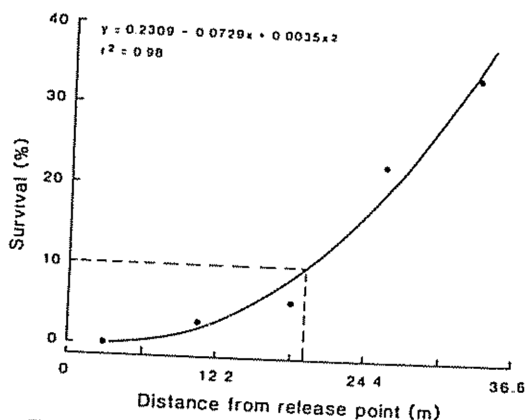

Fig. 4. Relationship of percent survival of *Culicoides furens* adults (data from both pole lines and all cage heights combined) to distance from fog release point at 24 hr after treatment.

abolic regression model (Fig. 4), from which the distance equivalent to a given percent survival can be estimated. The level of survival commensurate with human comfort is to some extent a matter of opinion and will depend also on the numbers of midges initially present. Giglioli et al. (1980) considered that 1 bite/min was equivalent to complete shirtless comfort, while Linley and Davies (1971) preferred a more conservative estimate of 1 bite/12 minutes. We will assume here that 10% survival can be taken as a working figure representing good control. Thus, from the equation in Fig. 4, the distance from the release point equivalent to 10% survival is about 19.6 m (64.3 ft). Other survival percentages of possible interest are 1, 5, 20 and 30%, which occur at about 8.6, 14.6, 26.3 and 31.5 m, respectively. Using the biting tolerance figure given by Giglioli et al. (1980), this means that a hand-held fogger will provide acceptable control out to about 20 m (66 ft) from the release point when the pretreatment biting rate is 600/hr. This is not, however, a particularly heavy biting rate compared, for example, to the 1,216 *C. furens*/hr collected from one leg only at a site in the Caribbean (Linley and Davies 1971). From the regression equation (Fig. 4), it is easy to calculate the effective range of the hand-held fogger (using naled) with respect to attaining the Giglioli et al. (1980) tolerable biting rate from different pretreatment population levels.

Naled was selected for test because of its current importance to mosquito control interests. However, it is not the most effective compound for use against *Culicoides*. In fact, according to the results of wind tunnel tests, naled was the third most ineffective of seven (Kline et al. 1981) and the most ineffective of nine (Floore 1985) chemicals evaluated. Pyrethroid compounds (resmethrin, permethrin, phenothrin) were substantially more effective and presumably would to some extent extend the range of control in thermal fog applications. As regards the general usefulness of thermal fogging as a control measure for *Culicoides*, the hand-held machine used here dispensed only 19–23 liters (5–6 gallons) of insecticides/hr, as compared to 114–151 liters (30–40 gallons)/hr put out by larger, vehicle-mounted machines. The range of control would perhaps be greater with a larger unit, although the greater dispensation rate would be offset to a large extent by the normally greater travel speed of the vehicle.

ACKNOWLEDGMENTS

We are grateful to Brian Benner, Susan Whitaker and operations personnel of Sarasota County Mosquito Control District for their cooperation during this study.

REFERENCES CITED

Floore, T. G. 1985. Laboratory wind tunnel tests of nine insecticides against *Culicoides* species (Diptera: Ceratopogonidae). Florida Entomol. 68:678–682.

Giglioli, M. E. C., E. J. Gerberg and R. G. Todd. 1980 Large scale field tests and environmental assessments of sumithion® (fenitrothion) against adult biting midges in Grand Cayman, West Indies. Mosq. News 40:1–5.

Haile, D. G., D. L. Kline, J. F. Reinert and T. L. Biery. 1984. Effects of aerial applications of naled on *Culicoides* biting midges, mosquitoes and tabanids on Parris Island, South Carolina. Mosq. News 44:178–183.

Kline, D. L., D. G. Haile and K. F. Baldwin. 1981. Wind tunnel tests with seven insecticides against adult *Culicoides mississippiensis* Hoffman. Mosq. News 41:745–747.

Linley, J. R. 1976. Biting midges of mangrove swamps and salt-marshes (Diptera: Ceratopogonidae), pp. 335–376. *In*: L. Cheng (ed.). Marine insects. North-Holland Publ. Co. (American Elsevier Publ. Co.), New York.

Linley, J. R. and J. B. Davies. 1971. Sandflies and tourism in Florida and the Bahamas and Caribbean area. J. Econ. Entomol. 64:264–278.

1986 Rathburn, Jr., C. B., J. C. Dukes, A. H. Boike, Jr., T. G. Floore and C. F. Hallmon
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The Efficacy of Formulations of Dibrom 14 in Citrus Oil for the Control of Mosquitoes and Stable Flies

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ABSTRACT

Laboratory adulticide tests of *Aedes taeniorhynchus* and *Culex quinquefasciatus* comparing Dibrom 14 to 10% Dibrom 14 in citrus oil resulted in no significant difference between the 2 formulations. Laboratory larvicide tests of citrus oil against *Cx. quinquefasciatus* were not effective at up to 5 gpa rate. Field adulticide tests against *Ae. taeniorhynchus*, *Cx. quinquefasciatus*, *Cx. nigripalpus* and *Stomoxys calcitrans* comparing 10% Dibrom 14 in citrus oil to 10% Dibrom 14 in soybean oil resulted in slightly better mortality with the soybean oil formulation. Respiratory irritation evaluations of field ULV sprays of 10% Dibrom 14 in citrus oil and 10% Dibrom in soybean oil were similar when sprayed at 5 psi air pressure, but the citrus oil formulation was considerably less irritating when sprayed at 2 psi. Spray droplets of Dibrom 14 and various formulations of Dibrom 14 in citrus oil all showed some damage to black acrylic lacquer automotive paint finishes.

INTRODUCTION

Several articles have demonstrated the insecticidal activity of citrus oil. Su et al. (1972) showed that lyophylized oils from citrus products were highly toxic to cowpea and rice weevils. Styer and Greany (1938) also demonstrated the toxicity of citrus peel oil and oil components (limonene) to the Caribbean fruit fly. Of more specific interest, Shepard (1983) demonstrated the insecticidal activity of volatile peel oil to several insects including the stable fly and house fly. In this research, tropical application of 1 μl of orange peel oil were shown to be toxic to the stable fly.

Dibrom 14 (naled) is presently labeled and used for control of mosquitoes and stable flies by ground ultra low volume (ULV) sprays. Because naled is a respiratory irritant, it is diluted in oils such as heavy aromatic naphtha (HAN) or soybean oil to reduce the irritation. Based on the toxicity of citrus oil to insects, it appeared that this oil might be an ideal diluent for use in Dibrom 14 formulations for ULV sprays. Therefore, the following research was designed to demonstrate the effectiveness of citrus oil and Dibrom 14-citrus oil formulations for the control of mosquitoes and stable flies.

METHODS

The citrus oil used in all tests was Citric Formula 1 (concentrate) manufactured by MJM Laboratories of Orlando, Florida. The active ingredient was distilled, stabilized citric oils (D-limonene). Commercially available Dibrom 14 (85% naled) and refined soybean oil were also used in the tests. The *Aedes taeniorhynchus* (Wied.), *Culex quinquefasciatus* Say, *Culex nigripalpus* Theobald and *Stomoxys calcitrans* (L.) used in the tests were from insecticide susceptible laboratory colonies.

The laboratory adulticide tests of Dibrom 14 and 10% Dibrom 14 in citrus oil were conducted in a wind tunnel using caged *Ae. taeniorhynchus* and *Cx. quinquefasciatus* as described by Rathburn et al. (1982). The data obtained were subjected to probit analysis for comparison of toxicity.

The field adulticide tests were conducted in the same beach residential area and using the same methods as described by Rathburn et al. (1981). Six cages of mosquitoes, 2 of *Ae. taeniorhynchus*, 2 of *Cx. quinquefasciatus* and 2 of *Cx. nigripalpus*, each containing 25 females each, were attached to poles. One cage of each species was placed at 6 ft and another at 2 ft above ground. The poles with cages attached were placed in 3 lines a block (600 ft) apart and at 165 and 330 ft downwind and perpendicular to the first swath of the aerosol generator. A second and third swath were applied 1 and 2 blocks (300 and 600 ft) upwind of the first swath. A like number of cages (12) of each species were used as untreated controls for each test. The adult *S. calcitrans* used in the tests were 3 days old and were handled in the same manner as the mosquitoes. The tests were conducted between the hours of 8:00 and 11:00 P.M. The temperatures during the tests ranged from 75 to 81°F, wind velocities from 3 to 7 mph and relative humidities from 63 to 74%. Mortality counts in all tests were made at approximately 12 hrs posttreatment. In addition, mortality counts of *S. calcitrans* were made at 0.5 hr posttreatment to determine knockdown. All tests were conducted with a Leco HD ULV aerosol generator operated at a vehicle speed of 10 mph. The discharge rate, 10 fl. oz/min, was calibrated prior to testing and the actual discharge for each test was determined. All tests were within 10% of the calibrated rate.

Irritation studies were conducted in conjunction with the 4 field adulticide tests comparing 10% Dibrom 14 in citrus oil to 10% Dibrom 14 in soybean oil. The irritation of each ULV spray formulation was evaluated by 3 subjects stationed at 50 ft downwind of the spray. Each subject evaluated each ULV application as to degree of eye burn, nose burn, skin (face) burn, throat burn, breathing (coughing), odor and taste. The rating scale used was 0 to 10 with 0 being no irritation and 10 being too severe to remain in the spray.

Panels of General Motors Corp. automotive paint standards, obtained from E. I. DuPont DeNemours and Co., were used to determine the effects of sprays of Dibrom 14 and citrus oil alone, and in various combinations, on automotive paint. The spray droplets were produced by a DeVilbiss No. 155 nozzle at 15 psi in the laboratory, and were collected on black acrylic lacquer paint panels placed 4 ft from the nozzle. The droplet size produced was approximately 35 μm VMD with individual droplets ranging from < 5 μm to approximately 150 μm. Damage was assessed 24 hrs posttreatment on portions of the panels which received no cleaning, those which were washed with liquid soap and water, and those which were washed with soap and water and then waxed with Blue Poly automotive cleaner-wax. Droplets which produced pitting of paint were said to have caused damage. The damage to the paint was assessed as no damage visable under a stereoscopic microscope at 10X magnification (1) and damage visable with the unaided eye (2).

Limited tests of citrus oil as a larvicide were conducted in 4 sq ft pans containing 16 liters of tap water and 200 third instar *Cx. quinquefasciatus* larvae per pan. Two tests were conducted, one at a 2 gpa and one at a 5 gpa rate. Each test consisted of one treated and one control pan and treatment was by means of a pipette. The rates selected were those recommended for other oil larvicides such as Golden Bear larvicidal oils, Flit MLO and the Florida mosquito larvicidal oil. Percent mortality was determined at 24 hrs and compared to the percent mortality obtained with the untreated larvae.

RESULTS

The results of the laboratory adulticide tests comparing Dibrom 14 alone and 10% Dibrom 14 in citrus oil are shown in Table 1. It is apparent from these tests that the addition of citrus oil did not result in an increase in mosquito mortality. There was no significant increase in the toxicity of Dibrom 14 at either the LC_{50} or LC_{90} dosage when the formulation of 10% Dibrom 14 in citrus oil was compared to Dibrom 14 alone against adults of *Ae. taeniorhynchus* or *Cx. quinquefasciatus*.

The results of the field tests comparing 10% Dibrom 14 in either citrus oil or soybean oil against 3 species of mosquitoes are shown in Table 2. Although the citrus oil formulation appeared to give poorer mortality than the soybean oil formulation against *Cx. quinquefasciatus*, the bulk of the data demonstrate only slight differences between the two formulations.

The field tests of the 2 oil formulations of Dibrom 14 against *S. calcitrans* are shown in Table 3. These tests showed the soybean oil formulation produced a hgher percent mortality than the citrus oil formulation, especially at the 0.5 hr posttreatment time.

Label recommendations for 10% Dib-

Table 1. Laboratory adulticide tests of Dibrom 14 compared to a formulation of 10% Dibrom 14 in citrus oil against adults of *Aedes taeniorhynchus* and *Culex quinquefasciatus*

Formulation	reps	Lethal concentrations in mg. Dibrom 14 per ml. acetone[1] LC_{50}	95% C.L.	LC_{90}	95% C.L.
			Aedes taeniorhynchus		
Dibrom	8	0.033	0.030-0.036	0.104	0.083-0.141
10% Dibrom 14 in citrus oil	8	0.025	0.019-0.033	0.092	0.057-0.314
			Culex quinquefasciatus		
Dibrom 14	8	0.067	0.062-0.073	0.161	0.139-0.195
10% Dibrom 14 in citrus oil	8	0.074	0.067-0.086	0.148	0.119-0.209

[1] LC_{50}, LC_{90} dosages and Confidence Limits (C.L.) obtained by probit analysis

Table 2. Field tests of 10% Dibrom 14 in soybean oil compared to 10% Dibrom 14 in citrus oil applied with a Leco HD ULV aerosol generator at 10 fl. oz. per men at 10 mph against caged adult mosquitoes.

Mosquito species	Diluent	Leco air psi	Wind mph	Temp °F	R.H. %	Corrected % mortality at downwind distance in feet 165	330	Avg.
Ae. taeniorhynchus	citrus oil	5	5	75	74	100	96.5	98.2
		2	3	81	63	100	96.9	98.5
	soybean oil	5	4	77	73	100	100	100
		5	7	80	66	100	100	100
Cx. quinquefasciatus	citrus oil	5	5	75	74	70.6	38.3	53.6
		2	3	81	63	79.6	80.1	79.9
	soybean oil	5	4	77	73	99.2	89.6	94.3
		5	7	80	66	94.6	84.0	89.6
Cx. nigripalpus	citrus oil	5	5	75	74	100	89.6	93.3
		2	3	81	63	100	100	100
	soybean oil	5	4	77	73	100	100	100
		5	7	80	66	100	100	100

rom 14 in HAN specify a nozzle pressure of 1.5 psi in order to obtain an effective droplet size because of the low visocity of the HAN formulation. Since citrus oil has a low viscosity, it was also tested at 2 psi. Although a slight increase in mortality was noted when citrus oil was sprayed at 2 psi with mosquitoes (Table 2) this was not the case with *S. calcitrans* (Table 3) in which poorer results were obtained with the lower pressure. The reason for this difference is not known. The mortalities shown in Tables 2 and 3 were corrected for control mortality which averaged 1.5% for *Ae. taeniorhycnhus*, 0% for *Cx. quinquefasciatus*, 1% for *Cx. nigripalpus* and 0.5% for *S. calcitrans* at 12 hr posttreatment, and 0% for *S. calcitrans* at 0.5 hr posttreatment.

Irritation evaluations of ground ULV sprays of 10% Dibrom 14 in citrus oil compared to 10% Dibrom 14 in soybean oil are shown in Table 4. The average irritation experienced by the 3 subjects with the Dibrom 14 formulation in citrus oil and in the soybean oil were similar when sprayed at a machine pressure of 5 psi. When the pressure was reduced to 2 psi with the citrus oil, the irritation was considerably less. Applications at this low pressure are not recommended and were not used with soybean oil because the aerosol droplets produced are too large for effective downwind kill.

The results of the effects of citrus oil, Dibrom 14 and various formulations of citrus oil and Dibrom 14 on black acrylic lacquer automotive paint are shown in Table 5. There was no damage to the automotive paint by the citrus oil when the panel was washed or washed and waxed, but the unwashed panel showed damage visable to the unaided eye. All other formulations tested resulted in damage which was visable to the unaided eye whether not cleaned, washed only or washed and waxed. It should be noted that in previous

Table 3. Field tests of 10% Dibrom 14 in soybean oil compared to 10% Dibrom 14 in citrus oil applied with a Leco HD ULV aerosol generator at 10 fl. oz. per min. at 10 mph against caged adult *Stomoxys calcitrans*.

Posttreatment time in hours	Diluent	Leco air psi	Wind mph	Temp °F	R.H. %	Corrected % mortality at downwind distance in feet 165	330	Avg.
0.5	citrus oil	5	5	75	74	91	65	78
		2	3	81	63	53	50	52
	soybean oil	5	4	77	73	98	99	98
		5	7	80	66	100	99	99
12.0	citrus oil	5	5	75	74	99	93	96
		2	3	81	63	85	71	78
	soybean oil	5	4	77	73	100	100	100
		5	7	80	66	100	100	100

Table 4. Irritation evaluations of ground ULV aerosols of 10% Dibrom 14 in citrus oil compared to 10% Dibrom 14 in soybean oil applied with a Leco HD ULV generator at 10 fl. oz. per min. and indicated air pressures.

Irritation type	Average rating of 3 subjects[1] Test 1 citrus oil @ 5 psi	Test 1 soybean oil @ 5 psi	Test 2 citrus oil @ 2 psi	Test 2 soybean oil @ 5 psi
Eye burn	7	7	2	6
Nose burn	5	5	1	5
Skin (face) burn	1	0	0	0
Throat burn	6	4	1	5
Breathing (cough)	8	6	1	5
Odor	6	3	1	3
Taste	4	0	0	2

[1]Rating scale: 0 = no irritation. 10 = too severe to remain in spray

Table 5. Effects of citrus oil, various formulations of Dibrom 14 in citrus oil, and Dibrom 14 on black acrylic lacquer automotive paint panels

Formulation	Paint damage[1] 24 hr posttreatment cleaning: none	washed only	washed & waxed
100% citrus oil	2	0	0
25% Dibrom 14-75% citrus oil	2	2	2
50% Dibrom 14-50% citrus oil	2	2	2
75% Dibrom 14-25% citrus oil	2	2	2
100% Dibrom 14	2	2	2

[1]Damage Code: 0 = no damage visible under 10X magnification
1 = damage visible only under 10X magnification
2 = damage visible with unaided eye

unpublished tests, 10% Dibrom in soybean oil did not damage black acrylic automotive paint, even with no cleaning. A formulation of 10% Dibrom in HAN resulted in the same damage as that obtained with the Dibrom-citrus oil formulations when the panels were not cleaned or washed only, but there was no visable damage after the panels were washed and waxed.

The limited laboratory larvicide test of citrus oil against third instar *Cx. quinquefasciatus* larvae gave 12.1% mortality at a dosage rate of 2 gpa and 42.0% mortality at a dosage rate of 5 gpa. The latter rate is the maximum dosage recommended for most oil larvicides such as Golden Bear oils and the Florida Mosquito Larvicide oil with which citrus oil would compete for usage. The mortality data obtained were corrected for check mortality which averaged 1% in the 2 gpa test and 0% in the 5 gpa test. Based on projections of the mortalities obtained at the rates tested, it would require 20 gpa of citrus oil to obtain a mortality of 90% and a rate of 50 gpa to obtain a mortality of 99%. Because of the poor mortality obtained in these tests, additional tests to determine an effective dosage were not conducted.

CONCLUSIONS

As stated previously, Shepard (1983) obtained excellent kill of stable flies with topical applications of 1 µl of orange peel oil. This dosage is very high considering the possible deposition on a fly from normal ULV applications, since 1 µl is equivalent to over one half million 15 µm droplets, the size normally produced by ground ULV application equipment. This fact may account for the poor results obtained in the tests reported here compared to those of Shepard.

Except for the mosquito larvicide tests, it was not the objective of these tests to determine the toxicity of citrus oil alone, but to determine the feasibility of increasing the toxicity, reducing the respiratory irritation or reducing the damage to automotive paint by substituting citrus oil for soybean oil or HAN in ULV spray formulations. Although citrus oil did not increase the toxicity of Dibrom formulations, it could be a suitable substitute for soybean oil or HAN in ULV sprays of Dibrom for adult mosquito control, particularly if machine pressures are reduced.

LITERATURE CITED

Rathburn, C. B. Jr., A. H. Boike, Jr., C. F. Hallmon and R. L. Wells. 1981. Field tests of insecticides applied as ULV sprays by ground equipment for the control of adult mosquitoes. Mosq. News 41(1):132-135.

Rathburn, C. B. Jr., A. H. Boike, Jr., L. A. Sizemore and M. W. Peters. 1982. Laboratory tests of mosquito adulticides. J. Fla. Anti-Mosq. Assoc. 53(2):92-96.

Sheppard, D. Craig. 1983. Toxicity of citrus peel liquids to the house fly and red imported fire ant. J. Agric. Entomol. 1(2):95-100.

Styer, S. C. and D. D. Greany. 1983. Increased susceptibility of laboratory-reared vs. wild Caribbean fruit fly, *Anastrepha suspensa* (Loew) (Diptera: Tephritidae), larvae to toxic citrus allelochemics. Environ. 12(5):1606-1608.

Su, Helen C. F., Roy D. Spiers and Patrick G. Mahany. 1972. Toxicity of citrus oils to several stored-products insects: Laboratory evaluation. J. Econ. Entomol. 65(5):1438-1441.

Effects of diflubenzuron on three estuarine decapods, *Callinectes* sp., *Palaemonetes pugio* and *Uca pugilator*

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ABSTRACT

Two studies were conducted to determine chronic effects of a 0.045 kg AI/ha diflubenzuron surface application on juvenile stages of 3 estuarine decapods, *Callinectes* sp., *Palaemonetes pugio* (Holthuis), and *Uca pugilator* (Bosc). In the first study the test organisms were present in the pools at the time of treatment. the mortality ranged from 40 to 60 percent and occurred within 11 days posttreatment. No significant mortality was observed in the second study where the organisms were introduced 7 days posttreatment. Chemical analysis of the water column indicated diflubenzuron concentrations as high as 3.6 and 0.69 µg/l in studies 1 and 2 respectively at the time of species introduction.

INTRODUCTION

Diflubenzuron (Dimilin®) is an insect growth regulator (IGR) that has shown potential as a larvicide for salt marsh mosquitoes (Rathburn and Boike 1975, Rogers

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1405

COMBINATION GROUND AND AERIAL ADULTICIDE APPLICATIONS AGAINST MOSQUITOES IN AN ARKANSAS RICELAND COMMUNITY[1,2]

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ABSTRACT. Simultaneous ground and aerial adulticide applications were evaluated against riceland mosquitoes in Stuttgart, AR, during July 1985. Naled was aerially applied at 52.6 ml/ha over 10.4 km² surrounding the city. Ground ULV applications of a mixture of malathion, HAN and resmethrin/PBO (1:1:0.0625) were applied within the city at a rate of 221.8 ml/min at 24 kph. Adult populations of *Anopheles quadrimaculatus* and *Psorophora columbiae* were reduced at 24 hr but resurgence of *Ps. columbiae* was evident at 48 hr posttreatment. Posttreatment data indicated that movement of both mosquitoes occurred along the path of prevailing wind

INTRODUCTION

Anopheles quadrimaculatus Say and *Psorophora columbiae* (Dyar and Knab) are the two primary pest mosquitoes found in Stuttgart, AR, a community in the rice growing region of eastern Arkansas (Meisch and Coombes 1975). Control of *An. quadrimaculatus* and *Ps. columbiae* in the Stuttgart area currently is attempted by ultra low volume (ULV) larviciding with *Bacillus thuringiensis* var. *israelensis (Bti)* (Sandoski et al. 1985) in ricefields surrounding the community and ULV adulticiding with ground (Mount et al. 1972) and aerial (Meisch and Mount 1978) sprays within and surrounding the community. Though excellent control may be achieved initially following ULV ground adulticiding, posttreatment dispersal of mosquitoes from adjacent non-treated areas often necessitates nightly adulticide applications (Walker and Meisch 1982). Knowledge of this movement is necessary to effectively implement community control. Horsfall (1942) stated that the flight range of *An. quadrimaculatus* was approximately 2 miles (3.2 km) while that of *Ps. columbiae* was up to 8 miles (19.9 km). Though *An. quadrimaculatus* appears to be a weak flier in comparison to *Ps. columbiae*, Horsfall (1955) later asserted that the flight range of *An. quadrimaculatus* was not completely resolved.

Rapid replacement of *An. quadrimaculatus* subsequent to mosquito adulticide treatments in Suttgart mandates the need for a better understanding of the flight behavior of this species. The long flight range of *Ps. columbiae*, a floodwater mosquito, precludes larviciding for this species; therefore, control tactics for Stuttgart are predicated upon larviciding for *An. quadrimaculatus* and adulticiding for both species.

During the summer of 1985, a study was conducted to determine if an effective chemical barrier could be created to prevent the dispersal of these two mosquito species into the community of Stuttgart. The effort was directed primarily towards *An. quadrimaculatus* since it was suspected that *Ps. columbiae* would quickly penetrate the barrier. The specific objectives of the study were to determine barrier persistence against each species, direction from which mosquito reinfestation occurred, and relation of wind direction to mosquito movements and barrier effectiveness.

MATERIALS AND METHODS

On the evening of July 3, 1985, between 2200 and 0100 hr, a twin-engine Piper® Aztec aircraft was used to apply 80% naled at 52.6 ml/ha over 10.4 km² surrounding the city of Stuttgart, AR. The aircraft was equipped with a tail-mounted boom containing 5 Teejet® 8535 nozzles with D_2 orifices. Altitude was 60–90 m and air speed was 241 kph during application. The treated area comprised a zone 1.6 km in width surrounding the city with additional extensions of approximately 1.6 km to the south and west against the direction of prevailing winds.

Ground ULV applications were conducted during the same period within the community

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using truck-mounted LECO® cold aerosol generators. A mixture (1:1:0.0625) of malathion (91%), heavy aromatic naphtha (HAN) and resmethrin/PBO (18%/54%) was applied at a rate of 221.8 ml/min while traveling at 24 kph. The entire city (ca. 6 km^2) was treated by the ground units on the evenings of July 2 and 3. Intensive larviciding was conducted July 2, on 1,758 ha of rice surrounding the community using Beecomist® applied *Bti*. Temperature during both aerial and ground applications was 28 ± 3°C, and wind velocity was 8–13 kph with gusts up to 16 kph from the southwest. Efficacy of the adulticide treatment was intensively monitored during the study with the 3 following methods.

RESTING STATIONS. Box-type resting stations (76.2 × 45.7 × 30.5 cm) were monitored daily for *An. quadrimaculatus* for 3 days pretreatment and 2 days posttreatment. Resting station design differed slightly from that of Edman et al. (1968) as follows: the inner cloth sleeve was omitted and the interior was painted red rather than black. Three stations were located within the city and 3 were placed within the surrounding buffer zone. One additional station placed outside of the treatment area served as a control. Collections from resting stations were made with hand-held, battery-powered aspirators described by Meek et al. (1985). Each collection was labelled, transported to the laboratory and separated by sex. Data were subjected to ANOVA. Pre- and posttreatment means for each sex were calculated for collections made within the city and the surrounding buffer area. Linear contrasts (SAS 1985) were used to demonstrate significant reductions in *An. quadrimaculatus* density at 12 and 36 hr posttreatment based on counts taken for 3 days pretreatment.

LANDING RATES. Landing rates were determined for both species 2 days pretreatment and 2 days posttreatment along 4 transects (N,S,E and W) that intersected at the center of town. Each transect was divided into 3 zones that included the area within the city treated by ground (Zone 1), the area receiving both ground and aerial treatment (Zone 2) and the aerially treated zone (Zone 3). Eight stations were established at 0.4 km intervals along each transect; thus, each transect covered a distance of 3.2 km from the center of the city in one of the 4 cardinal directions. The first station was located 0.4 km from the center. Zones 1 and 3 each contained 3 stations while zone 2 contained 2 stations along each transect. Four additional stations established 8.0 km outside the treated area served as controls. Two persons sampled each transect. Each station was sampled by waiting after arrival for 1 min and then aspirating alighted mosquitoes for 1 min. Collections from each station were labelled and transported to the laboratory. Data were subjected to ANOVA, and means were calculated by day for each transect and zone. Data were corrected for control reductions with Abbott's formula. Transect means were separated by the least-squares means procedure (SAS 1985), and percentage reductions were calculated for posttreatment counts. Standard errors and percentage reductions were calculated for means of each combination of day and zone.

SENTINEL CAGE OBSERVATIONS. Sentinel cages were used to assess treatment effectiveness against *An. quadrimaculatus*. Adult *An. quadrimaculatus* were collected with battery-powered aspirators from a barn located 15 km S of Stuttgart, AR. Collections consisted of 71, 12, and 17% blooded females, unblooded females, and males, respectively. Aspirator tubes containing mosquitoes were transported to the laboratory in insulated chests with damp paper toweling to maintain humidity. Mosquitoes were anesthetized with CO_2 and transferred to modified World Health Organization insect test kits (Roberts 1982) at a density of 20 mosquitoes/kit. Sentinel cages were placed along transects at each landing rate station (8 cages/transect). Four sentinel cages placed outside the treatment area served as controls. Sentinel cages were positioned at each station just before dusk and picked up immediately after treatments on the evenings of July 2 and 3. Mortality was observed 24 hr posttreatment. Percentage mortality data were corrected with Abbott's formula, transformed (arc sin) and subjected to ANOVA for testing the hypotheses that mortality among treatment regimes and among transects was equal. Means calculated for each treatment regime and transect were separated using the least-squares means procedure (SAS 1985).

RESULTS AND DISCUSSION

Mean pre- and posttreatment counts by zones and posttreatment percentage reductions of *An. quadrimaculatus* collected from resting stations are shown in Table 1. No reductions were observed in check counts at 12 or 36 hr posttreatment. Both longer lasting control and higher levels of reduction were achieved in the aerially treated buffer zone. Reductions of female and male mosquitoes within this zone at 12 hr were 90 and 77%, and at 36 hr, 81 and 84%, respectively. Posttreatment counts from the ground treated zone, inside the city, indicated reductions of only 60 and 56% at 12 hr, and 7 and 39% at 36 hr for female and

Table 1. Mean daily collections and posttreatment percentage reductions of *Anopheles quadrimaculatus* adults from resting stations in and near Stuttgart, AR, during July, 1985.

Zone*	Pretreatment		12 hr posttreatment		36 hr posttreatment	
	Female	Male	Female	Male	Female	Male
1	79.1	84.6	31.7	37.3	73.7	52.0
± S.E.	± 44.3	± 38.0	± 24.7	± 32.5	± 58.2	± 36.4
(% reduction)			(59.9)	(55.9)	(6.8)	(38.5)
2	360.2	647.4	37.0**	148.3**	68.3**	106.0**
± S.E.	±171.3	±317.0	± 33.6	±137.9	± 57.9	±103.0
(% reduction)			(89.7)	(77.1)	(81.0)	(83.6)
Check	103.3	135.7	192.0	296.0	129.0	215.0
± S.E.	± 16.3	± 45.1	—	—	—	—
(% reduction)			(0.0)	(0.0)	(0.0)	(0.0)

* Zone 1 was ground-treated and inside the city. Zone 2 was the aerially treated buffer zone.
** Significant reductions (P < 0.05) indicated by linear contrasts.

male mosquitoes, respectively. This indicated that initial control was lacking in the ground treated zone and that survivors of the ground ULV treatment and recent emergees may have accounted for the density observed after 36 hr.

Mean landing rates and posttreatment percentage reductions of both species are shown in Table 2 for each of the 3 landing rate zones. An initial reduction was indicated for both species in all 3 zones. No reductions were observed for *Ps. columbiae* at 48 hr posttreatment. Control of *An. quadrimaculatus* was achieved for 48 hr within the city (ground treated zone), though no reductions of this species were indicated by landing rate counts at 48 hr in the zone receiving ground and aerial treatments or in the aerially treated zone. Inward dispersal of mosquitoes from surrounding untreated areas would likely account for the increased landing rates in the outer zones at 48 hr posttreatment. Results of 48 hr posttreatment landing rates contradict those obtained from resting stations. The fact that resting stations measure the entire *An. quadrimaculatus* adult population whereas landing rates measure only blood-feeding females may account for this contradiction. Female mosquitoes collected from resting stations within the city at 36 hr may have been recent local emergees or newly migrated and not yet members of the biting population.

Fluctuations in both *Ps. columbiae* and *An. quadrimaculatus* density along each transect are shown in Table 3. Adequate reduction of *An quadrimaculatus* was achieved at 24 hr posttreatment except along the west transect. However,

Table 2. Mean landing rates (mosq./min.) and posttreatment percentage reductions of *Anopheles quadrimaculatus* and *Psorophora columbiae* by sample period and zone in and near Stuttgart, AR, during July, 1985.

Sampling*** Period	Zone Means ± S.E.*,**							
	Ground		Ground and aerial		Aerial		Check	
	Anopheles	*Psorophora*	*Anopheles*	*Psorophora*	*Anopheles*	*Psorophora*	*Anopheles*	*Psorophora*
−48 hr	1.33Aa	3.33Aa	1.75ABa	4.87AaB	2.92Ba	13.50Ba	1.50	26.75
	±0.40	± 0.86	± 0.67	± 1.42	± 0.51	± 1.99	± 0.43	± 6.48
−24 hr	0.92Aa	2.67Aa	1.37ABa	8.12Ba	2.42Ba	12.17Ba	4.25	57.25
	± 0.36	± 0.99	± 0.32	± 2.66	± 0.53	± 2.11	± 0.74	±13.29
24 hr	0.25Aa	0.67Aa	0.62Aa	2.25Ab	1.08Ab	4.17Ab	2.25	47.00
	± 0.18	± 0.38	± 0.42	± 0.98	± 0.36	± 1.89	± 0.41	± 6.03
(% reduction)	(71.6)	(77.7)	(49.3)	(65.4)	(48.4)	(67.5)	(21.7)	(0.0)
48 hr	0.33Aa	3.67Aa	2.67Aa	8.67Aab	3.50Aab	17.33Aab	6.00	83.00
	± 0.33	± 2.73	± 2.67	± 6.23	± 1.75	± 6.24	± 2.16	±43.15
(% reduction)	(70.7)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)

* Means for a particular species in the same row followed by the same upper case letter are not significantly different (P ≥ 0.05) by least-squares means.
** Means in the same column followed by the same lower case letter are not significantly different (P ≥ 0.05) by least-squares means.
*** Percent reductions based on average of pretreatment landing rates.

Table 3. Mean landing rates (mosq./min.) and posttreatment percentage reductions of *Anopheles quadrimaculatus* and *Psorophora columbiae* by transect and sampling period in and near Stuttgart, AR, during July, 1985.

Sampling*** period	Transect means*,** E	N	S	W	Check
−48 hr *Anopheles*	1.75Aab	3.25Aa	2.62Aa	0.50Bb	1.50
Psorophora	8.75Aa	6.00Aa	7.37BCa	8.00ABa	26.75
−24 hr *Anopheles*	0.75Aa	2.25ACa	1.62ABa	1.75Aba	4.25
Psorophora	6.37Aab	4.75ABb	8.87ABab	10.37Aa	57.25
24 hr *Anopheles*	0.25Aa	0.62Ba	0.25Ba	1.50Ba	2.25
(%reduction)	(74.4)	(71.3)	(84.9)	(0)	(21.7)
Psorophora	4.00Aa	0.12Ba	2.50Ca	2.87Ba	47.00
(% reduction)	(47.1)	(97.8)	(69.2)	(68.8)	(0)
48 hr *Anopheles*	rain	0.50BCb	3.50Aab	3.50Aa	6.00
(% reduction)		(81.8)	(0)	(0)	(0)
Psorophora	rain	1.75ABb	17.50Aa	16.00Aa	83.00
(% reduction)		(67.5)	(0)	(0)	(0)

* Means for a particular species in the same column followed by the same upper case letter are not significantly different ($P \geq 0.05$) by least-squares means.

** Means in the same row followed by the same lower case letter are not significantly different ($P \geq 0.05$) by least-squares means.

*** Percent reductions based on average of pretreatment landing rates.

landing rates had increased at 48 hr along the south and west transects, primarily in the 2 zones outside the city (Table 2). Sustained control in the north may have been due to insecticide drift with prevailing wind and lack of dispersal from untreated areas north of the city against prevailing wind. Data for the east transect were not obtained at 48 hr posttreatment because of heavy rains on the east side of town. Though these data are lacking, it appeared that movement of *An. quadrimaculatus* occurred from the south and west along the path of prevailing wind. These data contradict Horsfall (1955) who stated that *An quadrimaculatus* dispersed against prevailing wind to feeding sites. Movement observed in this study also may have been unrelated to feeding and merely a function of wind-directed dispersal from breeding or resting sites. Nevertheless, the data indicate that biting *An. quadrimaculatus* did not disperse back into the city within 48 hr posttreatment. Landing rate data for *Ps. columbiae* indicated results similar to those for *An. quadrimaculatus*. Initial reductions at 24 hr were followed by an increase in adult density at 48 hr. Excellent control obtained to the north of the city again was likely due to insecticide drift and lack of dispersal from the north. Resurgence along the south and west transects in all 3 zones (Table 2) at 48 hr posttreatment indicated that *Ps. columbiae* dispersed into the city along the path of prevailing wind.

Percentage mortality of sentinel *An. quadrimaculatus* due to ground applications alone and in combination with aerial applications are shown for each transect in Table 4. The mean mortalities of caged mosquitoes were low for both treatment regimes. Nevertheless, the dosage of naled applied was indeed on the lower portion of the recommended scale. Insecticide drift appeared to play a role in the

Table 4. Percentage mortality of caged *Anopheles quadrimaculatus* at 24 hr posttreatment due to ground ULV applications alone and in combination with an aerial adulticide application in and near Stuttgart, AR, during July, 1985.

Type of application	Transect means*,** E	N	S	W	Check
Ground	4.0Ab	44.0Aa	21.4Aa	3.5Ab	2.0
Ground and aerial	34.0Ba	44.4Aa	51.6Ba	52.8Ba	11.0

* Means in the same column followed by the same upper case letter are not significantly different ($P \geq 0.05$) by least-squares means.

** Means in the same row followed by the same lower case letter are not significantly different ($P \geq 0.05$) by least-squares means.

degree of mortality exhibited in the downwind portions of the treated area. Mortality of sentinel mosquitoes indicated that significantly ($P<.05$) greater control was obtained along all transects, except the north, by combination ground and aerial applications. The effect of prevailing wind on insecticide drift may have negated the difference between the 2 treatment regimes along the north transect. Also, the highest mortality of caged mosquitoes exposed to ground and aerial applications was exhibited in the south and west where resurgence was greatest at 48 hr posttreatment. These data further support the contention that reinfestation occurred along the path of prevailing wind. Extensions of the aerially treated buffer zone to the south and west may have induced the higher mortalities of sentinel mosquitoes observed along the south and west transects. If prevailing wind played a role in the effectiveness of the buffer zone, it is possible that widening the buffer selectively could reduce mosquito reinfestation from upwind areas.

The study indicates that movement of *An. quadrimaculatus* was much less rapid than that of *Ps. columbiae*. When outdoor activity and mosquito populations are at extremely high levels, such intensive applications are justifiable, but certainly not on a routine basis. Under these conditions of intensive rice culture, the concept of a perimeter buffer zone in which *An. quadrimaculatus* emergence and *Ps columbiae* dispersal might be inhibited by both larvicidal and adulticidal agents seems a plausible approach to community protection from riceland mosquitoes. The level of protection achieved should be correlated with the dispersal rate of the most mobile target mosquito and the width of the buffer.

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References Cited

Edman, J. D., F. D. S. Evans and J. A. Williams. 1968. Development of a diurnal resting box to collect *Culiseta melanura* (Coq.). Am. J. Trop. Med. Hyg. 17:451–456.

Horsfall, W. R. 1942. Biology and control of mosquitoes in the rice area. University of Arkansas Agricultural Experiment Station Bulletin No. 427, 46 pp.

Horsfall, W. R. 1955. Mosquitoes: Their bionomics and relation to disease. The Ronald Press Company, New York. 723 pp.

Meek, C. L., M. V. Meisch and T. W. Walker. 1985. Portable, battery-powered aspirators for collecting adult mosquitoes. J. Am. Mosq. Control Assoc. 1:102–105.

Meisch, M. V. and L. E. Coombes. 1975. A pilot abatement district in the rice growing areas of Arkansas. Proc. N.J. Mosq. Control Assoc. 62:190–195.

Meisch, M. V. and G. A. Mount. 1978. Ultra low volume aerial application of insecticides for mosquito control in Arkansas riceland communities. Mosq. News 38:343–346.

Mount, G. A., M. V. Meisch, J. T. Lee, N. W. Pierce and K. F. Baldwin. 1972. Ultra low volume ground aerosols of insecticides for control of rice field mosquitoes in Arkansas. Mosq. News 32:444–446.

Roberts, R. H. 1982. Efficacy of ground ULV aerosols of three pyrethroids against two mosquito species. Mosq. News 42:109–112.

Sandoski, C. A., M. M. Yates, J. K. Olson and M. V. Meisch. 1985. Evaluation of Beecomist®-applied *Bacillus thuringiensis* (H-14) against *Anopheles quadrimaculatus* larvae in rice fields. J. Am. Mosq. Control Assoc. 1:316–319.

SAS Institute Inc. 1985. SAS® User's Guide: Statistics, Version 5 Edition. Cary, NC: SAS Institute Inc. 956 pp.

Walker, T. and M. V. Meisch. 1982. Evaluation of pyrethrin and two synthetic pyrethroids alone and in mixtures with malathion as ULV ground aerosols against riceland mosquitoes. Mosq. News 43:167–171.

1985 Floore, T. G.
Laboratory Wind Tunnel Tests of Nine Insecticides Against Adult Culicoides Species (Diptera: Ceratopogonidae)
Florida Entomologist 68: 678-682 (Amvac Ref. #1403)

LABORATORY WIND TUNNEL TESTS OF NINE INSECTICIDES AGAINST ADULT *CULICOIDES* SPECIES (Diptera: Ceratopogonidae)

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ABSTRACT

Nine insecticides were tested against field collected adult sand flies in a non-thermal wind tunnel. *Culicoides mississippiensis* Hoffman represented more than 90% of the total sand flies tested. The insecticides included 5 organophosphate (OP) compounds (malathion, naled, fenitrothion, fenthion, and chlorpyrifos), 3 pyrethroids (resmethrin, phenothrin and permethrin) and a combination of malathion/resmethrin (90:1). Mortality was recorded at 1, 4, and 24 h posttreatment. Malathion, the standard, was intermediate among the OP compounds in effectiveness at the 24-h, LC_{90}, level. The OP compounds exhibited poor knockdown at the LC_{90} dosage levels and the addition of resmethrin to malathion only slightly increased the knockdown of malathion. The pyrethroids exhibited nearly 100% knockdown 1 h posttreatment at both the LC_{50} and LC_{90} levels, but some individual sand fly recovery occurred 24 h later.

RESUMEN

Se probaron en un túnel de viento no-termal, 9 insecticidas contra moscas de arena colectadas en el campo. *Culicoides mississippiensis* Hoffman representó más de un 90% de todas las moscas de arena probadas. Los insecticidas incluyeron 5 compuestos de organofosfatos (malathion, naled, fenitrothion, fenthion, y chlorpyrifos), 3 pyrethroids (resmethrin, phenothrin, y permethrin), y una combinación de malathion/resmethrin (90:1). Se registró la mortalidad a la 1, 4, y 24 horas después del tratamiento. Malathion, el patrón, fue intermedio en su infectividad entre los compuestos de organofosfatos a las 24 hrs., a un nivel de CL_{90} (CL=concentración letal). La rapidez con que los compuestos de organofosfatos ejercieron mortalidad fue muy lenta con la dosis de LC_{90}, y añadiendole resmethrin al malathion solo aumentó la mortalidad del malathion. Los pyrethroids demostraron casi un 100% de mortalidad 1 hr. después del tratamiento a ambos niveles de CL_{50} y CL_{90}, pero algunas moscas de arena se recuperaron 24 hrs. después.

Biting midges or sand flies (*Culicoides* spp.) are annoying insect pests in some coastal areas of Florida. They easily pass through standard window screen and may be annoying indoors as well as outdoors (Goodin 1980). Linley and Davies (1971) suggested that sand fly annoyance was detrimental to tourism in some areas of the state. Medically, *Culicoides* have been implicated as vectors of several pathogens of wild and domestic animals and man (Blanton and Wirth 1979).

In the past, sand fly control has been directed against the larval stages either as source reduction or as chemical application (Harrington and Bidlingmayer 1958, Rogers 1962, Clements and Rogers 1968). However, increasing environmental concerns and controls are making larval control impractical and unacceptable. Adult sand fly control has been limited to repellents, exclusion screens and/or insect repellent jackets (Schreck et al. 1979a, Schreck et al. 1979b). Giglioli et al. (1980), Kline et al. (1981), and the West Florida Arthropod Research Laboratory (WFARL) have initiated research to determine if adult sand flies may be controlled by routine adult mosquito control methods. This paper reports results obtained at WFARL on 9 adulticides; 5 organophosphate (OP) compounds (malathion, naled, fenitrothion, fenthion, and chlorpyrifos), 3 pyrethroids (resmethrin, permethrin, and phenothrin) and a malathion/resmethrin (90:1) mixture tested in a laboratory wind tunnel against field collected adult sand flies.

Materials and Methods

Adult sand flies were collected with a modified CDC trap using dry ice as an attractant. The traps were placed at the field site in the late afternoon and the following morning they were returned to the laboratory. The sand flies were collected in 90 mm diam X 165 mm long cylindrical cardboard containers and held in a 44 X 35 X 30 cm styrofoam cooler (Floore 1982). At the laboratory, actively flying adults were transferred to a 90 mm diam X 83 mm long cardboard container covered with a cotton pad containing a 10% sugar water solution. The sand flies were tested within 6 h of returning to the laboratory. The cardboard containers were replaced as needed, but usually lasted several weeks.

The sand flies were anesthetized with CO_2 in the small container and ca. 70 flies were aspirated into a number of other smaller cardboard containers. The bottom of all the containers were replaced with a 150 mm diam piece of 42/40 mesh polyethylene screen fabric (TEKO, Inc., NY) which was secured to the bottom of the container by the ring portion of a cardboard lid and masking tape. A cardboard lid covered the top of the container. The caged sand flies were placed in the test room for 30 min prior to testing to acclimate the flies to the room's environmental conditions (24 ± 5°C and 75 ± 5% R.H.).

The wind tunnel (Rathburn 1969 and Rathburn and Boike 1972) was modified (Ruff, WFARL, unpublished) to accept the cardboard container by inserting a 137 mm diam and 76 mm long wood and metal sleeve into the wind tunnel chamber on the atomizer side of the chamber cover. The sleeve narrowed from 137 mm to 90 mm to accept the container. The wind velocity channeled through the sleeve was ca 2.7 m/sec. (Alnor Instruments, Chicago). The sand flies were observed to be positively phototropic and were attracted to the screened end of the containers toward the light of four 6 V DC lantern bulbs and away from the removable lid.

The container of sand flies with the lid removed was inserted in the wind tunnel with the container's open end toward the atomizer. The sand flies were exposed to 0.5 ml of an insecticide solution sprayed into the wind tunnel at 1.1 kg/cm² through the wind tunnel via a DeVilbiss No. 155 atomizer (The DeVilbiss Co., Somerset, PA) for 5 seconds. Five sec later, the cage was removed from the chamber, the lid replaced and the sand flies anesthetized for 2-8 sec with CO_2. Then they were transferred to clean 0.24 liter Mason jars with a 42/40 screen inserted in the ring top. The process from inserting the container in the chamber to tightening the top on the jar required 18-22 seconds. A cotton pad moistened with a 10% sugar solution in water was placed on the screen and the jars were placed in a room maintained at ca. 24 ± 5°C and 65 ± 5% relative humidity. A test of each insecticide consisted of a series of 5 concentrations plus a check of acetone and was replicated 4 to 6 times. The check container and jar were handled in the same manner as each treated cage. Acetone was sprayed through the empty chamber to clean the chamber of any material remaining from the previous treatment. The cardboard containers used for the insecticide tests were discarded after the tests. The screens and mason jars were washed in acetone and baked at ca. 100°C for ca. 12 h in a Precision Scientific oven (Am. Sci. Products) for reuse.

The term "knockdown" (Beard 1960) was used to describe the condition that existed at 1 and 4 h posttreatment. The use of this term made it possible to distinguish between reversible paralysis and death. Some recovery was observed, especially in tests with the pyrethroids. Mortality data were corrected for control mortality by Abbott's formula (Abbott 1925) and the LC_{50} and LC_{90} and corresponding 95% confidence limits were calculated by probit analysis. Malathion was used as the standard because of its extensive use in Florida mosquito control programs.

Approximately 100 adults were retained for later identification from each weeks collections. Representative samples sent to Dr. W. W. Wirth for identification were primarily *C. mississippiensis* with some *C. furens* (Poey) and *C. mellus* (Coquilett) (Wirth, U. S. Natl. Museum, Washington, DC 1982, personal communication). Identifications at this laboratory supported this assessment.

Results and Discussion

The results of the wind tunnel tests against a natural sand fly population summarized in Table 1 show the LC_{50}, LC_{90}, and the corresponding 95% confidence limits for 1, 4, and 24 h posttreatment mortality. The compounds are ranked from the least effective to the most, based on the 24-h, LC_{90} mortality.

TABLE 1. Efficacy of selected insecticides against a natural population of *Culicoides* spp exposed in a laboratory wing tunnel 1982.

Insecticide	Post-treatment h	Lethal concentrations (mg AI/ml)			
		LC_{50}	95% C.L.[1]	LC_{90}	95% C.L.[1]
naled	1	0.1740	0.1690-0.1790	0.2930	0.2750-0.3140
(Dibrom)	4	0.0910	0.0870-0.0953	0.1932	0.1809-0.2073
	24	0.0586	0.0530-0.0649	0.1530	0.1420-0.1640
fenitrothion	1	0.1509	0.0797-0.2854	3.1176	1.6776-6.0214
(Sumithion)	4	0.0409	0.0386-0.0433	0.0891	0.0830-0.0959
	24	0.0325	0.0304-0.0348	0.0881	0.0817-0.0953
malathion (std)	1	0.0734	0.0658-0.0819	0.2030	0.1580-0.2610
(Cythion)	4	0.0319	0.0305-0.0335	0.0861	0.0773-0.0962
	24	0.0232	0.0219-0.0247	0.0667	0.0603-0.0736
malathion/resmethrin	1	0.0232	0.0211-0.0254	0.1445	0.1164-0.1794
(90:1)	4	0.0104	0.0092-0.0117	0.0886	0.0723-0.1085
	24	0.0067	0.0061-0.0074	0.0335	0.0285-0.0393
chlorpyrifos	1	0.0853	0.0790-0.0922	0.2189	0.1982-0.2418
(Dursban)	4	0.0153	0.0143-0.0164	0.0330	0.0287-0.0386
	24	0.0098	0.0085-0.0012	0.0274	0.0231-0.0324
fenthion	1	*	*	*	*
(Baytex)	4	0.0352	0.0304-0.0407	0.1066	0.0685-0.1660
	24	0.0110	0.0099-0.0124	0.0231	0.0207-0.0258
resmethrin	1	0.0002	0.0001-0.0006	0.0007	0.0004-0.0010
(SBP 1382-40F)	4	0.0008	0.0007-0.0009	0.0021	0.0019-0.0023
	24	0.0007	0.0004-0.0010	0.0135	0.0090-0.0209
permethrin	1	0.00029	0.00027-0.00031	0.0009	0.0008-0.0010
(PRAMEX)	4	0.00043	0.00041-0.00046	0.0011	0.0009-0.0013
	24	0.00050	0.00048-0.00058	0.0025	0.0021-0.0030
phenothrin	1	**	**	0.0016	0.0011-0.0024
(Sumithrin)	4	0.0020	0.0012-0.0032	0.0019	0.0017-0.0022
	24	0.0024	0.0022-0.0027	0.0012	0.0096-0.0131

[1]95% Confidence Limits
*Unable to determine LC_{50} and/or LC_{90} values statistically due to low mortality at highest dosages tested.
**Unable to determine LC_{50} and/or LC_{90} values statistically due to high mortality at the lowest dosages tested.

Some comparisons can be made between the susceptibility results obtained with the OP compounds, the pyrethroids and between the individual compounds. Naled was the least effective and phenothrin the most effective of the 9 insecticides observed 24 h after treating at the LC_{90} level. Among the OP compounds, malathion, the standard, was intermediate in effectiveness at the LC_{90} level 24 h posttreatment. Chlorpyrifos and fenthion at both the LC_{50} and LC_{90} levels 24 h after treating were more than twice as effective as malathion. None of the OP compounds exhibited rapid knowkdown 1 h posttreatment at the LC_{50} or LC_{90} levels. The efficacy of fenthion 1 h after treatment could not be determined because of the low mortality at the highest dosage tested. Kline et al. (1981) also reported fenthion the least effective compound at 1h posttreatment. Although recovery was observed with each of the 3 pyrethroids tested, they were more effective than the Op compounds at both the LC_{50} and the $LC_{90)}$ levels 1, 4 and 24 h after treating. Kline et al. (1981) and Rathburn et al. (1982) also reported recovery of pyrethroid treated insects over a 24-h period. Resmethrin was the most effective insectivcide tested 1 h after treating at the LC_{90} level. Resmethrin was ca. 290 X more effective than malathion, but at the end of the test its efficacy was only ca. 5 X malathion's.

A mixture of malathion-resmethrin (90:1) was compared to malathion only to try to increase the 1 h knockdown of malathion. A similar study with adult mosquitoes (Rathburn and Boike 1981) demonstrated a slight increase in toxicity with a malathion-resmethrin (90:1) mixture over malathion. This present study indicated a malathion-resmethrin formulation failed to substantially increase the mortality of malathion only at either 1 or 24 h posttreatment at the LC_{90} level. However, the formulation slightly increased the knockdown capability of malathion at the LC_{50} level 1 and 24 h after treatment. The increased cost of the formulation without a substantial increase in its efficacy over malathion only would make it economically impracticable in actual field control practices.

Comparisons of wind tunnel data from different sources and between different insect species should be done with caution because procedures and techniques vary from one facility to another. Laboratory wind tunnel procedures used at WFARL differ depending on the insect species used (Rathburn et al. 1982, unpublished WFARL procedures); however, reproduceability between tests within a study are consistent when utilizing standard procedures and similar insect populations. Wind tunnel data are useful in determining the relative order of effectiveness of a group of insecticides, and to compare the susceptibility of different insect species to various insecticides. Wind tunnel studies also eliminate those insecticides not toxic enough to justify further study, and provide a method of uniform insecticide exposure of test insects which contribute to statistical reliability.

Literature Cited

ABBOTT, W. S. 1925. A method of computing the effectiveness of an insecticide. J. Econ. Entomol. 18: 265-17.

BEARD, R. L. 1960. Post-exposure conditions and determination of end-point. pp. 19-27. In Shepard, H. H. (ed.). Methods of testing chemicals in insects. Burgess Publishing Co., Minneapolis, MN.

BLANTON, F. S. AND W. W. WIRTH. 1979. The sand flies (*Culicoides*) of Florida (Diptera: Ceratopogonidae). FL. Dep. Consumer Serv.: 204 p.

CLEMENTS, B. W. JR. AND A. J. ROGERS. 1968. Tests of larvicides for control of salt-marsh sand flies (*Culicoides*), 1967. Mosq. News 28: 529-34.

FLOORE, T. G. 1982. An improved miniature CDC light trap for collecting adult *Culicoides mississippiensis* Hoffman (Diptera: Ceratopogonidae). J. Florida Anti-Mosq. Assn. 53: 107-108.

GIGLIOLI, M. D. C., E. J. GERBERT, AND R. G. TODD. 1980. Large scale field tests and environmental assessments of Sumithion® (Fenitrothion) against adult biting midges in Grand Cayman, West Indies. Mosq. News 40: 105.

GOODIN, P. 1980. The most annoying Insect. Agric. Res. 28: 10.

HARRINGTON, R. W., JR. AND W. L. BIDLINGMAYER. 1958. Effects of Dieldrin on fishes and invertebrates of a salt marsh. J. Wildlife Management 22: 75-82.

KLINE, D. L., D. G. HAILE, AND K. F. BALDWIN. 1981. Wind tunnell tests with seven insecticides against adult *Culicoides mississippiensis* Hoffman. Mosq. News 41: 745-47.

LINLEY, J. R. AND J. B. DAVIES. 1971. Sandflies and tourism in Florida and the Bahamas and Carribbean area. J. Econ. Entomol. 64: 264-78.

RATHBURN, C. B. JR. 1969. A laboratory thermal aerosol generator for the testing of insecticidal aerosols. Mosq. News 29: 1-6.

RATHBURN, C. B. JR. AND A. H. BOIKE, JR. 1972. Laboratory thermal aerosol tests of new insecticides for the control of adult mosquitoes. Mosq. News 32: 179-183.

RATHBURN, C. B., JR. AND A. H. BOIKE, JR. 1981. Laboratory and field tests comparing formulations of malathion/resmethrin with malathion for the control of adult mosquitoes. Mosq. 41: 756-59.

RATHBURN, C. B. JR., A. H. BOIKE, JR., L. A. SIZEMORE, AND M. W. PETERS. 1982. Laboratory tests of mosquito adulticides. J. Florida Anti-Mosq. Assn. 53: 91-96.

ROGERS, A. J. 1962. Effects of impounding and filling on the production of sand flies (*Culicoides*) in Florida salt marshes. J. Econ. Entomol. 55: 521-27.

SCHRECK, C. E., D. KLINE, AND N. SMITH. 1979a. Protection afforded by the insect repellent jacket against four species of biting midge (Diptera: *Culicoides*). Mosq. News 39: 739-42.

SCHRECK, C. E., N. SMITH, AND T. P. MCGOVERN. 1979b. Repellency of selected compounds against two species of biting midges (Diptrera: Ceratopogonidae: *Culicoides*). J. Med. Entomol. 16: 525-27.

SUITALBILITY OF POTENTIAL WILD HOSTS OF *DIAPHANIA* SPECIES IN SOUTHERN FLORIDA

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ABSTRACT

The cucurbit weed, *Melothria pendula* L., was found to be an important wild host of pickleworm, *Diaphania nitidalis* (Stoll) and the melonworm, *Diaphania hyalinata* (L.), in southern Florida. Laboratory feeding tests showed that foliage of another abundant cucurbit weed, *Momordica chorantia* L., was unfavorable for larval survival, yet both insect species were found on this plant in field samples. It is believed that pickleworm larvae can develop on *Momordica* flowers and fruit, while melonworms found on *Momordica* may constitute a host race or sibling species.

1985 Boike, Jr., A. H., C. B. Rathburn, Jr., K. L. Lang, H. M. Masters and T. G. Floore
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1402

too early?

CURRENT STATUS ON THE FLORIDA ABATE MONITORING PROGRAM—SUSCEPTIBILITY LEVELS OF THREE SPECIES OF MOSQUITOES DURING 1984

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ABSTRACT. During 1984, larval susceptibility tests of temephos were performed on *Aedes taeniorhynchus* and *Culex nigripalpus* collected from the same general areas as in 1980–82, and the results compared to the susceptible laboratory strains. No resistance was detected against these two species. When strains of *Culex quinquefasciatus* from some new areas were tested against temephos, malathion, naled, fenthion and chlorpyrifos, their tolerance varied according to the insecticide tested and the origin of the strain. Some strains ranged from 1.6 to 43.0X more tolerant to temephos when compared to the West Florida Arthropod Research Laboratory strain (WFARL strain).

INTRODUCTION

The Florida Abate Monitoring program (Boike et al. 1982) was initiated during 1980–82 and resulted in testing 3 species of mosquitoes from 6 counties in Florida against temephos, malathion, naled, chlorpyrifos and fenthion. Results of tests during this period indicated no resistance of temephos by *Aedes taeniorhynchus* (Wied.) or *Culex nigripalpus* Theobald, but variable resistance of up to 22X by *Culex quinquefasciatus* Say.

The intention of the program is to test populations of these mosquito species against temephos every other year only to determine if any resistance was beginning to appear. If any tolerance to temephos was noted, tests for cross resistance to the other insecticides would be conducted.

MATERIALS AND METHODS

Wild populations of *Ae. taeniorhynchus* and *Cx. nigripalpus* were collected essentially from the same areas as those collected in 1980–81 by using CDC portable light traps baited with dry ice (Newhouse et al. 1966). Adults were shipped to the laboratory in styrofoam chests chilled with plastic freezer containers. Strains of *Cx. quinquefasciatus* (which is easily colonized) were sent to the laboratory either as egg rafts or larvae. Some strains were obtained from the same areas as in 1980; however, some new areas were selected in 1984 due to elimination of the original breeding area or for comparison to the area selected in 1980–81. These new strains were tested against all 5 insecticides. Adults of all species were fed on anesthetized chicks and were offered 10% sugar cotton pads for carbohydrate.

Laboratory bioassays consisted of pipetting 1 ml of an appropriate insecticide dilution into 200 ml of tap water. Twenty-five 3rd instar larvae in 49 ml tap water were then added to the beakers giving a total of 250 ml solution. All insecticide dilutions were in ACS acetone. A replication consisted of a control and 5–7 serial dilutions of the insecticide to be tested and an average of 12 replications were performed on each insecticide for a given species. All tests were performed in water baths at 27± 1°C and mortality counts made at 24 hrs. posttreatment (Rathburn and Boike, 1967, Boike et al. 1978).

The LC_{50} and LC_{90} values were calculated by probit analysis using the SAS program through the facilities of the NE Florida Regional Data Center and were expressed in µg AI/ml (ppm).

RESULTS

Results of larval susceptibility tests of *Ae. taeniorhynchus* are shown in Table 1, and those for *Cx. nigripalpus* are shown in Table 2. Tests of *Cx. quinquefasciatus* against temephos and malathion are shown in Table 3 and against naled, chlorpyrifos and fenthion are shown in Table 4. The resistance ratio was found by dividing the LC_{50} and LC_{90} values of the area strain by the LC_{50} and LC_{90} values of the susceptible strain (not shown in tables).

Aedes taeniorhynchus—Temephos—(Table 1): Of the 4 comparable areas sampled in 1984, all had similar LC_{50} and LC_{90} values compared to 1980, indicating no resistance to temephos. When tested against fenthion, the *Ae. taeniorhynchus* from Marco Island, Collier County, were comparable to the West Florida Arthropod Research Laboratory susceptible strain (WFARL strain).

Culex nigripalpus—Temephos, fenthion, naled—(Table 2): *Culex nigripalpus* from 3 areas in Collier, Lee and Polk counties showed less variation in susceptibility to temephos when compard to the WFARL strain. The two 1984 collections of *Cx. nigripalpus* from the Treesweet and Tropicana Company sites in Fort Pierce, St. Lucie County, showed a slight increase in toler-

Table 1. Susceptibility of *Aedes taeniorhynchus* larvae to temephos and fenthion.

County	Area	Year tested	Lethal concentration in μg AI/ml. (ppm) LC_{50}	95% C.L.[1]	LC_{90}	95% C.L.[1]	Resistance ratio[2] LC_{50}	LC_{90}
			Temephos					
Collier	Naples	1980	0.00074	0.00071–0.00078	0.00120	0.00114–0.00127	0.9	0.7
	Marcos Is.	1984	0.00148	0.00144–0.00151	0.00189	0.00183–0.00197	1.0	0.7
Lee	Sanibel Is	1980	0.00072	0.00066–0.00079	0.00144	0.00134–0.00155	0.8	1.0
	Sanibel Is.	1984	0.00126	0.00123–0.00129	0.00180	0.00172–0.00189	0.9	0.8
Manatee	Port Manatee	1980	0.00742	0.00068–0.00081	0.00179	0.00105–0.00196	0.8	1.3
	Manson's Farm	1984	0.00066	0.00046–0.00083	0.00170	0.00127–0.00342	0.5	0.9
St. Lucie	Ft. Pierce Bch	1980	0.00121	0.00116–0.00126	0.00233	0.00209–0.00261	1.5	1.3
	Ft. Pierce Bch.	1984	0.00199	0.00185–0.00218	0.00280	0.00247–0.00353	0.7	1.4
			Fenthion					
Collier	Marco Is.	1984	0.00181	0.00140–0.00250	0.00436	0.00314–0.00650	0.9	1.0

[1] Confidence limits.

[2] Resistance ratio $= \frac{LC_{50} \text{ or } LC_{90} \text{ of area strain}}{LC_{50} \text{ or } LC_{90} \text{ of susceptible strain}}$

Table 2. Susceptibility of *Culex nigripalpus* larvae to temephos, fenthion and naled.

County	Area	Year tested	Lethal concentration in μg AI/ml. (ppm) LC_{50}	95% C.L.[1]	LC_{90}	95% C.L.[1]	Resistance ratio[6] LC_{50}	LC_{90}
			Temephos					
Collier	Naples	1980	0.000291	0.000278–0.000304	0.000547	0.000513–0.000583	0.9	0.9
	Marco Is	1984	0.000792	0.000648–0.000949	0.001252	0.001017–0.002852	1.2	1.3
Hillsborough	Gibsonton	1980	0.000296	0.000283–0.000309	0.000609	0.000564–0.000658	0.9	1.0
	Gibsonton[2]	1984	0.001313	0.001193–0.001460	0.004031	0.003244–0.005493	2.1	4.5
	Gibsonton[3]	1984	0.001115	0.000877–0.001348	0.003402	0.002490–0.006450	1.7	3.9
Lee	Ft. Myers	1980	0.000250	0.000227–0.000275	0.000527	0.000466–0.000596	0.8	0.9
	Ft. Myers	1984	0.000786	0.000721–0.000858	0.001131	0.001003–0.001427	1.1	1.2
Polk	Mulberry	1981	0.000517	0.000494–0.000540	0.000792	0.000728–0.000862	0.9	0.9
	Mulberry	1984	0.000672	0.000648–0.000696	0.000989	0.000931–0.001071	1.0	1.1
St. Lucie	Ft. Pierce	1981	0.000562	0.000546–0.000579	0.000919	0.000863–0.000979	0.9	1.0
	Ft. Pierce[4]	1984	0.001072	0.000947–0.001244	0.002099	0.001704–0.002954	1.6	2.3
	Ft. Pierce[5]	1984	0.001115	0.000914–0.001629	0.001905	0.001396–0.004851	1.7	2.1
			Fenthion					
Hillsborough	Gibsonton	1981	0.00302	0.00295–0.00309	0.00417	0.00402–0.00434	0.9	0.9
	Gibsonton	1984[3]	0.00732	0.00647–0.00828	0.01932	0.01580–0.02582	2.7	5.6
			Naled					
Hillsborough	Gibsonton	1981	0.0528	0.0512–0.0544	0.0895	0.0810–0.0990	1.4	1.7
	Gibsonton	1984[3]	0.0722	0.0659–0.0851	0.1822	0.1337–0.3371	2.0	4.2

[1] Confidence limits.

[2] Collection of July 1984.

[3] Collection of Oct. 1984.

[4] Treesweet Company (Collection of April 3, 1984).

[5] Tropicana Company (Collection of May 21, 1984).

[6] Resistance ratio $= \frac{LC_{50} \text{ or } LC_{90} \text{ of area strain}}{LC_{50} \text{ or } LC_{90} \text{ of susceptible strain}}$

ance to temephos compared to 1981, while the 2 collections of *Cx. nigripalpus* from Gibsonton, Hillsborough County, indicated a substantial increase in tolerance to temephos of approximately 2X at the LC_{50} level and 4–4.5X at the LC_{90} level. When tested against fenthion, the *Cx. nigripalpus* from Gibsonton were 2.7X and 5.6X more tolerant than the WFARL strain. A slight increase in tolerance to naled was also shown. This is the first time a population of *Cx. nigripalpus* in Florida exhibited a substantial tolerance to temephos, fenthion and naled.

Culex quinquefasciatus—Temephos, malathion, naled, chlorpyrifos and fenthion—(Tables 3 and 4): The *Cx. quinquefasciatus* strain from the City of Naples Public Works Department (which is approximately 2–3 miles from the Collier Mosquito Control District Headquarters), Collier County, (1984) was highly resistant to temephos (17.4X at the LC_{50} level and 43.0X at the LC_{90} level). The population was also resistant to fenthion (7.5X at the LC_{50} level and 11.1X at the LC_{90} level) and progressively less resistant to chlorpyrifos, malathion, and naled. The Public Works Department strain was more resistant to all insecticides tested when com-

Table 3. Susceptibility of *Culex quinquefasciatus* larvae to temephos and malathion.

County	Area	Year tested	Lethal concentration in µg AI/ml. (ppm) LC_{50}	95% C.L.[1]	LC_{90}	95% C.L.[1]	Resistance ratio[7] LC_{50}	LC_{90}
				Temephos				
Collier	Naples	1980	0.00236	0.00220–0.00252	0.00767	0.00670–0.00878	2.1	3.3
	Naples[2]	1982	0.00585	0.00536–0.00638	0.01879	0.01599–0.02203	11.2	22.3
	Naples[3]	1984	0.01056	0.00893–0.01265	0.03921	0.02854–0.06471	17.4	43.0
	Immokalee	1984	0.00119	0.00112–0.00124	0.00188	0.00177–0.00204	1.9	1.6
Hillsborough	Seffner	1980	0.00258	0.00232–0.00287	0.02328	0.01812–0.02991	3.4	12.5
	Seffner	1984	0.00316	0.00252–0.00399	0.01818	0.01169–0.03826	5.2	20.0
Lee	Ft. Myers	1980	0.00287	0.00251–0.00329	0.03459	0.02603–0.04597	2.5	15.0
	Ft. Myers[4]	1984	0.00871	0.00724–0.01069	0.02501	0.01860–0.03965	11.3	23.1
Manatee	Ellenton	1984	0.00522	0.00359–0.00887	0.03517	0.01724–0.13930	7.6	34.9
Polk	Eagle Lake	1980	0.01365	0.01301–0.01432	0.03007	0.02782–0.03198	18.1	16.1
	Lakeland	1984	0.00357	0.00290–0.00434	0.01032	0.00790–0.01560	4.2	8.0
St. Lucie	Ft. Pierce	1980	0.00492	0.00445–0.00544	0.02150	0.01886–0.02450	6.6	11.5
	Ft. Pierce[5]	1984	0.01371	0.01108–0.01689	0.03006	0.02280–0.05318	21.2	32.1
	Ft. Pierce[6]	1984	0.01836	0.01644–0.02092	0.03329	0.02756–0.04633	28.4	35.6
				Malathion				
Collier	Naples	1980	0.310	0.279–0.344	1.534	1.332–1.767	2.2	5.3
	Naples[2]	1982	0.700	0.662–0.740	1.545	1.434–1.667	7.0	10.2
	Naples[3]	1984	0.466	0.434–0.498	1.119	1.020–1.248	4.6	7.8
	Immokalee	1984	0.148	0.144–0.152	0.240	0.229–0.251	1.8	1.6
Lee	Ft. Myers	1980	0.451	0.412–0.494	1.617	1.435–1.823	2.5	4.2
	Ft. Myers[4]	1984	0.293	0.282–0.304	0.555	0.523–0.589	3.5	3.8
Manatee	Ellenton	1984	0.203	0.189–0.216	0.463	0.422–0.521	2.0	3.2
Polk	Eagle Lake	1980	1.133	1.090–1.177	2.716	2.499–2.952	6.4	7.1
	Lakeland	1984	0.323	0.295–0.351	1.141	0.976–1.395	3.2	9.8

[1] Confidence limits.
[2] Collier Mosquito Control District Headquarters.
[3] City of Naples Public Works Department.
[4] River Trails Trailer Park.
[5] Collection of April 3, 1984 (Treesweet Company).
[6] Collection of May 21, 1984 (Tropicana Company).
[7] $\text{Resistance ratio} = \frac{LC_{50} \text{ or } LC_{90} \text{ of area strain}}{LC_{50} \text{ or } LC_{90} \text{ of susceptible strain}}$

pared to the strain tested in 1982 from the Collier Mosquito Control District headquarters in Naples.

A strain of *Cx. quinquefasciatus* from Immokalee, Collier County, was tested against all insecticides and was found to have LC_{50} and LC_{90} values of <2X for temephos, malathion and naled. When tested against fenthion and chlorpyrifos, the LC_{50} and LC_{90} values were between 2.6X–2.9X. These results are in agreement with Boike et al. (1984) and Palmisano et al. (1976) who showed that populations of *Cx. quinquefasciatus* collected from areas having little or no mosquito programs are more susceptible to OP insecticides than areas having active mosquito control programs.

The *Cx. quinquefasciatus* strain from the River Trails Trailer Park located on the Caloosahatchee River in Fort Myers, Lee County, tested in 1985 was more tolerant to all insecticides tested when compared to the strain tested in 1980 which was from a shopping center on US 41. The Eagle Lake, Polk County strain tested in 1980 was from a sewage tank which had been treated heavily with temephos, giving an LC_{50} value of 18X compared to the WFARL strain. In 1984, the strain from a school yard in Lakeland, Polk County, was considerably less tolerant than the Eagle Lake strain to all insecticides tested. In Fort Pierce, the *Cx. quinquefasciatus* strains tested for 1980 and 1984 were both from sites at the Treesweet Company. A substantial increase in tolerance to temephos was noted for the 2 collections of 1984 compared to 1980.

DISCUSSION

Aedes taeniorhynchus tested during 1984 were as susceptible to temephos as those tested during the initial phase of the Abate Monitoring Program (Boike et al. 1982). *Culex nigripalpus* from 3 areas in Collier, Lee and Polk counties were as susceptible to temephos in 1984 as in 1980–81 indicating no change in resistance. However, *Cx. nigripalpus* collected from sites at the Treesweet and Tropicana companies in 1984 near Fort Pierce indicate a slight increase in tolerance to temephos compared to results obtained in 1980. In addition, substantial tolerance to temephos was found in 2 collections of *Cx. nigripalpus* from Gibsonton in 1984. Also, these populations of *Cx. nigripalpus* were toler-

Table 4. Susceptibility of *Culex quinquefasciatus* larvae to naled, chlorpyrifos and fenthion.

County	Area	Year tested	Lethal concentration in μg AI/ml. (ppm)				Resistance ratio[6]	
			LC_{50}	95% C.L.[1]	LC_{90}	95% C.L.[1]	LC_{50}	LC_{90}
				Naled				
Collier	Naples[2]	1982	0.356	0.344–0.369	0.644	0.594–0.698	3.7	4.9
	Naples[3]	1984	0.399	0.379–0.418	0.759	0.706–0.829	4.7	6.1
	Immokalee	1984	0.147	0.140–0.156	0.215	0.195–0.250	1.4	1.5
Lee	Ft. Myers	1981	0.142	0.137–0.147	0.240	0.223–0.258	1.1	1.0
	Ft. Myers	1984	0.334	0.306–0.371	0.655	0.552–0.844	4.2	6.1
Manatee	Ellenton	1984	0.338	0.297–0.396	0.777	0.606–1.183	4.2	7.3
Polk	Eagle Lake	1980	0.646	0.620–0.673	1.140	1.060–1.226	5.3	5.6
	Lakeland	1984	0.249	0.221–0.289	0.521	0.416–0.759	2.9	4.4
				Chlorpyrifos				
Collier	Naples	1981	0.00396	0.00368–0.00426	0.00967	0.00851–0.01100	2.2	2.4
	Naples[2]	1982	0.00490	0.00472–0.00509	0.00957	0.00902–0.01020	7.0	4.5
	Naples[3]	1984	0.00893	0.00743–0.01045	0.02085	0.01680–0.02998	8.2	9.2
	Immokalee	1984	0.00234	0.00195–0.00296	0.00423	0.00326–0.00733	2.7	2.9
Lee	Ft. Myers	1981	0.00222	0.00209–0.00235	0.00431	0.00393–0.00472	1.3	1.1
	Ft. Myers[4]	1984	0.00493	0.00398–0.00610	0.00806	0.00642–0.01377	7.2	6.6
Manatee	Ellenton	1984	0.00472	0.00357–0.00583	0.01582	0.01154–0.02884	6.9	12.8
Polk	Eagle Lake	1980	0.00621	0.00587–0.00656	0.02204	0.01944–0.02500	3.5	6.0
	Lakeland	1984	0.00375	0.00346–0.00406	0.00780	0.00693–0.00910	3.4	3.4
				Fenthion				
Collier	Naples[3]	1982	0.0283	0.0270–0.0296	0.0553	0.0525–0.0583	5.9	7.1
	Naples[2]	1984	0.0360	0.0320–0.0400	0.0837	0.0720–0.1029	7.5	11.1
	Immokalee	1984	0.0104	0.0102–0.0106	0.0162	0.0156–0.0170	2.7	2.6
Lee	Ft. Myers	1981	0.0088	0.0084–0.0092	0.0186	0.0170–0.0205	0.9	1.1
	Ft. Myers[4]	1984	0.0278	0.0247–0.0314	0.0451	0.0381–0.0634	6.2	6.4
Manatee	Ellenton	1984	0.0374	0.0272–0.0561	0.1587	0.0899–0.6708	8.7	18.7
Polk	Eagle Lake	1980	0.0413	0.0379–0.0450	0.2439	0.2017–0.2946	5.0	14.8
	Lakeland	1984	0.0328	0.0268–0.0417	0.1099	0.0777–0.1878	3.2	9.8
St. Lucie	Ft. Pierce	1980	0.0157	0.0146–0.0170	0.1004	0.0813–0.1240	1.9	6.1
	Ft. Pierce[5]	1984[5]	0.0320	0.0265–0.0378	0.0810	0.0652–0.1116	6.1	8.9

[1] Confidence limits.
[2] Collier Mosquito Control District Headquarters
[3] City of Naples Public Works Department.
[4] River Trails Trailer Park.
[5] Treesweet Company (Collection of April 3, 1984).
[6] $\text{Resistance ratio} = \frac{LC_{50} \text{ or } LC_{90} \text{ of area strain}}{LC_{50} \text{ or } LC_{90} \text{ of susceptible strain}}$

ant to fenthion and naled. The increase in tolerance to temephos at the citrus canning companies at Fort Pierce was probably due to temephos being used as a larvicide in the effluent ponds prior to June 1980. At Gibsonton, no immediate reason is known for the increase in tolerance to temephos, fenthion and naled. It is postulated that agricultural operations may have influenced the results. Additional collections of *Cx. nigripalpus* from nearby areas this summer (1985) will be made in an attempt to determine how widespread is this increase in tolerance to OP compounds.

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References Cited

Boike, A. H., Jr., C. B. Rathburn, Jr., L. A. Sizemore and M. W. Peters. 1984. Susceptibility of eighteen strains of *Culex quinquefasciatus* Say from Florida to five organophosphate insecticides. J. Fla. Anti-Mosq. Assoc. 55:1–5.

Boike, A. H. Jr., C. B. Rathburn, Jr., L. A. Sizemore and M. W. Peters. 1982. Results of the Florida program for monitoring mosquito susceptibility to temephos, 1980–1982. J. Fla. Anti-Mosq. Assoc. 53:84–92.

Boike, A. H. Jr., C. B. Rathburn, Jr., C. F. Hallmon and S. G. Cotterman. 1978. Insecticide susceptibility tests of *Aedes taeniorhynchus* and *Culex nigripalpus* in Florida 1974–1976. Mosq. News 38:210–217.

Newhouse, V. F., R. W. Chamberlain, J. B. Johnston and W. D. Sudia. 1966. Use of dry ice to increase mosquito catches of the CDC miniature light trap. Mosq. News 26:126–129.

Palmisano, C. T., F. D. Steelman and P. E. Schilling. 1976. Relative effects of insecticide usage in Louisiana mosquito control programs on the susceptibility of adult female *Culex pipiens quinquefasciatus* populations. Mosq. News 36:521–527.

Rathburn, C. B., Jr. and A. H. Boike, Jr. 1967. Studies of insecticide resistance in Florida mosquitoes. Mosq. News 27:377–382.

1985 Dukes, J. C., C. F. Hallmon, J. P. Ruff, and J. C. Moore
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Downwind Drift and Droplet Distribution of Naled Aerial Sprays Applied for Stable Fly Control Over Gulf Beaches

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Large numbers of stable flies, which are believed to originate in the agricultural areas of Florida, Alabama, and Georgia, appear on the Gulf beaches of Florida's panhandle in late summer and fall. These flies are brought to the beaches by the passage of cold fronts or periods of sustained northerly winds (Hester et al. 1978, Hogsette and Ruff 1985). In the absence of their normal hosts, these blood feeding stable flies become an unbearable nuisance to the beach residents and often send tourists away (Anon. 1971, Fye et al. 1980).

A control program for stable flies in northwest Florida is operated by the Florida Department of Health and Rehabilitative Services and utilizes aerial spraying similar to that used for adult mosquito control but is unique with regards to time of application and wind conditions (Rogers et al. 1972). The sensitivity of adult stable flies to wind direction has been a key factor in the success of the aerial control programs. Sustained land to water winds cause the flies to concentrate in a narrow band along the beaches but a sea breeze, which often occurs in the afternoon, sends the flies inland almost immediately. Because of the cool early morning temperatures encountered in the fall, and the flies' inactivity at night, the application of aerial sprays are made from mid-morning to mid-afternoon in winds of 5-15 mph by flying over land and allowing the spray to drift towards the water's edge.

The West Florida Arthropod Research Laboratory has had a continuing program to study the effectiveness of aerial sprays on stable flies and mosquitoes. Recent environmental concerns about pesticide effects on non-target organisms prompted this study to determine the deposition of the spray over land and possibly in the Gulf waters.

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METHODS

The aerial spray tests were conducted at Panama City Beach and utilized a concrete fishing pier which extends 1500 ft out into the Gulf. A park located behind the pier contained an open grassland area extending approximately 1500 ft inland. This provided 3000 ft of near unobstructed area in which to study downwind drift of aerial spray droplets. Stakes equipped to hold caged stable flies, potassium iodide (KI) dye card, and Teflon® coated slides were placed at 100 ft intervals throughout the length of the study area.

Laboratory reared stable flies used for bioassay were held in screened cages constructed of a copper sleeve approx 1.5 inches in depth and approx 5.5 inches inside diameter and covered with 14 × 14 mesh bronze screen. Cages over land were 3 ft above the ground while those located on the pier were 20 ft above the water. All cages were placed with the screen facing into the wind. Droplet data were obtained by the use of KI dye cards and Teflon® coated microscope slides hanging vertically into the wind. The cards were 3 × 5 in. Kromokote cover paper treated with a potassium iodide solution as described by Koundakjian 1965. The naled sensitive cards discolor when impinged by the insecticide droplets. The number of droplets per in^2 was recorded from an area at the center of each card with the aid of a microscope at 10 times magnification. Insecticide droplets collected on Teflon® coated slides were counted and evaluated using methods described by Rathburn 1970 for MMD on impinged slides.

To quantify chemical deposition in the last test, 9 in diameter filter papers (Whatman #4) were used to collect droplets for chemical residue analysis. Papers were placed and pinned in a horizontal position to styrofoam sheets or floats and placed at

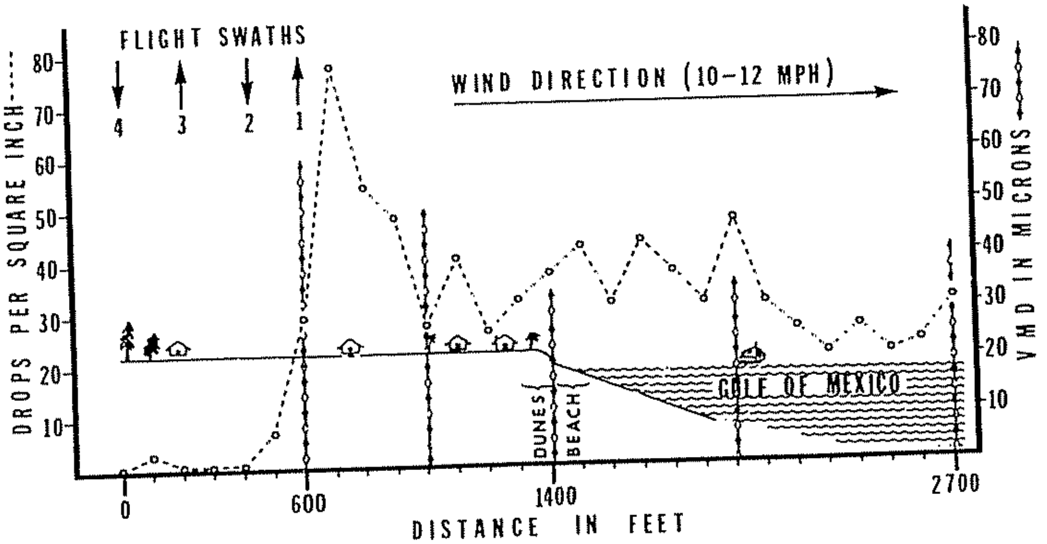

Fig. 1. Downwind distribution and droplet size for aerial insecticide sprays for stable fly control over Gulf beaches in northwest Florida, 1982.

uniform distances downwind from the spray swaths. Floats placed at 300 ft intervals extended 1500 into the water, each held 1 horizontal paper collector. Additional plexiglass filter paper holders, 12 × 12 in with a 6.5 × 6.5 opening, were attached to the pier's railings such that the opening faced into the wind. The filter paper was cut so as to remove 0.5 in strips on 1 in centers in that portion of the paper located in the opening of the holder. The vertical collectors and horizontal floats were parallel and at equal distances downwind. Thirty min posttreatment, the filter papers were collected and placed into vials containing methylene chloride, wrapped in foil, and refrigerated. Samples were shipped to the Gulf Breeze EPA laboratory 36 h post spray and analyzed using a Hewlett-Packard model 5710 gas chromatograph equipped with a nitrogen phosphorus detector.

Control sample containers with solvent were taken to the field for determination of inadvertent contamination with naled or other possible interfering compounds. Average recovery of 2.7 μg naled/filter paper was 94.2 with range (90-98) for n = 5 samples. All filter papers were cleaned with solvents and certified contaminant-free using gas chromatographic analysis prior to use in the field for sample collection.

Naled was applied by the Dog Fly Control Program using currently recommended procedures (Office of Entomology, Memo No. 213, July 1972). A 25% formulation of naled in soybean oil (v/v) was applied in four 200 ft spray swaths starting 800 ft upwind from the primary dune line. The aircraft (DC-3) was outfitted with 36 flat fan nozzles (Spraying Systems 8001) mounted on a tail boom. The application rate was 3.75 gal/min or approximately 0.2 lb AI/a when flown at 150 mph.

Wind speed and direction were monitored throughout each test period using a recording anemometer.

RESULTS

Fig. 1 shows the mean of volume mean diameters (VMD's) and droplet densities for 4 tests each flown under operational conditions with the 4 flight swaths marked and flagged from the ground. Wind speed and direction was NE at 10-12 mph and was typical of frontal conditions which deposit large numbers of stable flies onto Gulf beaches. The number of droplets/in.^{2}, deposited on KI cards, shows that 500-700 ft "off-set" downwind is required before even the largest droplets fall to the surface from the 150 ft altitude of the aircraft. The greatest density of droplets was recorded downwind (700 ft) of the 4th swath of the aircraft, with the density of droplets rapidly decreasing and then remaining fairly uniform over the beach and

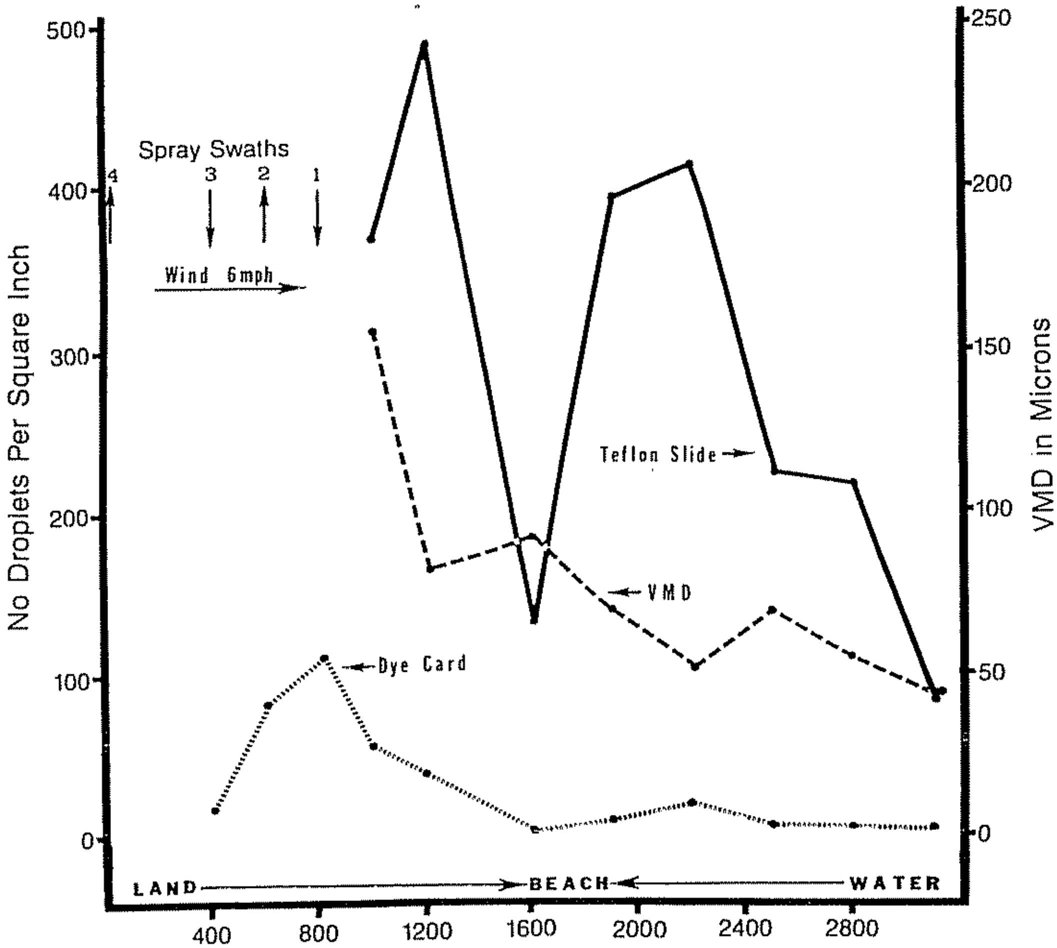

Fig. 2. Droplet distribution of aerial spray deposits, 1984.

throughout the length of the pier. Data on droplet size (VMD) were collected at 5 different locations downwind of the aircraft swaths. These data show that droplet distribution parallels that collected on KI cards with the largest VMD of 60 µm being recorded at 600 ft downwind of the last swath (4th). Droplets having a VMD of 30-40 µm drifted out over the beach and beyond.

Thornton and Davis (1956) stated that spray droplets smaller than 40 µm did not produce visible spots on oil-sensitive cards. This was readily apparent when KI cards were compared with data collected on Teflon coated microscope slides. A minimum of 200 droplets were measured within the area of a glass slide (2.5 × 1 in.) while KI cards placed adjacent to the slides recorded as few as 25 droplets/in.². Rathburn (1970) reported that slides were less than 10% efficient in collecting spray droplets 10 µm or smaller. Although both of the methods used for sampling droplets have specific advantages, neither gave a true and accurate picture of actual numbers of spray droplets passing through an area.

The results of a single test with 4 swaths designed to compare the efficiency of KI cards with Teflon coated slides for monitoring spray drift and to quantify naled deposition are shown in Fig. 2. The major difference in environmental conditions between this test (Fig. 2) and the previous series (Fig. 1) was reduced wind velocity from 10-12 to 6 mph. This wind velocity change resulted in a reduced "off set" distance downwind and a reduction in number of droplets collected on KI cards beyond 1600 ft downwind. Droplets deposited within a known surface area on the Teflon slides resulted in a VMD of 156 µm at a distance of 200 ft downwind of the 1st swath and decreased to 70 µm at the beach (target area). Droplets VMD's collected at stations located on the pier averaged approximately 50 µm.

The droplet density data collected on Teflon coated slides shows that 490 droplets/in.^{2} were collected at 1200 ft downwind of the 4th swath. From that point through 3100 ft downwind, the density of droplets continuously decreased to 84/in.^{2} at the last collection station located at the end of the pier. The only exception to the decreased pattern was located at 1500 ft where the collection station was located immediately downwind of a building at the pier's entry. Disturbances in wind currents at that station may be a possible explanation for the decrease in droplet density and the slight increase in VMD.

A comparison of droplet density data between KI dye cards and Teflon slides shows that the dye cards collected only 10-20% of the number of droplets/in.^{2} collected on the Teflon coated slides. The KI cards indicated that the bulk of the droplets had deposited on land. On the other hand, the slides show that most of the droplets beyond 1000 ft were probably too small to chemically initiate a staining reaction even though they may have been collected on dye cards.

Results of analysis of the filter papers using gas chromatography showed naled being detected at the first 2 stations downwind (1000 and 1200 ft). Residues at these 2 stations were 1.20 and 0.30 µg/cm^2 respectively with all other samples located between 1600-3100 ft downwind being below the detection limit of 0.0030 µg/cm^2. The positive samples were horizontal collections located immediately downwind of all 4 flight swaths and in the area where the largest droplets VMD's and number of droplets/in^2 were recorded. Although solvent extracts were placed in ice and kept in the dark, analyses should have been completed within eight hours to avoid significant loss of naled. The lack of detectable quantity of naled in these samples does not necessarily infer poor deposition but may have been the results of degradation during transport after collection. Although more naled was deposited at the first 2 sites than at other sites, the analysis probably underestimates the actual amounts deposited. Bioassay indicated excellent control (92-100%) extending out over Gulf waters.

DISCUSSION

These tests have shown that Teflon coated microscope slides were more effective for monitoring insecticide spray drift and gave a better representation of all droplet size ranges than did potassium iodide dye cards. However, dye cards do have the advantage of giving immediate results in the field to diagnose spray coverage, and slides require tedious observation in the laboratory using a compound microscope.

The data shows that aerial sprays for stable fly control were carried for long distances downwind from the aircraft path but the large spray droplets fell to the surface within 1200-1400 ft downwind of the upwind swath and did produce detectable residue levels depositing on the ground. Smaller droplets (40-60 µm VMD) were carried through the beach target area and out over Gulf waters but did not produce detectable residue levels.

Although tests show that aerial spray droplets are carried out over the gulf, Chen 1984 reported that the hydrolytic and photolytic degradation of naled and it's breakdown products occurs rapidly to innocuous products. The Dog Fly Control Program in northwest Florida should not pose undue environmental stress within the gulf when aerial sprays are applied at recommended distances upwind from the water's edge.

LITERATURE CITED

Anonymous. 1971. Division of Health Annual Report. pp. 103-104. Florida Department of Health and Rehabilitative Services, Tallahassee.

Chen, Yong S. 1984. Metabolism and breakdown products of Dibrom® 14. Jour. Fla. Anti-Mosq. Assn. 55(1)46-47.

Fye, Richard L., John Brown, Joe Ruff, and Lawrent Buschman. 1980. A survey of northwest Florida for potential stable fly breeding. Fla. Entomo. 63:246-251.

Hester, Philip G., B. W. Clements, Jr., J. C. Dukes, and W. N. Swenson 1978. Effects of Dibrom applied as aerial sprays on non-target salt marsh organisms in northwest Florida. Proc. Fla. Anti-Mosq. Assn. pp. 3-5.

Hogsette, Jerome A. and Joseph P. Ruff. 1985. Stable fly (Diptera:Muscidae) migration in northwest Florida. Environ. Entomol. 14:170-175.

Koundakjian, T. H. 1965. The detection and measurement of Dibrom LV concentrate aerospray droplets. California Chem Co., Mimeograph, File No. 721:101, 6 pp., 6 fig.

Rathburn, Carlisle B., Jr. 1970. Methods of assessing

droplet size of insecticidal sprays and fogs. Mosq News 30(4):501-513.
Rogers, A. J., B. W. Clements, Jr., C. B. Rathburn, Jr., A. H. Boike, Jr. and N. W. Thomas, Jr. 1972. Strip spraying of naled by aircraft for control of adult stable flies and mosquitoes. Fla. Anti-Mosq. Assn., Rep. Annu. Mtg. 43:28-32.
Thornton, D. G. and J. M. Davis. 1956. A method of sampling for drop size of aerial spray deposits. Jour. Econ. Entomol. 49(1)80-83.

Laboratory Observations on the Life History of *Culex (Melanoconion) caudelli* Dyar and Knab in Trinidad, West Indies

1984 Boike, Jr., A. H., C. B. Rathburn, Jr., L. A. Sizemore, and M. W. Peters
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Susceptibility of Eighteen Strains of *Culex quinquefasciatus* Say from Florida to Five Organophosphate Insecticides

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ABSTRACT

Tests of larval susceptibility to temephos malathion, naled, fenthion and chlorpyrifos were performed on 12-18 strains of *Culex quinquefasciatus* Say collected from 11 counties in Florida over a 5 year period (1978-1982). The strains varied in their susceptibility with the insecticide tested and the origin of the strain. When tested against temephos, the most susceptible strain was 24.7 X more susceptible at the LC_{50} level than the least susceptible strain, whereas with naled, there was only a 7.9 X difference between the most and least susceptible strains. Generally, the least susceptible strains originated from areas having well organized mosquito control programs.

INTRODUCTION

From 1980 to 1982, the State of Florida was engaged in a monitoring program to gather base-line information and detect any resistance resulting from the increased use of temephos for mosquito control in several counties (Boike, et al. 1982). Three species, *Aedes taeniorhynchus* (Wied.), *Culex nigripalpus* Theob., and *Culex quinquefasciatus* (Say), were monitored in this program and tested against 5 organophosphate insecticides (temephos, malathion, naled, chlorpyrifos, fenthion). This paper gives the results of strains of *Culex quinquefasciatus* tested during the state monitoring program plus additional strains collected from various areas of the state.

MATERIALS AND METHODS

The various strains of *Cx. quinquefasciatus* were collected as egg rafts, larvae or adults and transported to the laboratory for colonization. Larvae were fed a slurry mixture of 3 parts liver + 2 parts yeast while adults were maintained on 10% sugar water and blood fed on anesthetized chicks. There were nine strains originating from sewage treatment plants, two strains from citrus processing plant effluents, two from light traps in residential areas, two from pasture settling ponds and one each from a meat processing plant, a garbage can and water collections from an old boat. Collection data are shown in Table 1. Not all 18 strains were tested against each of the 5 insecticides. Larval susceptibility tests were performed according to methods described by Rathburn and Boike (1967) and Boike et al. (1978).

RESULTS

Results of the larval susceptibility tests against temephos, malathion, naled, chlorpyrifos and fenthion are shown in Tables 2, 3, 4, 5, and 6, respectively, and are arranged in order of increasing susceptibility at the LC_{50} level. The LC_{50} and LC_{90} values and the 95% confidence limits were calculated by probit analysis using a Sharp programmable calculator or the facilities of the NE Regional Data Center.

TEMEPHOS (Table 2): Of the 18 strains tested, 5 had an LC_{50} value of 0.00558 μg AI/ml. or greater, 9 had values between 0.00492 and 0.00100 μg AI/ml., while the remaining 4 were below 0.00100 μg AI/ml. The least susceptible strain from Eagle Lake was 24.7 X less susceptible at the LC_{50} level than the Cottondale strain and 41.2 X less susceptible at the LC_{90} level.

MALATHION (Table 3): The LC_{50} values for the 16 strains varied from 0.081 μg AI/ml. for the Cottondale strain to 1.133 μg AI/ml. for the Eagle Lake strain. Seven of the strains had values of 0.451 μg AI/ml. to 1.133 μg AI/ml. while 6 strains had values of 0.338 μg AI/ml. to 0.223 μg AI/ml.

Table 1. Source of colonized test strains of *Culex quinquefasciatus* (Say).

County	Area	Habitat	Date of collection	Stages and methods of collection[1]
Collier	Mosq. Cont. Hdqtrs.-I	garbage can	11/20/82	E*
Collier	Naples-II	residential area	7/15/80	A**
Highlands	Sebring	sewage trtmt. plant	3/15/80	E*
Hillsborough	Seffner	pasture pond	5/22/80	E,L*
Hillsborough	Plant City	Lykes Bros. meat polishing pond	4/28/82	E L*
Hillsborough	Tampa	sewage trtmt. plant	10/12/78	E,L*
Jackson	Cottondale	rain water in old boats	7/8/77	L*
Lee	Ft. Myers	town area	7/24/80	A**
Marion	Ocala	sewage trtmt. plant	6/7/79	L P*
Okaloosa	Ft. Walton Beach	sewage trtmt. plant	9/4/80	E,L*
Osceola	Kissimmee	Reedy Creek pasture pond	7/2/80	E*
Polk	Eagle Lake	sewage tank	6/5/80	E L P*
Polk	Lake Wales	Saddlebag sewage trtmt. plant	6/5/80	E.L.P*
Polk	Bartow Air Base	sewage disposal area	3/10/82	L P.A*,**
Polk	Wahaneta	sewage trtmt. plant	5/12/82	L.P.A*,**
St. Johns	St. Augustine Shores	sewage trtmt. plant	10/5/82	L*
Polk	Lake Alfred	Morris Canning Co. effluent	6/15/81	E*
St. Lucie	Ft. Pierce	Freesweet Citrus Co. effluent	7/24/80	E*

[1]E = eggs. L = larvae. P = pupae. A = adults. *dipper. **CDC light trap.

The remaining 3 strains had LC_{50} values of 0.177, 0.168, and 0.081 µg AI/ml., respectively.

NALED (Table 4): The strain from Eagle Lake in Polk County was also least susceptible to naled; having an LC_{50} value of 0.646 µg AI/ml. compared to the most susceptible strain from Cottondale which had an LC_{50} value of 0.070 µg AI/ml. Between these 2 strains, 5 had LC_{50} values

Table 2. Susceptibility of various strains of *Culex quinquefasciatus* Say larvae to temephos.

Collection area	County	Year tested	Lethal concentration in µg AI/ml. (ppm) LC_{50}	95% C.L.[1]	LC_{90}	95% C.L.[1]
Eagle Lake	Polk	1980	0.01365	0.01300-0.01432	0.03007	0.02782-0.03178
Bartow Air Base	Polk	1982	0.00875	0.00805-0.00953	0.04178	0.03296-0.05296
Wahaneta	Polk	1982	0.00843	0.00798-0.00889	0.04083	0.03532-0.04710
Naples-I	Collier	1982	0.00585	0.00536-0.00638	0.01879	0.01599-0.02203
Plant City	Hillsborough	1982	0.00558	0.00515-0.00605	0.01866	0.01644-0.02118
Ft. Pierce	St. Lucie	1980	0.00492	0.00445-0.00544	0.02150	0.01886-0.02450
Ft. Walton	Okaloosa	1980	0.00381	0.00341-0.00426	0.02244	0.01730-0.02911
Tampa	Hillsborough	1978	0.00321	0.00296-0.00349	0.02766	0.02334-0.03272
Ft. Myers	Lee	1980	0.00287	0.00251-0.00329	0.03459	0.02603-0.04597
Seffner	Hillsborough	1980	0.00258	0.00232-0.00287	0.02328	0.01812-0.02991
Naples-II	Collier	1980	0.00236	0.00220-0.00252	0.00767	0.00670-0.00878
Lake Alfred	Polk	1981	0.00166	0.00156-0.00177	0.00634	0.00562-0.00717
Ocala	Marion	1980	0.00101	0.00087-0.00116	0.00805	0.00635-0.01020
Kissimmee	Osceola	1980	0.00100	0.00090-0.00111	0.00691	0.00594-0.00805
Lake Wales	Polk	1980	0.00083	0.00077-0.00090	0.00258	0.00231-0.00287
Sebring	Highlands	1980	0.00075	0.00072-0.00078	0.00187	0.00171-0.00206
St. Augustine Shores	St. Johns	1983	0.00072	0.00051-0.00085	0.00131	0.00113-0.00179
Cottondale	Jackson	1978	0.00055	0.00054-0.00056	0.00073	0.00072-0.00075

Table 3. Susceptibility of various strains of *Culex quinquefasciatus* Say larvae to malathion.

Collection area	County	Year tested	Lethal concentration in µg AI/ml. (ppm)			
			LC_{50}	95% C.L.[1]	LC_{90}	95% C.L.[1]
Eagle Lake	Polk	1980	1.133	1.090-1.177	2.716	2.499-2.952
Naples-I	Collier	1982	0.700	0.622-0.740	1.545	1.434-1.667
Tampa	Hillsborough	1978	0.610	0.575-0.646	1.950	1.700-2.249
Kissimmee	Osceola	1980	0.586	0.550-0.623	1.507	1.349-1.681
Plant City	Hillsborough	1982	0.556	0.536-0.605	1.452	1.321-1.592
Ft. Pierce	St. Lucie	1980	0.521	0.493-0.551	1.508	1.368-1.166
Ft. Myers	Lee	1980	0.451	0.412-0.494	1.617	1.435-1.823
Seffner	Hillsborough	1980	0.338	0.324-0.353	0.783	0.708-0.866
Naples-II	Collier	1980	0.310	0.279-0.344	1.534	1.332-1.767
Ft. Walton	Okaloosa	1981	0.305	0.281-0.327	0.940	0.830-1.065
Lake Alfred	Polk	1981	0.248	0.234-0.261	0.666	0.602-0.737
St. Augustine Shores	St. Johns	1983	0.234	0.219-0.250	0.497	0.410-0.584
Ocala	Marion	1980	0.223	0.152-0.310	0.533	0.367-1.428
Sebring	Highlands	1980	0.177	0.168-0.186	0.383	0.356-0.411
Lake Wales	Polk	1980	0.168	0.160-0.177	0.395	0.369-0.423
Cottondale	Jackson	1978	0.081	0.079-0.082	0.116	0.112-0.120

[1]Confidence limits.

ranging from 0.356 to 0.210 µg AI/ml. while 8 strains had LC_{50} values from 0.179 µg AI/ml. down to 0.112 µg AI/ml. Fifteen strains were tested against naled.

CHLORPYRIFOS (Table 5): Twelve strains were tested against chlorpyrifos with Eagle Lake being the least susceptible strain having an LC_{50} value of 0.00621 µg AI/ml. The other strains had LC_{50} values which gradually decreased to 0.00079 µg AI/ml. for Cottondale, which was 7.9 X more susceptible than the Eagle Lake strain.

FENTHION (Table 6): Fourteen strains were tested against fenthion with Bartow Air Base being the least susceptible strain and Cottondale the most susceptible. The variation of the LC_{50} level was from 0.0461 µg AI/ml. to 0.0037 µg AI/ml. or Bartow Air Base being 12.2 X less susceptible than the Cottondale strain. Eight of the strains had LC_{50} values of 0.0461-0.0125 µg AI/ml while the remaining 6 had LC_{50} values from 0.0098-0.0037 µg AI/ml.

Table 4. Susceptibility of various strains of *Culex quinquefasciatus* Say larvae to naled.

Collection area	County	Year tested	Lethal concentration in µg AI/ml. (ppm)			
			LC_{50}	95% C.L.[1]	LC_{90}	95% C.L.[1]
Eagle Lake	Polk	1980	0.646	0.620-0.673	1.140	1.060-1.226
Naples-I	Collier	1982	0.356	0.334-0.369	0.644	0.594-0.698
Kissimmee	Osceola	1980	0.283	0.254-0.317	0.635	0.541-0.786
Plant City	Hillsborough	1982	0.236	0.223-0.250	0.560	0.492-0.635
Ft. Walton	Okaloosa	1981	0.222	0.209-0.235	0.618	0.537-0.711
Tampa	Hillsborough	1978	0.210	0.198-0.223	0.745	0.644-0.863
Ft. Pierce	St. Lucie	1980	0.179	0.168-0.191	0.680	0.612-0.756
Lake Alfred	Polk	1981	0.167	0.160-0.174	0.334	0.315-0.376
Seffner	Hillsborough	1980	0.164	0.161-0.168	0.253	0.242-0.264
Ocala	Marion	1980	0.159	0.154-0.161	0.312	0.290-0.337
Ft. Myers	Lee	1981	0.142	0.137-0.147	0.240	0.223-0.258
Lake Wales	Polk	1980	0.134	0.128-0.111	0.302	0.271-0.337
Sebring	Highlands	1980	0.122	0.119-0.121	0.203	0.195-0.211
St. Augustine Shores	St. Johns	1983	0.112	0.109-0.115	0.168	0.161-0.177
Cottondale	Jackson	1978	0.070	0.068-0.071	0.092	0.090-0.095

Table 5. Susceptibility of various strains of *Culex quinquefasciatus* Say larvae to chlorpyrifos.

Collection area	County	Year tested	Lethal concentration in μg AI/ml (ppm)			
			LC_{50}	95% C.L.[1]	LC_{90}	95% C.L.[1]
Eagle Lake	Polk	1980	0.00621	0.00587-0.00656	0.02204	0.01944-0.02499
Plant City	Hillsborough	1982	0.00529	0.00496-0.00563	0.01230	0.01089-0.01388
Naples-I	Collier	1982	0.00490	0.00472-0.00509	0.00957	0.00902-0.01016
Ft. Pierce	St. Lucie	1980	0.00412	0.00386-0.00440	0.01788	0.01566-0.02041
Naples-II	Collier	1981	0.00396	0.00368-0.00426	0.00967	0.00851-0.01100
Ocala	Marion	1980	0.00303	0.00287-0.00328	0.01095	0.00937-0.01280
Tampa	Hillsborough	1978	0.00254	0.00243-0.00264	0.00716	0.00665-0.00771
Lake Alfred	Polk	1982	0.00239	0.00225-0.00255	0.00711	0.00618-0.00817
Ft. Myers	Lee	1981	0.00222	0.00209-0.00235	0.00431	0.00393-0.00472
Sebring	Highlands	1980	0.00177	0.00170-0.00185	0.00367	0.00341-0.00394
St. Augustine Shores	St. Johns	1983	0.00141	0.00132-0.00153	0.00243	0.00215-0.00290
Cottondale	Jackson	1978	0.00079	0.00077-0.00080	0.00113	0.00110-0.00116

[1]Confidence limits

DISCUSSION

Results indicate that *Cx quinquefasciatus* from different areas of Florida vary widely in susceptibility to OP insecticides. The strain from Eagle Lake in Polk County was the least susceptible to all but one insecticide tested. This was anticipated since it originated from a sewage treatment tank which was under heavy insecticidal treatment as well as being from an area which has an intensive mosquito control program. Tests with the Cottondale strain indicated that it was the most susceptible strain to all 5 insecticides. The absence of mosquito control practices in the Cottondale area plus the untreated rain water from which the strain originated were factors for its high susceptibility to the insecticides tested.

In general, the top 50% of the strains in each table originated from areas having well organized mosquito control programs while the remaining lower 50% of the strains originated mainly from areas having little or no mosquito control. Similar results reported by Palmisano et al. (1976) showed that populations of *Cx. pipiens quinquefasciatus* collected from southern Louisiana parishes having mosquito con-

Table 6. Susceptibility of various strains of *Culex quinquefasciatus* Say larvae to fenthion.

Collection area	County	Year tested	Lethal concentration in μg AI/ml (ppm)			
			LC_{50}	95% C.L.[1]	LC_{90}	95% C.L.[1]
Bartow Air Base	Polk	1982	0.0461	0.0446-0.0479	0.0912	0.0845-0.0984
Eagle Lake	Polk	1980	0.0413	0.0379-0.0450	0.2438	0.2017-0.2946
Naples-I	Collier	1982	0.0283	0.0270-0.0296	0.0553	0.0525-0.0583
Ft. Walton	Okaloosa	1981	0.0225	0.0195-0.0259	0.2738	0.1642-0.4557
Ft. Pierce	St. Lucie	1980	0.0157	0.0146-0.0170	0.1004	0.0813-0.1241
Tampa	Hillsborough	1978	0.0145	0.0136-0.0157	0.0626	0.0535-0.0734
Plant City	Hillsborough	1982	0.0143	0.0135-0.0151	0.0397	0.0347-0.0454
Seffner	Hillsborough	1980	0.0125	0.0110-0.0142	0.0914	0.0666-0.1260
Ocala	Marion	1980	0.0098	0.0094-0.0103	0.0270	0.0239-0.0306
Lake Alfred	Polk	1982	0.0091	0.0086-0.0095	0.0285	0.0252-0.0323
Ft. Myers	Lee	1981	0.0087	0.0084-0.0091	0.0186	0.0170-0.0205
Sebring	Highlands	1980	0.0083	0.0080-0.0085	0.0165	0.0153-0.0177
St. Augustine Shores	St. Johns	1983	0.0058	0.0052-0.0058	0.0083	0.0076-0.0095
Cottondale	Jackson	1978	0.0037	0.0036-0.0038	0.0058	0.0056-0.0059

[1]Confidence limits.

trol programs were significantly less susceptible to organophosphate insecticides than those from parishes having no control programs. In a 5-year survey with field populations of *Cx. pipiens quinquefasciatus* Steelman and Dewitt (1976) found that the application of chlorpyrifos as a larvicide and malathion and naled as adulticides resulted in the development of tolerance to these 3 organophosphate insecticides in 2 Louisiana mosquito control districts. In Africa, strains of *Cx. quinquefasciatus* from several urban areas in Tanzania have become resistant to chlorpyrifos and other commonly used organophosphates that were used as larvicides (Curtis and Pasteur, 1981).

The variation in susceptibility of *Cx. quinquefasciatus* from different areas of Florida is in contrast to that of *Cx. nigripalpus*. During the past 15 years, *Cx. nigripalpus* collected in various areas of the state has shown little variation in susceptibility to five insecticides when compared to the susceptible West Florida Arthropod Research Laboratory (WFARL) colony (Rathburn and Boike, 1967, Boike et al. 1978, 1980, 1982). For example, a population of *Cx. nigripalpus* from Ft. Pierce had almost the same susceptibility to temephos as the WFARL strain; but a strain of *Cx. quinquefasciatus* originating from the same locality was about 9 X less susceptible than the Cottondale strain at the LC_{50} level.

CONCLUSIONS

Strains of *Cx quinquefasciatus* from various areas of Florida show varying susceptibility to the organophosphate insecticides commonly used by mosquito control districts. Control of this species as a nuisance or as a proven disease vector would be affected by the degree of susceptibility of the local population being treated.

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LITERATURE CITED

Boike, A. H. Jr., C. B. Rathburn, Jr., C. F. Hallmon, and S. G. Cotterman. 1978. Insecticide susceptibility tests of *Aedes taeniorhynchus* and *Culex nigripalpus* in Florida. 1974-1976. Mosquito News 38(2):210-217.

Boike. A. H. Jr., C. B. Rathburn, Jr., C. F. Hallmon and R. L. Welles. 1980. Monitoring for resistance in mosquitoes from several selected areas in Florida for 1979. Jour. Fla. Anti-Mosq. Assn. 51:47-51.

Boike, A. H. Jr., C. B. Rathburn. Jr., L. A. Sizemore and M. W. Peters. 1982. Results of the Florida program for monitoring mosquito susceptibility to Temephos, 1980-1982. Jour. Fla. Anti-Mosq. Assn. 53(2):84-92.

Curtis, C. F. and Pasteur. N. 1981. Organophosphate resistance in vector populations of the complex of *Culex pipiens* L. (Diptera: Culicidae). Bull. Ent. Res. 71:153-161.

Palmisano, C. T., C. D. Steelman. and P. E. Schilling. 1976. Relative effects of insecticide usage in Louisiana mosquito control programs on the susceptibility of adult female *Culex pipiens quinquefasciatus* populations. Mosquito News 36(4):521-527.

Rathburn. C. B. Jr. and A. H. Boike, Jr. 1967. Studies of insecticide resistance in Florida mosquitoes. Mosquito News 27(3):377-382.

Steelman, C. B and D. S. Dewitt. 1976. Development of organophosphate tolerance in field populations of *Culex pipiens quinquefasciatus* Say in Louisiana. Mosquito News 36(3):361-363

1984 Haile, D. G., D. L. Kline, J. F. Reinert, and T. L. Biery
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1401

EFFECTS OF AERIAL APPLICATIONS OF NALED ON *CULICOIDES* BITING MIDGES, MOSQUITOES AND TABANIDS ON PARRIS ISLAND, SOUTH CAROLINA[1]

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ABSTRACT. Field experiments were conducted during 1981 and 1982 to evaluate the effectiveness of ultra low volume (ULV) aerial applications of naled (Dibrom® 14) against natural populations of *Culicoides* biting midges, mosquitoes and tabanids at Parris Island, SC. Effectiveness of the applications was measured by trapping natural populations of all 3 groups of insects and by bioassays with caged mosquitoes and biting midges.

The first test (1981) consisted of 2 applications of a 1:5 mixture of Dibrom 14 in heavy aromatic naphtha (HAN) at a rate of 1.5 oz/acre (0.25 oz/acre Dibrom 14) on the same day spaced ca. 20 min apart. A very low reduction (24%) in the biting midge population following this treatment indicated that the dose of active ingredient (0.5 oz/acre) was inadequate under the prevailing weather conditions, which included marginally high winds.

The second test (1982) consisted of 2 applications of undiluted Dibrom 14 at a rate of 1.0 oz/acre each on consecutive days. Results of this test showed that the larger dose of undiluted Dibrom 14 (2 oz/acre total) provided excellent control (99%) of biting midges, as well as mosquitoes and tabanids, for 3 days after the treatments.

INTRODUCTION

Biting midges (*Culicoides* spp.) are a severe nuisance problem in many coastal areas of the United States and other parts of the world. They are a particularly serious problem at the Marine Corp Recruit Depot (MCRD), Parris Island, SC, where high spring and fall biting midge populations inflict numerous bites upon the military personnel exposed during training and bivouac exercises. Prolonged scratching of bites has caused cellulitis problems in some individuals that require medical attention. In 1976, the Preventive Medicine Unit of the U.S. Naval Hospital, Beaufort, SC, recorded 200 skin infection cases from *Culicoides* bites. This resulted in numerous hospitalizations and the loss of 1,500 man-days at a total cost of $25,000 including pay and hospitalization (unpublished data). Other biting insects, including mosquitoes and, to a lesser extent, the tabanid *Chrysops fuliginosus* Wiedemann, contribute to the annoyance problem at the MCRD.

Parris Island was selected as a site to conduct research for the development of control techniques for biting midges in coastal areas. Reported here is an evaluation of ultra low volume (ULV) aerial adulticide applications made over the entire 8047 acres (3257 ha) of the island, which includes 3274 acres (1325 ha) of dry land, 4344 acres (1758 ha) of salt marsh, and 429 acres (174 ha) of salt water creeks and ponds (Fig. 1). The dry land area includes a mixture (ca. 50%) of open and forest (primarily pine and pine-hardwood) areas. The salt marsh area contained a vegetative cover of cordgrass, *Spartina alterniflora* Loiseleur. The island is bounded by Archers Creek on the north, the Beaufort River on the east, Port Royal Sound on the south, and the Broad River on the west and is only partially isolated from surrounding biting midge populations. Previous studies by Giglioli et al. (1980) in the Cayman Islands indicated that aerial applications of fenitrothion were effective for biting midge control on an isolated island. Kline et al. (1981) reported that organophosphate compounds presently used for adult mosquito control had potential for use against biting midges, based on laboratory wind tunnel evaluations.

The purpose of these experiments was to evaluate the effectiveness of ULV aerial applications of Dibrom® 14, an 85% formulation of naled (1,2-dibromo-2,2-dichloroethyl dimethyl

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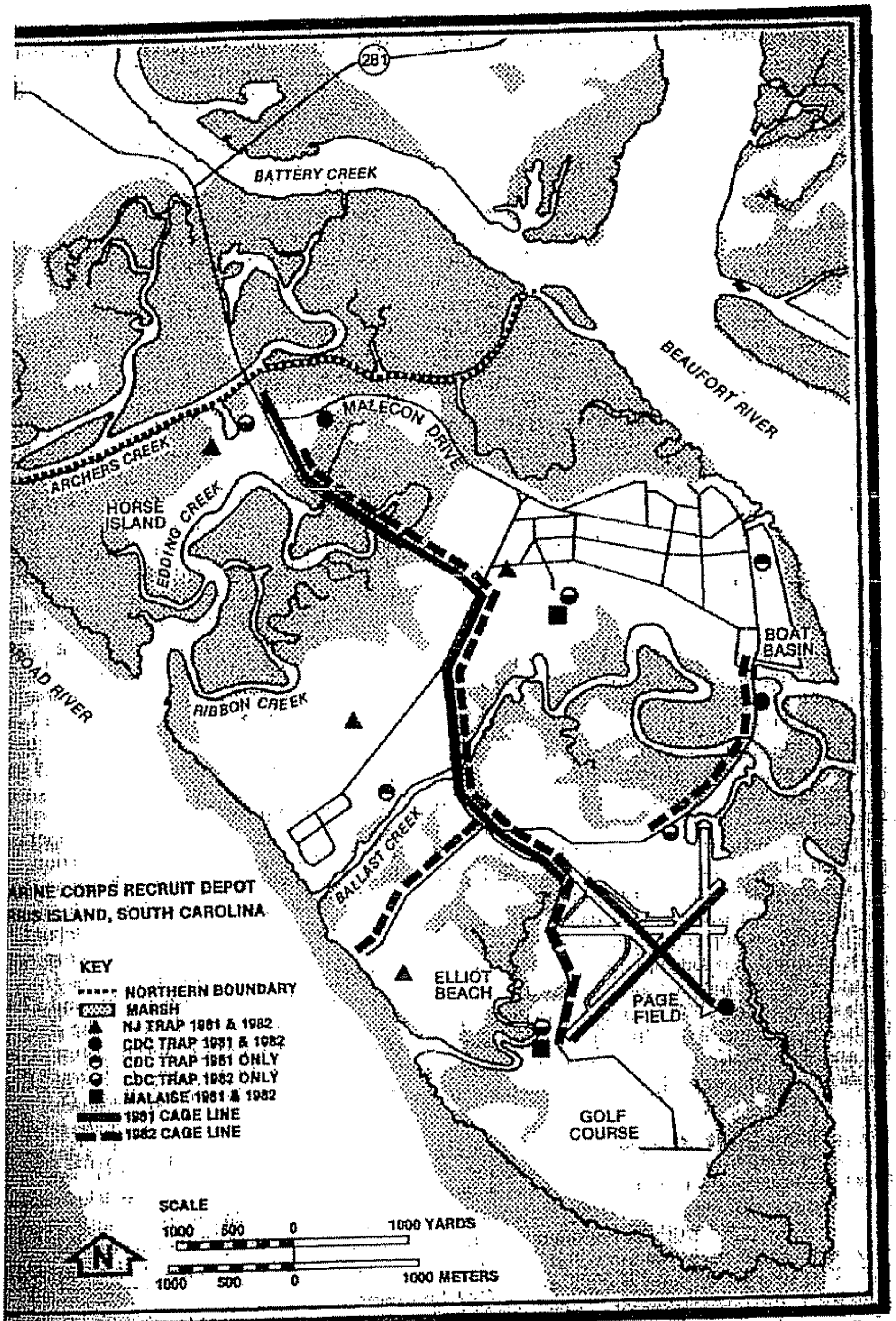

...l. Map of Parris Island, SC, showing the type and location of traps used to survey biting insect populations and the placement of caged insects for evaluation of aerial application experiments.

phosphate) against natural populations of adult biting midges on Parris Island. The effectiveness of the applications for control of mosquitoes and *Chrysops fuliginosus* was also assessed.

METHODS AND MATERIALS

Two aerial application experiments were conducted (1981 and 1982) using U.S. Air Force UC-123K aircraft (Table 1). The planes were equipped with TeeJet® nozzles (Spraying Systems Co.) oriented 45° down and forward (into the wind) on wing booms. Air speed during applications was 160 mph (257 km/h). The applications were timed to coincide with the first spring population peak of biting midges and suitable weather for aerial applications. Weather measurements during the insecticide applications were made by a meteorological team from the Marine Corps Air Station (MCAS), Beaufort, SC.

The 1981 experiment consisted of 2 applications of a 1:5 mixture of Dibrom 14:heavy aromatic naphtha (HAN) at a rate of 1.5 oz/acre (110 ml/ha) which contained 0.25 oz/acre (18.3 ml/ha) of Dibrom 14 each on the same day spaced ca. 20 min apart to take advantage of any flushing action from the first application. Two aircraft were used for these tests. A swath width of 2000 ft (610 m) was used for each aircraft, however, each spray run of the second aircraft was offset by 1000 ft (305 m). Thus, the overall effect of both applications was similar to an application of 0.5 oz/acre (36.5 ml/ha) of Dibrom 14 with 1000 ft (305 m) swaths. The planned altitude for these tests was 300 ft (91 m), however, the first aircraft flew at 250 ft (76 m) due to high winds at the upper altitude.

The 1982 experiment consisted of 2 applications of undiluted Dibrom 14 at the rate of 1.0 oz/acre (73.1 ml/ha) each on 2 consecutive days. A swath width of 1000 ft (305 m) was used for both applications. The altitude was 200 ft (61 m) and 150 ft (46 m) for the first and second applications, respectively.

A combination of natural population surveys and caged insect bioassays was used to measure application effectiveness. For this study, CO_2-baited CDC light traps and unbaited New Jersey light traps were used for assessment of natural biting midge and mosquito populations and malaise traps were used for the tabanid population. Trap locations during the 1981 and 1982 tests are recorded in Fig. 1. The 4 New Jersey and 2 malaise trap locations were the same for both tests. Five baited CDC traps were operated during the 1981 test and 7 for the 1982 test. In the 1982 test, some CDC trap locations were altered to provide better coverage of the treatment area.

Survey traps were also placed in an untreated (check) area for comparison with those in the treated area. For the 1981 test, the check area was located on Lemon Island, SC, ca. 2 mi (3.2 km) west of Parris Island and consisted of 2 baited CDC traps and 1 New Jersey trap. For the 1982 test, the check area was located at Sam's Point, SC, ca. 10 mi (16.1 km) northeast of Parris Island and consisted of 3 baited CDC traps and 1 New Jersey trap.

CDC traps were placed ca. 4 ft (1.2 m) above the ground on metal stakes. CO_2 gas was metered from 20 lb (9.1 kg) pressurized cylinders at a flow rate of 200 cc/min with a floating ball flowmeter, pressure regulator, and needle valve. The CDC traps were powered by 6 volt Gel-Cell® batteries that were changed and recharged daily. The New Jersey traps were located near 120 volt AC power sources. The CDC and New Jersey traps were operated 24 hr/day to provide suction trap action during daylight, as well as darkness, because the peak activity period for one of the predominant biting midge species, *C. hollensis* (Melander and Brues), includes some early morning and late evening daylight hours. Specimens from traps were collected daily between 1600 and 1700 hr.

Based on trap collections on the day before treatment, the *Culicoides* species present during the 1981 test were primarily *C. hollensis* (97.3%) with a few *C. melleus* (Coquillett) (2.6%). The

Table 1. Summary of weather conditions (ground level) and spray parameters during aerial adulticide applications at Parris Island, SC.

Spray date	Time of spray Start	Time of spray End	Flight altitude (m)	Flight headings (°)	Swath width (m)	Wind direction (°)/speed(km/h) Start	Wind direction (°)/speed(km/h) End	Temperature (°C)/RH (%) Start	Temperature (°C)/RH (%) End
				1981 Experiment					
April 7	1729	1753	76.2	138/318	609.6	080/13	090/13	16/51	16/5[illegible]
April 7	1750	1811	91.4	138/318	609.6	090/13	090/13	16/58	16/58
				1982 Experiment					
April 21	1815	1845	61.0	098/278	304.8	210/07	Calm	23/80	22/8[illegible]
April 22	1745	1820	45.7	098/278	304.8	050/11	020/06	20/67	18/66

trap collections of mosquitoes and tabanids during the 1981 test were too low for control evaluations.

During the 1982 test, 3 species of biting midges were present as follows (based on trap collections before treatment): 80.6% *C. hollensis*, 12.4% *C. melleus* and 7.0% *C. furens* (Poey). The mosquito species present during the 1982 tests included 31.4% *Culex quinquefasciatus* Say, 22.8% *Aedes vexans* (Meigen), 18.1% *Anopheles crucians* Wiedemann, 17.2% *Ae. taeniorhynchus* (Wiedemann), 8.3% *Ae. sollicitans* (Walker) and 2.1% *Ae. infirmatus* Dyar and Knab. The only tabanid collected in sufficient numbers for control assessment was *Chrysops fuliginosus*. Data analysis for these tests was based on the sum of both sexes of all species collected for each of the 3 insect groups.

In addition to the natural population surveillance, caged mosquitoes and biting midges were placed in the treated area to measure spray distribution and effectiveness. Caged insects were available for all but the first 1982 application. *Aedes taeniorhynchus* females reared in the laboratory at Gainesville, FL were used in the caged insect bioassays as described by Haile et al. (1982) and Mount et al. (1970). Mosquitoes were placed in cages (25/cage) and transported to Parris Island on the day of treatment. The mosquitoes were transferred to clean holding cages ca. 30 min after exposure and held for 12 hr before recording mortality. The biting midges used in cages were field-collected from Parris Island on the day of application using a modified CDC trap baited with CO_2. They were aspirated into cages (ca. 25/cage) constructed of ½ pint (0.24 liter) cylindrical paper cartons with 40 ga brass screen wire on the top and bottom. Cages of both insects were placed on wooden stakes ca. 4 ft (1.2 m) above the ground. During the 1981 applications, 65 cages of mosquitoes were placed in the treated area (Fig. 1), at ca. 0.1 mi (0.16 km) intervals, along with 11 cages of biting midges. During the second application in 1982, 30 cages each of mosquitoes and biting midges were placed along roadways of the island at ca. 0.2 mi (0.32 km) intervals (Fig. 1). A limited number (5) of cages of both insects were also placed in the check areas to monitor the natural mortality in the cages, which was very low (less then 8%) in these tests. No corrections for natural mortality were made in the analysis of mortality in the treated area.

RESULTS AND DISCUSSION

Results of the 1981 applications indicated only a low level of control of *Culicoides* biting midges after the application of 0.5 oz/acre (36.5 ml/ha) of Dibrom 14. The surveillance trap collections of biting midges in the treated area actually increased from 888/trap before treatment to 2,575/trap on the day after treatment. However, trap collections in the check area also increased (1,238 to 4,696/trap) and, assuming that the same rate of increase would have occurred in the treated area, 24% control could be attributed to the aerial applications. The results of the caged insect bioassays were only slightly better with a mean mortality of 58% in caged biting midges and 67% in caged mosquitoes.

We think that the most important factors contributing to the low level of control for the 1981 applications include the low dose of active ingredient, marginally high winds and high spray altitude. The combination of these factors resulted in an inadequate penetration of toxicant into vegetated areas. This lack of penetration was demonstrated by the pattern of kill in the caged mosquitoes, where an average of 87% mortality was obtained in cages placed in open or sparsely vegetated areas and only 40% kill was noted in cages protected by dense vegetation. Observations in the treatment area during the applications suggest that the insecticide produced an increase in biting by the *Culicoides*, however, the dose of active ingredient was apparently too low to provide significant relief from biting.

The survey trap collections during the 1982 test indicated a satisfactory reduction in the natural population of *Culicoides* spp., as well as mosquitoes and *Chrysops fuliginosus*, (Fig. 2) following the 2 applications of 1.0 oz/acre (73.1 ml/ha) of undiluted Dibrom 14. Trap collections on the day following the second spray were reduced by more than 99% compared to the day before the first treatment. This level of suppression was maintained for at least 3 days following the last treatment. Trap collections of biting midges and mosquitoes (no *Chrysops fuliginosus* were collected) in the check area (Sam's Point) were consistently lower than those on Parris Island, but counts remained relatively stable throughout the test period (Fig. 3). Part of the reduced trap collections on Parris Island could have resulted from environmental effects, however the depth and duration of the reduction indicate that the sprays were the major factor. The reduction in numbers of specimens collected in traps in the treated area on the day following the first application (before the second spray) was 63, 80 and 69%, for *Culicoides* spp., mosquitoes and *Chrysops fuliginosus*, respectively. However, these values do not represent the full impact of the first application since many of the specimens in the post treatment trap collections were collected during and immediately after the spray application. This is particularly true for *Culicoides* spp. since ground observations indicated that biting activity increased as a result of the chemical application, as it did in the 1981 test. However, observations during both 1982 spray applications showed that the increase in biting activity lasted only ca. 5 min before the effects of the insecticide began to suppress *Culicoides* spp. biting.

Further evidence of the effectiveness of the 1982 sprays was indicated by the high mortality of caged insects in the treated area during the second spray, which averaged 95% for *Culicoides* spp. and 96% for mosquitoes. Only insects in cages placed at the northern end of the spray

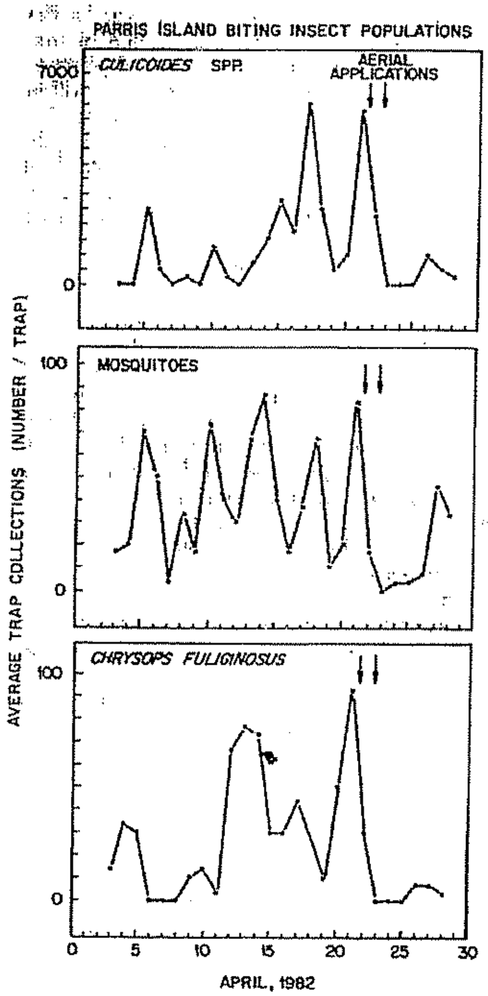

Fig. 2. Graphs of the natural population trends of *Culicoides* biting midges, mosquitoes and *Chrysops fuliginosus* based on average trap collections during April 1982, showing the effects of aerial applications of 1.0 oz/acre of Dibrom 14® on April 21 and 22.

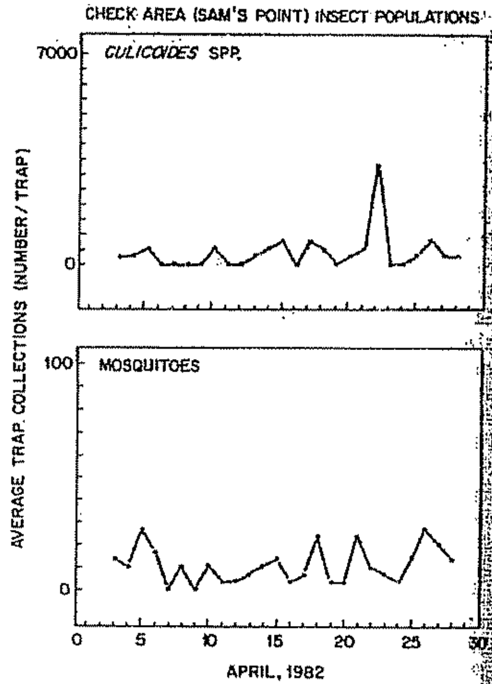

Fig. 3. Graphs of the natural population trends for *Culicoides* biting midges and mosquitoes in an untreated area (Sam's Point) during the 1982 aerial applications.

area (which was the windward side for this application) had significantly less than 100% mortality because of spray offset downwind. The high mortality in caged insects over the remainder of the island, whether open or vegetated, indicated that good penetration of vegetation was obtained with the higher dose of active ingredient applied in the 1982 test.

In conclusion, the 1982 experiment showed that ULV aerial applications of insecticides can be effectively used to reduce populations of *Culicoides* spp., as well as mosquitoes and tabanids, in non-isolated coastal areas, when the applications are made with sufficient toxicant dose levels and frequency. Additional field tests are needed to further define the effect of weather conditions, chemical dilution, operational parameters and application interval on overall efficiency and duration of control.

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References Cited

Giglioli, M. E. C., E. J. Gerberg and R. G. Todd. 1980. Large scale field tests and environmental assessments of Sumithion® (fenitrothion) against adult biting midges in Grand Cayman, West Indies. Mosq. News 40:1–5.

Haile, D. G., T. L. Biery, J. F. Reinert and N. W. Pierce. 1982. Aerial applications of naled diluted in HAN with UC-123K aircraft for adult mosquito control. Mosq. News 42:41–48

Kline, D. L., D. G. Haile and K. F. Baldwin. 1981. Wind tunnel tests with seven insecticides against adult *Culicoides mississippiensis* Hoffman. Mosq. News 41:745–747.

Mount, G. A., C. T. Adams, C. S. Lofgren and D. E. Weidhaas. 1970. Altitude and drift of ultralow volume aerial sprays of technical malathion for mosquito control. Mosq. News 30:580–584.

1982 Boike, A. H., Jr., C. B. Rathburn, Jr., L. A. Sizemore, and M. W. Peters
Results of the Florida Program for Monitoring Mosquito Susceptibility to Temephos, 1980-82
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1982 (1395)

SELECTED REFERENCES

Collectively, the references listed below contain detailed descriptions, records of occurrence and distribution, biological notes and bibliographic information pertinent to the systematics of Florida mosquitoes.

Belkin, J. N., S. J. Heinemann and W. A. Page. 1970. Mosquito studies (Diptera, Culicidae) XXI. The Culicidae of Jamaica. Contr. Amer. Ent. Inst. 6(1):1-458.

Breeland, S. G. 1982. Bibliography and notes on Florida mosquitoes with limited distribution in the United States. Mosq. Syst. 14(1):53-72.

Carpenter, S. J. and W. J. LaCasse. 1955. Mosquitoes of North America (North of Mexico). Univ. of Calif. Press, Berkeley 360 pp.

Carpenter, S. J., W. W. Middlekauff and R. W. Chamberlain. 1946. The mosquitoes of the Southern United States east of Oklahoma and Texas. Amer. Mid. Nat. Monog. No. 3. 292 pp.

Darsie, R. F., Jr., and R. A. Ward. 1981. Identification and geographical distribution of the mosquitoes of North America. North of Mexico. Mosq. Syst. Supplement 1:1-113.

FMEL. 1979. Distribution of mosquitoes in Florida. Unpublished table. Florida Medical Entomology Laboratory, Institute of Food and Agricultural Sciences. University of Florida, Vero Beach.

King, W. R., G. H. Bradley, D. N. Smith and W. C. McDuffie. 1960. A handbook of the mosquitoes of the southeastern United States. U.S.D.A. Agr. Handbook No. 173. 188 pp.

Results of the Florida Program for Monitoring Mosquito Susceptibility to Temephos, 1980-82

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ABSTRACT

Larval susceptibility tests of temephos, malathion, naled, fenthion, and chlorpyrifos were performed on 3 species of mosquitoes; *Aedes taeniorhynchus* (Wied.), *Culex nigripalpus* Theob., and *Culex quinquefasciatus* Say collected from 6 counties in Florida over a 3 year period (1980-1982 inclusive). All tests were compared to the susceptible West Florida Arthropod Research Laboratory (WFARL) strains. Results with *Aedes taeniorhynchus* indicated variable resistance (LC_{90} values of 3.7X — 35.8X) to malathion, with no resistance to temephos, naled, chlorpyrifos, or fenthion. *Culex nigripalpus* from 5 counties was susceptible to all 5 insecticides tested indicating no resistance of the species. Strains of *Culex quinquefasciatus* varied in their susceptibility with the insecticide tested and the origin of the strain. Some strains were 11.5X — 22.5X more tolerant to temephos when compared to the WFARL strain, and these same strains also showed possible cross-resistance to fenthion.

INTRODUCTION

Because of increased costs of both insecticides and manpower for the control of mosquitoes in the State of Florida, a number of mosquito control districts initiated the use of temephos (Abate) in their larval control programs due to its low cost as compared to oils, and its effectiveness at extremely low rates. This is a deviation from the policy of the State to treat mosquito breeding areas only with oils or insect growth regulators. In anticipation of possible development of resistance to temephos and cross-resistance to other currently used insecticides, a program was initiated in 1980 for monitoring the susceptibility of mosquito populations from selected areas in the State that had used temephos or were initiating its use. This is a report of results obtained during 3 years of the monitoring program.

MATERIALS AND METHODS

Typical breeding areas of three species of mosquitoes, *Aedes taeniorhynchus* (Wied.), *Culex nigripalpus* Theob. and *Culex quinquefasciatus* Say were selected in 6 counties (Collier, Hillsborough, Lee, Manatee, Polk, and St. Lucie) which had used temephos or planned to use it in their control programs. During the first year (1980), efforts were aimed at obtaining baseline susceptibility levels for these 3 species against temephos, malathion, naled, chlorpyrifos and fenthion. During the next successive years, plans were to test populations of these species against temephos only to determine if any resistance was beginning to appear. If any tolerance to temephos was noted, tests for cross-resistance to the other insecticides would be conducted.

Because of the difficulty of colonizing wild *Ae. taeniorhynchus* and *Cx. nigripalpus*, only adults of these species were shipped to the laboratory and tests were conducted on first generation larvae. Since *Cx. quinquefasciatus* is easily colonized, either egg rafts, larvae, or adults were sent to the laboratory and tests were performed on larvae from these colonized strains. Larval susceptibility tests were performed according to methods described by Rathburn and Boike (1967) and Boike et al. (1978). Results of tests of wild populations of *Ae. taeniorhynchus* and *Cx. nigripalpus* were compared to those of the susceptible West Florida Arthropod Research Laboratory (WFARL) strains of these 2 species. Results of tests of wild populations of *Cx. quinquefasciatus* were compared to the laboratory designated Sebring strain, a strain selected from approximately 10 strains tested from various areas within the state as being a normally susceptible strain.

RESULTS

Results of susceptibility tests with temephos against *Ae. taeniorhynchus*, *Cx. nigripalpus*, and *Cx. quinquefasciatus* from selected areas in the state are shown in Table 1. Baseline results of these 3 species of mosquitoes tested against malathion, naled, chloropyrifos, and fenthion are shown in Tables 2, 3, 4, 5, respectively. The LC_{50} and LC_{90} values and the 95% confidence limits were calculated by probit analysis using a Sharp programmable calculator. The resistance ratio (RR) was found by dividing the LC_{50} or LC_{90} values of the area strain by the LC_{50} or LC_{90} values of the susceptible laboratory strain.

TEMEPHOS (Table 1): Although the original intention of the Abate monitoring program was to obtain data beginning in 1980, followed by yearly collections from the same area, the lack of mosquito collections from some areas selected in 1980 or the inability of collected mosquitoes to lay eggs, dictated the establishing of new areas for 1981 and 1982. However, populations of *Ae. taeniorhynchus* from 3 areas in Hillsborough, Lee and St. Lucie counties tested on 2 successive years showed little variation in the LC_{50} and LC_{90} values. When the LC_{50} and LC_{90} values for *Ae. taeniorhynchus* from the 5 counties were compared, the variation ranged from 0.7X to 1.5X as susceptible as the WFARL strain. The LC_{50} and LC_{90} values for *Cx. nigripalpus* from 5 counties show great similarity and are almost identical to the values for the susceptible laboratory strain. The LC_{50} and LC_{90} values for *Cx. quinquefasciatus* tested against temephos from areas in 5 counties vary from 1.7X to 22.3X, indicating varying susceptibility when compared to the laboratory strain. Adult populations from only one area (Seffner/Valrico in Hillsborough County) were tested successively in 1980, 1981, and 1982, and results showed substantial tolerance to temephos for 3 years.

MALATHION (Table 2): *Ae. taeniorhynchus* sampled from areas in 5 counties for baseline data gave LC_{50} values of 1.9X – 18.3X and LC_{90} values of 3.7X – 35.8X that of the laboratory strain, indicating resistance to malathion in this species. Larval tests of *Cx nigripalpus* populations from 5 counties revealed low LC_{50} and LC_{90} values (1.1X – 2.6X) indicating no resistance to malathion when compared to the susceptible laboratory strain. LC_{50} values for *Cx. quinquefasciatus* varied from 1.8X – 7.0X while LC_{90} values varied from 2.0X to 10.2X indicating a small amount of resistance in some areas.

NALED (Table 3): The LC_{50} and LC_{90} values for *Ae. taeniorhynchus* and *Cx. nigripalpus* varied little (0.8X – 1.7X) indicating populations of these two species to be almost as susceptible as the WFARL strains. Similar results were obtained with *Cx. quinquefasciatus* with the exception of an area in Polk County (Eagle Lake) were an LC_{50} and LC_{90} RR of 5.3 and 5.6 were obtained and an area in Collier

Table 1. Susceptibility of *Aedes taeniorhynchus* (Wied.), *Culex nigripalpus* Theob. and *Culex quinquefasciatus* Say larvae to temephos.

County	Area	Year tested	Lethal concentration in ug AI/ml. (ppm)				Resistance ratio	
			LC_{50}	95% C.L.[1]	LC_{90}	95% C.L.[1]	LC_{50}	LC_{90}
			Aedes taeniorhynchus					
Collier	Naples	1980	.000742	(.000708-.000778)	.00120	(.00114-.00127)	0.9	0.7
	Pelican Bay	1980	.000807	(.000772-.000843)	.00133	(.00123-.00143)	0.9	0.9
Hillsborough	Tampa Shores	1979	.00145	(.00142-.00147)	.00228	(.00218-.00238)	1.4	1.3
	Tampa Shores	1981	.000975	(.000942-.00101)	.00145	(.00136-.00155)	0.9	0.8
Lee	Sanibel Island	1980	.000724	(.000663-.000791)	.00144	(.00134-.00155)	0.8	1.0
	Sanibel Island	1981	.00119	(.00115-.00122)	.00178	(.00168-.00188)	1.1	1.0
Manatee	Port Manatee	1980	.000742	(.000678-.000812)	.00179	(.00105-.00196)	0.8	1.3
St. Lucie	Ft. Pierce Bch.	1980	.00121	(.00116-.00126)	.00233	(.00209-.00261)	1.5	1.3
	Ft. Pierce Bch.	1981	.00138	(.00135-.00141)	.00204	(.00193-.00215)	1.3	1.1
			Culex nigripalpus					
Collier	Naples	1980	.000291	(.000278-.000304)	.000547	(.000513-.000583)	0.9	0.9
	Marco Island	1982	.000478	(.000469-.000488)	.000645	(.000626-.000665)	0.9	0.8
Hillsborough	Gibsonton	1980	.000296	(.000283-.000309)	.000609	(.000564-.000658)	0.9	1.0
	Gibsonton	1981	.000327	(.000315-.000340)	.000700	(.000651-.000754)	0.5	0.8
	Gibsonton	1982	.000389	(.000377-.000402)	.000626	(.000605-.000648)	0.7	0.7
Lee	Ft. Myers	1980	.000250	(.000227-.000275)	.000527	(.000466-.000596)	0.8	0.9
	Sanibel Island	1981	.000400	(.000386-.000415)	.000702	(.000660-.000747)	0.7	0.8
Polk	Mulberry	1981	.000517	(.000494-.000540)	.000792	(.000728-.000862)	0.9	0.9
	Mulberry	1982	.000416	(.000406-.000426)	.000589	(.000572-.000607)	0.7	0.7
St. Lucie	Ft. Pierce	1981	.000562	(.000546-.000579)	.000919	(.000863-.000979)	0.9	1.0
	Ft. Pierce	1982	.000513	(.000502-.000525)	.000791	(.000761-.000822)	1.0	0.9
			Culex quinquefasciatus					
Collier	Naples	1980	.00236	(.00220-.00252)	.00767	(.00670-.00878)	2.1	3.3
	District Hdqtrs.	1982	.00585	(.00536-.00638)	.0188	(.0160-.0220)	11.2	22.3
Hillsborough	Seffner/Valrico	1980	.00258	(.00232-.00287)	.0233	(.0181-.0299)	3.4	12.5
	Seffner/Valrico	1981	.00242	(.00217-.00269)	.0164	(.0121-.0207)	2.5	9.0
	Seffner/Valrico	1982	.00265	(.00241-.00293)	.0126	(.0102-.0156)	4.5	13.1
Lee	Ft. Myers	1980	.00287	(.00251-.00329)	.0346	(.0260-.0460)	2.5	15.0
Polk	Eagle Lake	1980	.0136	(.0130-.0143)	.0301	(.0278-.0318)	18.1	16.1
	Lake Alfred	1981	.00166	(.00156-.00177)	.00634	(.00562-.00717)	1.7	3.5
St. Lucie	Ft. Pierce	1980	.00492	(.00445-.00544)	.0215	(.0189-.0245)	6.6	11.5

[1]Confidence limits.

Table 2. Susceptibility of *Aedes taeniorhynchus* (Wied.), *Culex nigripalpus* Theob., and *Culex quinquefasciatus* Say larvae to malathion.

County	Area	Year tested	Lethal concentration in ug AI/ml. (ppm) LC_{50}	95% C.L.[1]	LC_{90}	95% C.L.[1]	Resistance ratio LC_{50}	Resistance ratio LC_{90}
			Aedes taeniorhynchus					
Collier	Naples	1980	.156	(.140-.175)	.831	(.662-1.044)	3.5	10.5
Hillsborough	Tampa Shores	1979	.859	(.813-.907)	2.612	(2.281-2.989)	18.3	35.8
Lee	Sanibel Island	1980	.228	(.199-.260)	1.810	(1.328-2.466)	5.1	22.9
Manatee	Port Manatee	1980	.0834	(.0736-.0945)	.291	(.252-.337)	1.9	3.7
St. Lucie	Ft. Pierce Bch.	1980	.251	(.233-.271)	1.061	(.932-1.207)	5.6	13.4
			Culex nigripalpus					
Collier	Naples	1980	.0242	(.0231-.0253)	.0452	(.0422-.0484)	1.8	2.3
	Marco Island	1982	.0330	(.0322-.0337)	.0470	(.0450-.0490)	1.1	1.2
Hillsborough	Gibsonton	1980	.0242	(.0237-.0247)	.0357	(.0343-.0372)	1.8	1.8
Lee	Ft. Myers	1980	.0272	(.0260-.0284)	.0505	(.0463-.0551)	2.0	2.6
Polk	Mulberry	1981	.0432	(.0417-.0447)	.0594	(.0556-.0635)	1.4	1.5
St. Lucie	Ft. Pierce	1981	.0353	(.0335-.0372)	.0571	(.0520-.0628)	1.1	1.5
			Culex quinquefasciatus					
Collier	Naples	1980	.310	(.279-.344)	1.534	(1.332-1.767)	1.8	4.0
	District Hdqtrs	1982	.700	(.662-.740)	1.545	(1.434-1.667)	7.0	10.2
Hillsborough	Seffner/Valrico	1980	.338	(.324-.353)	.783	(.708-.866)	1.9	2.0
Lee	Ft. Myers	1980	.451	(.412-.494)	1.617	(1.435-1.823)	2.5	4.2
Polk	Eagle Lake	1980	1.133	(1.090-1.177)	2.716	(2.499-2.952)	6.4	7.1
	Lake Alfred	1981	.248	(.234-.264)	.666	(.602-.737)	2.2	2.8
St. Lucie	Ft. Pierce	1980	.521	(.493-.551)	1.508	(1.368-1.663)	2.9	3.9

[1]Confidence limits

Table 3. Susceptibility of *Aedes taeniorhynchus* (Wied.), *Culex nigripalpus* Theob., and *Culex quinquefasciatus* Say larvae to naled.

County	Area	Year tested	Lethal concentration in ug AI/ml. (ppm)				Resistance ratio	
			LC_{50}	95% C.L.[1]	LC_{90}	95% C.L.[1]	LC_{50}	LC_{90}
			Aedes taeniorhynchus					
Collier	Naples	1980	.0711	(.0655-.0771)	.165	(.146-.187)	0.9	0.7
Hillsborough	Tampa Shores	1979	.144	(.139-.149)	.211	(.195-.229)	1.1	0.8
Lee	Sanibel Island	1980	.122	(.114-.129)	.177	(.166-.189)	1.5	0.8
St. Lucie	Ft. Pierce Bch.	1980	.0768	(.0728-.0810)	.189	(.171-.210)	0.9	0.9
			Culex nigripalpus					
Collier	Naples	1981	.0416	(.0404-.0429)	.0583	(.0554-.0614)	1.1	1.1
	Marco Island	1982	.0408	(.0397-.0421)	.0624	(.0585-.0664)	1.1	1.2
Hillsborough	Gibsonton	1981	.0528	(.0512-.0544)	.0895	(.0810-.0990)	1.4	1.7
Lee	Ft. Myers	1982	.0497	(.0489-.0505)	.0631	(.0611-.0650)	1.3	1.3
Polk	Mulberry	1981	.0420	(.0412-.0427)	.0627	(.0603-.0653)	1.1	1.2
St. Lucie	Ft. Pierce	1981	.0484	(.0476-.0492)	.0663	(.0641-.0686)	1.3	1.3
			Culex quinquefasciatus					
Collier	District Hdqtrs.	1982	.356	(.344-.369)	.644	(.594-.698)	3.7	4.9
Hillsborough	Seffner/Valrico	1980	.164	(.161-.168)	.253	(.242-.264)	1.3	1.2
Lee	Ft. Myers	1981	.142	(.137-.147)	.240	(.223-.258)	1.1	1.0
Polk	Eagle Lake	1980	.646	(.620-.673)	1.140	(1.060-1.226)	5.3	5.6
	Lake Alfred	1981	.167	(.160-.174)	.344	(.315-.376)	1.4	2.0
St. Lucie	Ft. Pierce	1980	.179	(.168-.191)	.680	(.612-.756)	1.6	3.3

[1]Confidence limits.

Table 4. Susceptibility of *Aedes taeniorhynchus* (Wied.), *Culex nigripalpus* Theob., and *Culex quinquefasciatus* Say larvae to chlorpyrifos.

County	Area	Year tested	Lethal concentration in ug AI/ml. (ppm) LC_{50}	95% C.L.[1]	LC_{90}	95% C.L.[1]	Resistance ratio LC_{50}	Resistance ratio LC_{90}
			Aedes taeniorhynchus					
Hillsborough	Tampa Shores	1981	.00105	(.00101-.00109)	.00153	(.00144-.00163)		
Lee	Sanibel Island	1980	.000943	(.000879-.00101)	.00141	(.00123-.00161)	0.9	0.9
St. Lucie	Ft. Pierce Beach	1980	.000911	(.000882-.000940)	.00137	(.00128-.00147)	0.8	0.8
							0.8	0.8
			Culex nigripalpus					
Collier	Marco Island	1982	.000633	(.000607-.000661)	.00114	(.00107-.00121)		
Hillsborough	Gibsonton	1981	.000781	(.000762-.000801)	.00102	(.000984-.00106)	1.0	1.0
Lee	Ft. Myers	1982	.000819	(.000800-.000836)	.00119	(.00113-.00122)	1.1	0.6
Polk	Mulberry	1981	.000659	(.000637-.000680)	.000908	(.000869-.000949)	1.4	1.3
St. Lucie	Ft. Pierce	1982	.000676	(.000650-.000696)	.00122	(.00116-.00129)	0.9	0.5
							1.0	0.7
			Culex quinquefasciatus					
Collier	Naples	1981	.00396	(.00368-.00426)	.00967	(.00851-.0110)		
Collier	District Hdqtrs.	1982	.00490	(.00472-.00509)	.00957	(.00902-.0102)	2.2	2.4
Hillsborough	Seffner/Valrico	1980	.00222	(.00210-.00236)	.00640	(.00572-.00714)	7.0	4.5
Lee	Ft. Myers	1981	.00222	(.00209-.00235)	.00431	(.00393-.00472)	1.3	1.7
Polk	Eagle Lake	1980	.00621	(.00587-.00656)	.0220	(.0194-.0250)	1.3	1.1
Polk	Lake Alfred	1982	.00239	(.00225-.00255)	.00711	(.00618-.00817)	3.5	6.0
St. Lucie	Ft. Pierce	1980	.00412	(.00386-.00440)	.0179	(.0157-.0204)	1.6	2.5
							2.3	4.9

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Table 5. Susceptibility of *Aedes taeniorhynchus* (Wied.), *Culex nigripalpus* Theob., and *Culex quinquefasciatus* Say larvae to fenthion.

County	Area	Year tested	Lethal concentration in ug AI/ml. (ppm)				Resistance ratio	
			LC_{50}	95% C.L.[1]	LC_{90}	95% C.L.[1]	LC_{50}	LC_{90}
			Aedes taeniorhynchus					
Hillsborough	Tampa Shores	1981	.00270	(.00261-.00279)	.00429	(.00402-.00458)	1.5	1.5
Lee	Sanibel Island	1981	.00283	(.00275-.00290)	.00501	(.00473-.00532)	1.5	1.7
St. Lucie	Ft. Pierce Beach	1980	.00241	(.00234-.00248)	.00378	(.00364-.00394)	1.3	1.3
			Culex nigripalpus					
Collier	Marco Island	1982	.00353	(.00348-.00359)	.00530	(.00510-.00621)	1.1	1.3
Hillsborough	Gibsonton	1981	.00302	(.00295-.00309)	.00417	(.00402-.00434)	0.9	0.9
Lee	Ft. Myers	1982	.00352	(.00342-.00362)	.00583	(.00545-.00625)	1.1	1.4
Lee	Sanibel Island	1981	.00312	(.00290-.00335)	.00584	(.00497-.00686)	0.9	1.3
Polk	Mulberry	1982	.00337	(.00328-.00348)	.00482	(.00461-.00502)	1.0	1.2
St. Lucie	Ft. Pierce	1982	.00346	(.00336-.00357)	.00594	(.00547-.00647)	1.0	1.4
			Culex quinquefasciatus					
Collier	District Hdqtrs.	1982	.0283	(.0270-.0296)	.0553	(.0525-.0583)	5.9	7.1
Hillsborough	Seffner/Valrico	1980	.0125	(.0110-.0142)	.0914	(.0666-.126)	1.5	5.5
Lee	Ft. Myers	1981	.00879	(.00843-.00916)	.0186	(.0170-.0205)	0.9	1.1
Polk	Eagle Lake	1980	.0413	(.0379-.0450)	.243	(.2017-.2946)	5.0	14.8
Polk	Lake Alfred	1982	.00910	(.00865-.00955)	.0285	(.0252-.0323)	1.4	2.1
St. Lucie	Ft. Pierce	1980	.0157	(.0146-.0170)	.100	(.0813-.124)	1.9	6.1

[1] Confidence limits.

County where an LC_{50} and LC_{90} RR of 3.7 and 4.9 were obtained.

CHLORPYRIFOS (Table 4): Baseline data for *Ae. taeniorhynchus* and *Cx. nigripalpus* from areas in the selected counties indicate no resistance in either species as indicated by the low RR values. LC_{90} values for *Cx. quinquefasciatus* from the selected counties vary from 1.1X to 6X indicating some tolerance in the populations from these areas.

FENTHION (Table 5): Baseline data for *Ae. taeniorhynchus* and *Cx. nigripalpus* from the selected areas indicate no resistance. LC_{50} and LC_{90} values for *Cx. quinquefasciatus* show a wide variation (0.9X to 14.8X) indicating tolerance to fenthion in some of the areas.

DISCUSSION

In part, this is a continuation of insecticide resistance surveillance in Florida against *Ae. taeniorhynchus, Cx. nigripalpus*, and *Cx. quinquefasciatus* as previously reported by Boike et al. 1978, 1979, 1980. This reported temephos monitoring program differs from the previously mentioned surveillance programs in that populations of the 3 species of mosquitoes were first tested against temephos, then baseline values for the other 4 insecticides were obtained. A similar monitoring program has been reported by Helson et al. (1979) in southern Ontario where larvae of *Culex spp.* and *Aedes* spp. from areas of no known history of insecticide treatment were tested against chlorpyrifos and temephos for baseline information following an outbreak of St. Louis Encephalitis in 1975. Sutherland and Evans (1976) stated the necessity for monitoring the susceptibility of field populations to insecticides in use in order to maintain a high quality of mosquito control.

The variable resistances of *Ae. taeniorhynchus* to malathion follows a similar trend reported in previous years by Boike et al., 1978, 1979, 1980. This report indicates that populations of *Ae. taeniorhynchus* tolerant to malathion, were as susceptible to temephos as the susceptible WFARL strain, indicating no cross-resistance from the use of temephos (as of 1982). Similar results by Boike et al. (1980) show that malathion tolerant populations of *Ae. taeniorhynchus* (from areas other than those reported in this paper) were as susceptible to temephos as the WFARL strain. *Cx. nigripalpus* continues to be susceptible to all insecticides tested. Populations of *Cx. quinquefasciatus* varied considerably in their susceptibility to all insecticides tested. Of the 6 strains of *Cx. quinquefasciatus* tested against the 5 insecticides, 4 had LC_{90} values > 11.5X when tested against temephos. When these same strains were tested against fenthion, they had LC_{90} values of > 5.5X that of the WFARL strain, indicating possible cross resistance. It is concluded that the variable tolerance of *Cx. quinquefasciatus* to different insecticides is not only the result of insecticide pressure from mosquito control, but, in many cases, pressure from insecticide run-off from agricultural applications.

It is concluded that the use of temephos by mosquito control agencies in the areas sampled in this report did not produce resistance in populations of *Ae. taeniorhynchus* or *Cx. nigripalpus*. The biology and bionomics of *Cx. quinquefasciatus* are possibly the governing factors for the variable susceptibility of this species to the insecticides tested. It should be noted, however, that this monitoring is a continuing program and current results do not preclude the possible development of resistance to temephos or the cross-resistance to other organophosphate insecticides in the future.

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LITERATURE CITED

Boike, A. H. Jr., C. B. Rathburn, Jr., C. F. Hallmon, and S. G. Cotterman. 1978. Insecticide susceptibility tests of *Aedes taeniorhynchus* and *Culex nigripalpus* in Florida, 1974-1976. Mosquito News 38(2):210-217.

Boike, A. H. Jr., C. B. Rathburn, Jr., C. F. Hallmon, and S. G. Cotterman. 1979. Insecticide susceptibility levels of some Florida mosquitoes for 1977-78. Proc. Fla. Anti-Mosq. Assn. 50:62-67.

Boike, A. H. Jr., C. B. Rathburn, Jr., C. F. Hallmon, and R. L. Welles. 1980. Monitoring for resistance in mosquitoes from several selected areas in Florida in 1979. Proc. Fla. Anti-Mosq. Assn. 51: 47-51.

Helson, B. V., G. A. Surgeoner and W. E. Ralley. 1979. Susceptibility of *Culex* spp. and *Aedes* spp. larvae (Diptera: Culicidae) to temephos and chlorpyrifos in southern Ontario. Proc. Ent. Soc. of Ontario 110:79-83.

Rathburn, C. B. Jr. and A. H. Boike, Jr. 1967. Studies of insecticide resistance in Florida mosquitoes. Mosquito News 27(3):377-382.

Sutherland, D. J. and E. S. Evans, Jr. 1976. Insecticide resistance in New Jersey mosquitoes: a five-year summary. Proc. New Jersey Mosq. Exter. Assn. 63:176-181.

Laboratory Tests of Mosquito Adulticides

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ABSTRACT

Non-thermal aerosol sprays of several pyrethroids, several organophosphates and one carbamate were tested as adulticides against *Aedes taeniorhynchus* (Wied.), *Culex nigripalpus* Theobald and *Culex quinquefasciatus* Say in a laboratory wind tunnel. Bendiocarb, chlorpyrifos, fenthion, naled and fenitrothion were more toxic to the three mosquito species than malathion used as a standard. The pyrethroids, flucythrinate, fluvalinate, permethrin, phenothrin and pyrethrum plus piperonyl butoxide were more toxic than the standard resmethrin when tested against *Ae. taeniorhynchus* but allethrin was significantly less toxic. When tested against *Cx. nigripalpus*, permethrin was more toxic and allethrin was less toxic than the standard resmethrin. Although not all pyrethroids were tested against *Cx. quinquefasciatus*, those tested against this species resulted in a toxicity similar to that obtained with *C. nigripalpus*.

INTRODUCTION

The West Florida Arthropod Research Laboratory conducts laboratory wind tunnel tests of promising, safe, and environmentally acceptable mosquito adulticides in a continuing program to develop new insecticides for use in the adult mosquito control programs in the State. Adulticides which show promise in these tests are further evaluated in field tests prior to being recommended for use. This report contains the results of laboratory non-thermal aerosol tests of 14 insecticides against three species of mosquitoes.

MATERIALS AND METHODS

All tests were conducted in a laboratory wind tunnel similar to that described by Rathburn (1969) with the exception that the heater and condensation tube of the thermal aerosol generator were not used. Test methods were similar to those described in Rathburn and Boike (1972) and Boike and Rathburn (1975). Treatment consisted of spraying 0.5 ml of an insecticide solution, diluted to a predetermined concentration in acetone, into a wind tunnel containing a cage of 25 adult female mosquitoes. The aerosol was drawn through the wind tunnel, which contained the 15 cm. diameter screen test cage, by means of a fan at an air velocity of 1.3 m/sec. Each replication of each insecticide consisted of one cage of mosquitoes for each of a series of 5 insecticide dilutions and the control. The control cages were exposed in the same manner to an aerosol of acetone only. Each test consisted of at least 2 replications or cages of each dosage and

1982 Erickson, L. A.
Effectiveness of Aerial Applications of Naled 85 Concentrate on Rocky Point, Florida
J. Florida Anti-Mosquito Association 34-38 (Amvac Ref. #1396)

1396

pressure in selected habitats.

Results are promising, and further laboratory and field evaluations are planned to determine the operational feasibility and cost-effectiveness of the liquid and solid formulations.

REFERENCES CITED

Levy, R., C. M. Powell and T. W. Miller, Jr 1984. Efficacy of Arosurf®MSF (Monomolecular Surface Film) Base Formulations of *Bacillus thuringiensis israelensis* Againt Mixed Populations of Mosquito Larvae and Pupae: Bioassay and Preliminary Field Evaluations. Mosquite News (In press).

Levy, R., C. M. Powell and T. W. Miller, Jr. 1984. Investigations on the Mosquito Control Potential of Formulations of Arosurf®MSF and Conventional Larvicides. Mosquito News (In press).

Effectiveness of Aerial Applications of Naled 85 Concentrate on Rocky Point, Florida

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ABSTRACT

Evaluation of aerial applications of Naled 85 concentrate against adult populations of *Aedes taeniorhynchus* was conducted on Rocky Point. Martin County, Florida. The applications were determined effective in reducing adult populations at a rate of 0.50 ounce per acre. Results showed that aerial applications of Naled 85 concentrate has important advantages over conventional ground operated ULV spray trucks.

INTRODUCTION

In Martin County Florida, Rocky Point has historically harbored large populations of pest mosquitos. It is located between the Manatee Pocket on the west and the Great Pocket on the east (Fig. 1). Mangrove swamps cover a great deal of the shore margins along the waterways surrounding Rocky Point. Plans are being drawn for the north end of Jupiter Island, a protected area covered by mangrove swamps, to become a State Park.

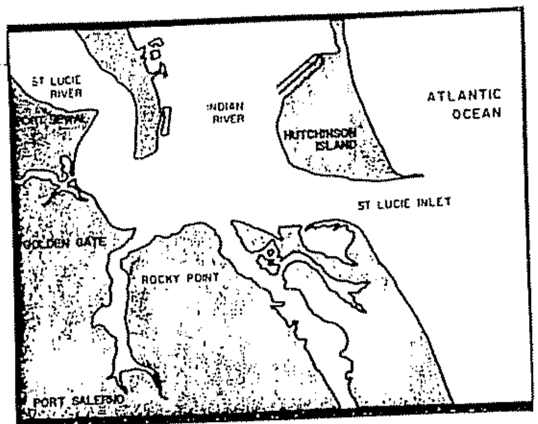

Fig. 1. Map Showing Location of Rocky Point, Martin County, Fl.

Citizens requests for relief from biting mosquitos plague mosquito control workers year round. Efforts to control larval populations include ground larviciding with diesel fuel or *Bacillus thuringiensis israelensis*, aerial applications of Altosid SR-10 and others. Each method has its own drawbacks. Many areas are difficult to get to from the ground while the length of the effectiveness of growth regulators is difficult to determine. Some of the issues which must be considered in the overall control of the mosquitos are weather, cost effectiveness, environmental impact, dispersal, requests of the residents and re-infestation.

Because of the large areas of woodlands and the lack of access roads in the area, the effectiveness of ground ULV is questionable. Therefore, in the past, control of mosquitos on Rocky Point has been a hit and miss situation. Requests would often come on the night after ground ULV had occured. In the fall of 1980, another option of control was made available to mosquito control workers. A confiscated Cessna 337 aircraft was donated to Environmental Services by the Martin County Sheriff's Department. Previously, aircraft had to be hired at a much higher cost than could now be achieved. The plane was then equipped with a 35 gallon fiberglass tank and set up for spraying. This paper attempts to point out some of the advantages of aerial application of ULV as compared to ground ULV on Rocky Point, Florida.

MATERIALS AND METHODS

New Jersey light trap collections seemed to show that the summer of 1980 was no worse than previous years. However, population levels of pest mosquitos were unbearable to local residents. The mosquitos were biting in bright sunlight and getting worse during the crepuscle. This made it almost impossible for residents to barbeque, walk their dogs, or just sit on their front porch. Although ground ULV trucks sprayed Rocky Point a total of 66 nights that year, it did not appease some residents. One resident was so angry with the situation that on November 5, 1980 he called the Office of Entomology in Jacksonville and talked with Dr. Mulrennan. This conversation resulted in several trips to Rocky Point by the State Entomologist-Inspector, Susan McKnight. A landing rate count was made at 5:15 P.M. on November 10. The results were 27 mosquitos during a one minute period. The collected mosquitos were identified as *Aedes taeniorhynchus*. On the 19th only one mosquito was observed from 8:30 A.M. to 12:30 A.M and a north-east wind was observed by the Entomologist-Inspector. An inspection and mapping of mosquito breeding areas was set up for the 25th of November. The results showed that areas accessible to mosquito control workers were being maintained. Also, four potential breeding areas were located. It seemed that with a southeast wind, infestation from Jupiter Island was imminent. Being an environmentally sensitive area and housing two protected parks, part of Jupiter Island was excluded from chemical control for mosquitos by Environmental Services. Interested parties were contacted and an agreement was made for aerial application of Altosid SR-10 to take place on Jupiter Island. Much of the information found by the state was already known by mosquito control workers in Martin County and little improvement of the problem was expected with the excep-

Table 1. Application of ULV Spray on Rocky Point, Martin County, Fl. 1980.

Month	Nights sprayed	Hours & minutes	Cost—dollars
March			
Aircraft			
Truck	1	3′40″	142.10
April			
Aircraft			
Truck	3	7′15″	321.10
May			
Aircraft			
Truck	2	4′20″	175.14
June			
Aircraft			
Truck	11	29′55″	1251.98
July			
Aircraft			
Truck	10	35′20″	1381.76
August			
Aircraft			
Truck	9	33′20″	1297.39
September			
Aircraft			
Truck	8	29′35″	1151.44
October			
Aircraft			
Truck	15	53′40″	2088.81
November			
Aircraft			
Truck	7	21′25″	888.72
Total			
Aircraft			
Truck	66	259′30″	8699.05

	Total acres		Cost per acre
Aircraft			
Truck	81.109		.11¢
	81.109		

Table 2. Application of ULV Spray on Rocky Point. Martin County. Fl. 1981.

Month	Nights sprayed	Hours & minutes	Cost—dollars
March			
Aircraft			
Truck			
April			
Aircraft			
Truck			
May			
Aircraft			
Truck	4	15′20″	703.43
June			
Aircraft			
Truck	9	32′20″	1498.61
July			
Aircraft	1	30″	395.49
Truck	9	27′20″	1253.95
August			
Aircraft	3	1′30″	1186.47
Truck	3	8′10″	374.66
September			
Aircraft	1	30″	395.49
Truck	8	25′30″	1280.71
October			
Aircraft	1	30″	395.49
Truck	6	23′45″	1089.57
November			
Aircraft			
Truck	2	7′40″	351.72
Total			
Aircraft	6	3′00″	2372.94
Truck	41	140′05″	6552.65
			8926.59

	Total acres	Cost per acre
Aircraft	13.958	.17¢
Truck	52.000	.13¢
	65.958	

Table 3. Application of ULV Spray on Rocky Point. Martin County. Fl. 1982.

Month	Nights sprayed	Hours & minutes	Cost—dollars
March			
Aircraft			
Truck	2	2′30″	112.60
April			
Aircraft	1	30″	418.86
Truck	5	12′30″	562.59
May			
Aircraft	1	30″	418.86
Truck	5	19′50″	866.35
June			
Aircraft	6	3′00″	2513.16
Truck	6	16′05″	716.34
July			
Aircraft	1	30″	418.86
Truck	8	22′00″	1001.38
August			
Aircraft			
Truck	7	20′00″	922.63
September			
Aircraft	4	2′00″	1675.44
Truck	8	19′20″	870.11
October			
Aircraft	2	1′00″	837.72
Truck	3	6′50″	307.53
November			
Aircraft	1	30″	418.86
Truck	2	6′00″	270.02
Total			
Aircraft	16	8′00″	6701.76
Truck	49	134′40″	6053.35
			12755.11

	Total acres	Cost per acre
Aircraft	37.232	.18¢
Truck	51.188	.12¢
	88,120	

tion of quieting the complaints of one angry resident. Therefore, it seemed some other method of controlling adult mosquito populations on Rocky Point needed implementation.

By the summer of 1981 the twin engine Cessna 337 fixed wing aircraft was ready for aerial application of Dibrom 14 at a rate of .5 ounces per acre. The plant was equipped with a 35 gallon fiberglass tank which enabled spraying of approximately 9000 acres per tank load. Rocky Point was sprayed six nights that year covering a total of 13,958 acres. In 1981, a total of 65,958 acres were sprayed on Rocky Point at a cost of $8926.59 (see Table 2). In 1980 a total of 81,109 acres were sprayed from the ground at a cost of $8699.05 (see Table 1). In the overall spraying of Rocky Point this amounted to 3 cents an acre more in 1981 than in 1980. To mosquito control management this seemed a small amount to pay for a much better control.

The real test was in 1982 when the aircraft was run all season with little or no problems. New Jersey Light traps were operated to monitor mosquito populations. A total of 37,232 acres were treated by air that year at a cost of $6701.76 (see Table 3). By ground 51,188 acres were sprayed at a cost of $6053.35. Together 88,420 acres were sprayed at a cost of $12.755.11 or 15 cents per acre.

RESULTS

On May 5th and 6th, 1982 two New Jersey light traps were operated in different areas of Rocky Point. They were run the night before and the night of aerial application of ULV. One trap operated at the Hurchalla's residence yielding a total of 147 mosquitos the night before spraying and 9 mosquitos after treatment. The other trap was operated at the Hutchin's residence yielding 96 and 15 respectively. Due to the urgency to reduce mosquito populations, this experiment was only done one more time that year on June 8th, 9th, and 10th. The Hurchalla trap yielded 142 the night before spraying and 76 the night of spraying, while Hutchin's yielded 62 the night before and 35 the night of spraying. One possible cause of the lower knock-down rate was the prevailing south-east wind which can cause reinfestation from untreated areas. On June 10th mosquito complaints continued to flood Environmental Services. That night the plane flew once more over Rocky Point. The traps were set and the results were significantly better. Hurchalla's trap was down to 17 while Hutchin's collected only 1 mosquito. This seemed to be a level the residents could live with and complaints ceased for a few days.

CONCLUSIONS

Some of the advantages of aerial application of ULV that were noted during 1982 were higher knock-down rates, better coverage, quicker reduction rates, and reduced complaints from residents. Although Rocky Point is only one small area which was monitored, similar results are consistent throughout the county. With the addition of another Cessna 337, Martin County Mosquito Control is looking forward to giving even better services to its residents in the coming years.

1982 Haile, D. G., T. L. Biery, J. F. Reinert, and N. W. Pierce
Aerial Applications of Naled Diluted in HAN with UC-123K Aircraft for Adult Mosquito Control
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1397

AERIAL APPLICATIONS OF NALED DILUTED IN HAN WITH UC-123K AIRCRAFT FOR ADULT MOSQUITO CONTROL[1]

DANEL G. HAILE[2], TERRY L. BIERY[3], JOHN F. REINERT[4] AND NED W. PIERCE[5]

ABSTRACT. Aerial application experiments with technical and diluted Dibrom® 14 were conducted at Avon Park Air Force Range, Florida, using caged mosquitoes to bioassay effectiveness and downwind aerosol distribution. A total of 9 tests were conducted with caged *Aedes taeniorhynchus* females placed at 0.1 mi intervals for a distance of ca 2 mi in a line perpendicular to aircraft flight and parallel to wind direction. A dilute formulation of Dibrom14 in heavy aromatic naphtha (HAN), 1:5 ratio, was applied at rates of 0.75 and 1.5 oz/acre (0.125 and 0.25 oz/acre Dibrom14); and undiluted Dibrom14 was applied at rates of 0.25 and 0.75 oz/acre based on a 2000 ft swath width and 150 mph aircraft airspeed. The results indicated that the dilute formulation applied at 1.5 oz/acre (0.25 oz/acre Dibrom14) was more effective than 0.25 oz/acre Dibrom14 undiluted and equal to 0.75 oz/acre Dibrom14 undiluted. These results cannot be considered totally conclusive due to the variability of atmospheric conditions between tests and the lack of replication for some tests. However, the results strongly suggest that dilution substantially improved the application efficiency and that the rate of 1.5 oz/acre of the 1:5 Dibrom 14:HAN mixture gave excellent mosquito control under the environmental conditions existing during these tests. Additional research will be needed to determine the applicability of this technique under other environmental conditions and to verify the effect on natural populations.

Ultra low volume (ULV) aerial applications of Dibrom® 14, an 85% formulation of naled (1,2-dibromo-2,2-dichloroethyl dimethyl phosphate), have been successfully used for large scale control of adult mosquitoes for a number of years (Glancey et al. 1966, Mount and Lofgren 1967, Sutherland et al. 1978). However, recent increases in the cost of insecticides and fuel, as well as environmental concern, have renewed the incentive to improve the efficiency of this technique. To reduce the application rate and cost, the U.S. Air Force Reserve Aerial Spray Branch, Rickenbacker ANGB, Ohio, developed a technique for applying Dibrom 14 diluted in heavy aromatic naphtha (HAN) at a 1:5 ratio (Unpublished Annual Reports for 1973–79). This mixture has been applied at a rate of 1.5 oz/acre (0.25 oz/acre Dibrom14 and 1.25 oz/acre HAN) which represents a 67% reduction in dose of Dibrom14 from the 0.75 oz/acre normally used as a technical ULV application (label recommended rate is 0.5 to 1 oz/acre). The Office of Pest Management, Maryland Department of Agriculture, used this technique in 1978 in an experimental application with good results in controlling *Aedes sollicitans* (Walker) (S. Joseph, personal communication).

The objective of this study was to compare the effectiveness of this mixture with

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[1] This paper reports the results of research only. Mention of a pesticide in this paper does not constitute a recommendation for use by the U. S. Department of Agriculture or the Department of Defense, nor does it imply registration under FIFRA as amended. Also, mention of a commercial or proprietary product in this paper does not constitute an endorsement of this product by the USDA or DoD.

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applications of undiluted Dibrom14 in field bioassays using caged mosquitoes.

MATERIALS AND METHODS

Field tests with caged mosquitoes were conducted at Avon Park Air Force Range, Florida during April 1980 using procedures similar to those employed by Mount et al. (1970). The test site was predominantly an open area with only low shrubs and scattered trees. Caged *Aedes taeniorhynchus* (Wiedemann) females (25/cage) were placed on 4 ft stakes at 0.1-mi intervals along a roadway that was perpendicular to aircraft flights and ca parallel to wind direction. The test area included 3 intersecting roadways that allowed cages to be set for 3 different wind directions. The number of cages set for each test varied from 15 to 21 (covering a distance of 1.4 to 2.0 mi) and depended on the roadway length and availability of caged mosquitoes.

Laboratory-reared adult mosquitoes (3-6 days old) were used in all tests. The mosquitoes were immobilized in a cold room (ca 2°C) and placed in cylindrical cages (3.5 cm diam x 15 cm long) made of 16 mesh screen wire for exposure to insecticide treatments. The screen wire cage was attached to a plastic cage (3.5 cm diam x 12 cm long) which was used to hold the mosquitoes after exposure (Fig. 1). The cages of mosquitoes were placed in an ice chest with a cotton pad moistened with water and a container of ice for transport to the test site. Mosquitoes were transferred from the screen cage to the plastic holding cage ca 15 min after exposure. A cotton ball moistened with a 10% sugar-water solution was placed on each holding cage and the cages were held in another ice chest for ca 12 hr before mortality readings were made.

Four application treatments were considered in these tests. These included applications of the dilute formulation (1:5 Dibrom 14/HAN) at rates of 0.75 oz/acre (0.125 oz/acre Dibrom14) and 1.5 oz/acre (0.25 oz/acre Dibrom14) and with technical (undiluted) Dibrom14 at rates of 0.25 oz/acre and 0.75 oz/acre. For this paper, a code was developed to reflect the formulation applied and the application rate of Dibrom14 (oz/acre) as follows:

Treatment code	Formulation	Application rate of Dibrom® 14 oz/acre	Total application rate oz/acre
⅛-MIX	1:5 Dibrom 14/HAN mixture	⅛	¾
¼-MIX	1:5 Dibrom 14/HAN mixture	¼	1–1½
¼-TECH	Dibrom 14 undiluted	¼	¼
¾-TECH	Dibrom 14 undiluted	¾	¾

All applications were made with a U.S. Air Force UC-123K aircraft equipped with Spraying Systems Company TeeJet® nozzles on wing booms. The number and size of nozzles, as well as pressure were varied to obtain the proper flowrate for each of the above treatments with a 2000 ft swath width and 150 mph air speed (Table 1). For calibration, the flow was collected and measured from 4 or 8 nozzles for either 30 or 60 sec. The flow was adjusted to within ±1% of the desired rate before each test.

Limited droplet size measurements were made for the dilute formulations at 1.5 oz/acre (1/4-MIX) and the technical application at 0.75 oz/acre (3/4-TECH). Droplet samples were collected on Teflon®-coated slides by impaction with a spinning device. Two spray passes were made over the collection devices at a low altitude (25 to 40 ft). Low altitude was used for these samples in order to maximize the collection of droplets from the entire size distribution. Only 1 collection was made for each of the 2 treat-

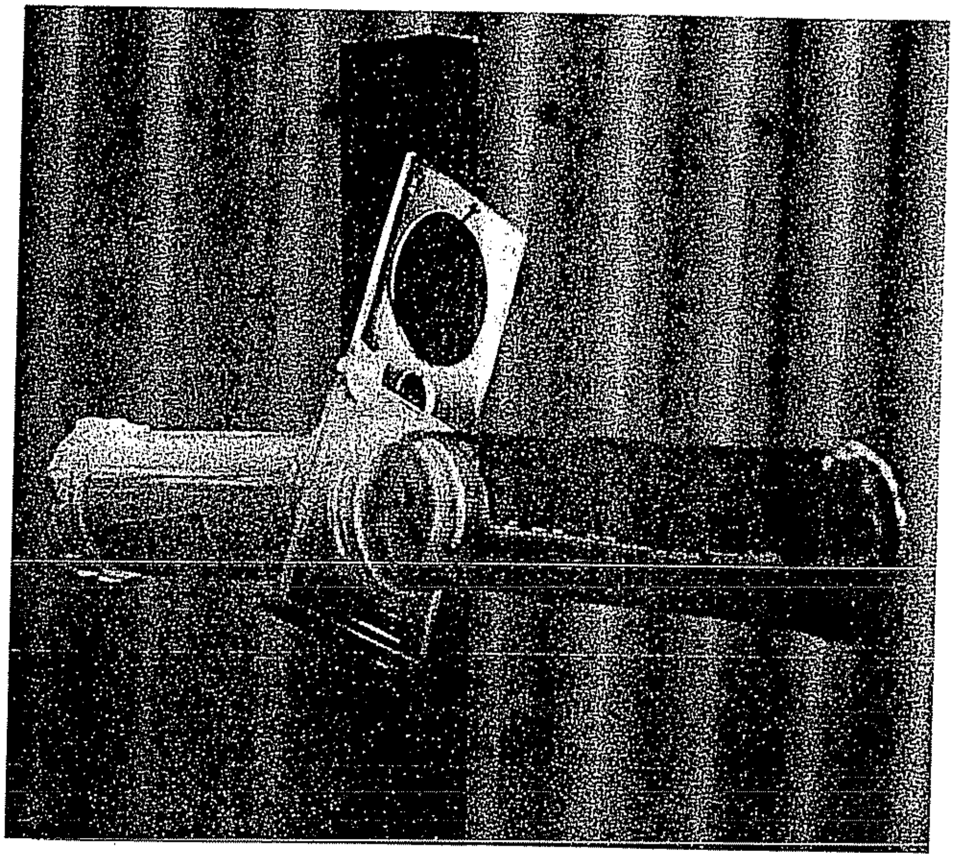

Fig. 1. Screen wire cage for exposure of mosquitoes attached to plastic holding cage.

ments. Each collection resulted in 3 slide samples and 100 droplets from each slide were measured using a microscope equipped with a micrometer (total of 300 droplets for each treatment). These measurements indicated a volume median di-

Table 1. Spray equipment and flow data for aerial application treatments.

Treatment code	Nozzle size[a]	Number of nozzles	Pressure, Psi	Desired flow[b] gal/min
⅛-MIX	8004	18	—[c]	3.55
¼-MIX	8004	18	44	7.11
¼-TECH	8003	4	—[d]	1.19
¾-TECH	8003	12	—[d]	3.56

[a] Spraying Systems Company catalog designation.
[b] Based on 2000 ft swath width and 150 mph air speed. Monitored by a Barton I.T.T. digital flowmeter during spray operation.
[c] No reading.
[d] Pressure gauge defective.

ameter (VMD) of 21 μm for the dilute formulation (1/4-MIX) and 38 μm for the technical formulation (3/4-TECH).

Weather measurements were made during the tests by a meteorological team from McDill Air Force Base, Florida. Wind speed and direction were measured at ground level and at 250-, 500-, 750- and 1000-ft altitude by release of weather balloons. Dry bulb and dew point temperatures were also measured at ground level. Measurements were made every half hour during test periods and those taken closest to the actual application time were used as the ones prevailing during the treatment.

A total of 9 tests were completed under various conditions. A summary of the environmental conditions and application variables is given in Table 2 for each test. Single swath applications were made for the 2 doses of the dilute formulation (Tests 1 and 3), while 3 swaths were applied for the remaining tests. The swaths were applied at 0.4 mi (2112 ft) intervals rather than the theoretical 2000 ft. The spray was released for ca 1.25 mi on either side of the cage line (2.5 mi total spray run/1 min spray time) for each swath. Aircraft speed was constant at 150 mph. Spray altitude varied from ca 200 to 270 ft with the exception of one test at 130 ft during relatively high velocity winds. Four cages of mosquitoes were placed ca 0.5 mi upwind of the treatment area during each test to indicate natural (no treatment) mortalities (Table 2). Natural mortality in these tests was relatively low (overall average 5%, range 2 to 10%) indicating that the laboratory-reared mosquitoes were healthy and handling and transport procedures were adequate.

RESULTS AND DISCUSSION

The mortality of caged mosquitoes at each distance (Figs. 2 and 3) gives an indication of insecticide movement and effectiveness of the different treatments under the particular environmental conditions during each test. Tests 1 and 2 with the 1/8-MIX treatment indicated a low level of kill at this low dose of chemical. The single swath (Test 1) showed evidence of a low level of kill for a distance of ca 1.5 mi downwind from the swath. The multiple swath treatment (Test 2) indicated an average kill of 56% from distances −0.3 to 1.2 mi (1.5 mi total distance). Tests 3 and 4 indicate considerably better kill with the higher dose of the 1/4-MIX treatment. The single swath (Test 3) showed 96–100% kill in the 4 cages immediately downwind (no offset) with the aircraft flying low (130 ft) in relatively high winds (9–11 mph). Again, a lower level of kill was observed for ca 1.5 mi downwind from the single swath. Test 4 indicated an average kill of 84% from −0.3 to 1.2 mi (1.5 mi total) for 3 swaths. This average was reduced by apparent skips in the downwind effects of the insecticide. Ground observations indicated that these skips probably resulted from the wind speed rapidly decreasing and the direction varied to near parallel to the flight path for short periods during the application. This could not be validated by the weather data because measurements were made only at 30 min intervals.

Tests 5 and 6 gave a direct comparison of the 3/4 TECH and the 1/4 MIX treatments under light wind conditions (2-3 mph). Both treatments were highly effective; the average for Test 5 was 93% from the cage at −0.4 mi to the last cage 1 mi downwind of the first swath (1.4 mi total) and the average for Test 6 was 94% from the cage at −0.3 mi to the last downwind cage (1.3 mi total). The high kill probably would have extended for a longer distance, but the number of cages in these 2 tests was limited by the length of road available. A clear indication of swath offsets of 0.4 and 0.5 mi, respectively, is shown in these tests. The approximately equal effect in these 2 tests indicates that dilution improved the insecticidal efficiency of the application since only one-third as much active chemical was applied. Further evidence of this is indicated by Tests 7, 8 and 9, where applica-

Table 2. Weather and application data for 9 aerial application tests.

Test No.	1	2	3	4	5	6	7	8	9
Treatment code	⅛ MIX	⅛ MIX	¼ MIX	¼ MIX	¾ TECH	¼ MIX	¼ TECH	¼ MIX	¼ TECH
Date (1980)	4–14	4–14	4–15	4–15	4–16	4–16	4–17	4–17	4–17
Time of day (hr)	1855	1925	1735	1815	1754	1855	1745	1827	1905
Number of swaths	1	3	1	3	3	3	3	3	3
Altitude (ft)	240	240	130	200	200	200	270	200	200
Temperature (°C)									
Dry bulb			21.1	19.4	22.8	16.7	23.3	20.0	20.0
Dew point			9.4	9.4	11.1	11.1	13.3	11.7	10.6
Wind speed (mph)									
Ground level	5	6	9	5	2	2	8	5	7
250 ft altitude	8	7	12	9	3	3	8	9	12
Wind direction (deg)									
Ground level	290	290	300	290	050	060	100	080	090
250 ft altitude	285	285	275	285	045	055	095	080	085
Cage line (deg)	270	270	270	270	000	000	090	090	090
Check mortality (% avg 4 cages/test)	6	10	3	3	6	5	2	6	—

tions of 0.25 oz/ac Dibrom14 technical (Tests 7 and 9, 1/4 TECH) was compared to 0.25 oz/ac Dibrom14 diluted (Test 8, 1/4 MIX). The 1st test with 1/4 TECH (Test 7) showed a low level of kill (average 55%) for a distance of 1.6 mi (−0.4 to 1.2 mi). The effectiveness in this test was about equivalent to Test 2 with 0.125 oz/ac Dibrom diluted. The 2nd 1/4 TECH test (9) gave considerably more kill (average of 84%) from −0.4 mi to the end of the cage line (14 cages). However, the 1/4 MIX dilute formulation (Test 8) gave an average of 98% kill for a total of 1.6 mi (−0.3 mi to end of the cage line), which was the most effective application in this series.

A possible explanation for the increased insecticidal efficiency of the diluted formulation of Dibrom14 is that increased atomization of this material, as indicated by our size measurement data, produces smaller droplets that are closer to the optimum size range required for

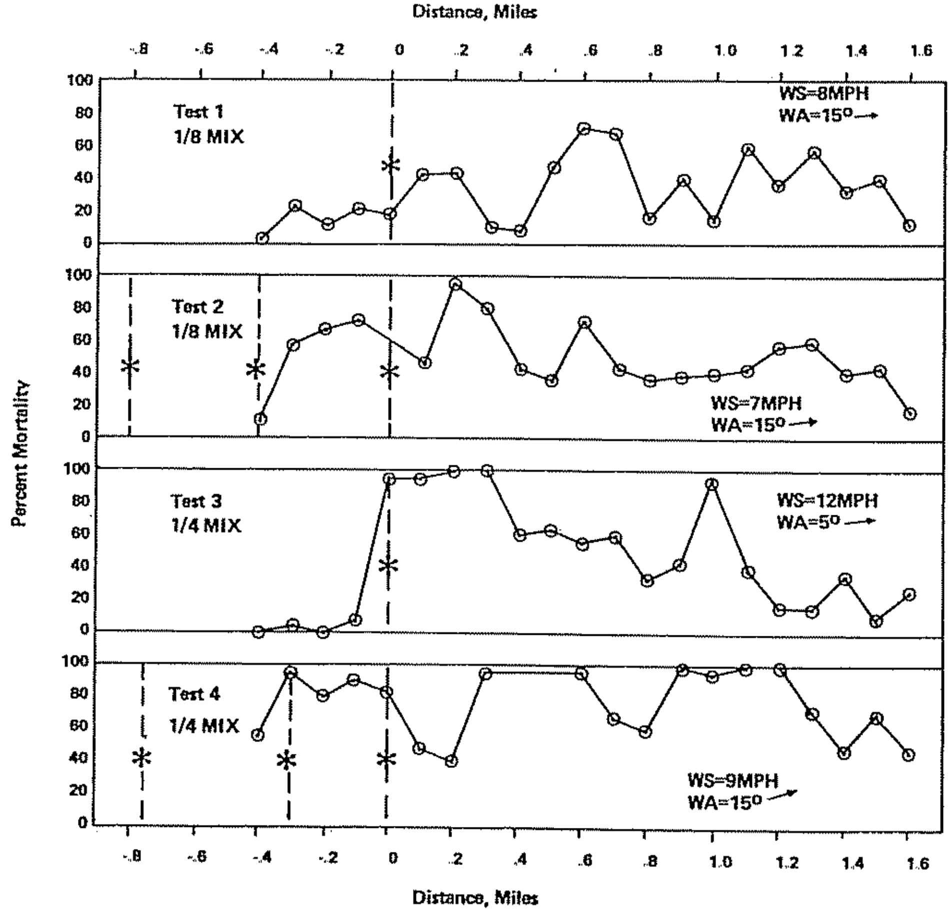

Fig. 2. Percent mortality vs. distance for aerial application tests 1–4 (asterisk indicates aircraft flight line, WS indicates wind speed at 250 ft altitude, and WA indicates the angle between wind direction at 250 ft altitude and the cage line).

effective aerial application. Other possible factors contributing to the increased efficiency may include increased number of droplets and volume of material dispersed.

SUMMARY AND CONCLUSIONS

A series of aerial application experiments were conducted at Avon Park Air Force Range, Florida, to compare the ef-

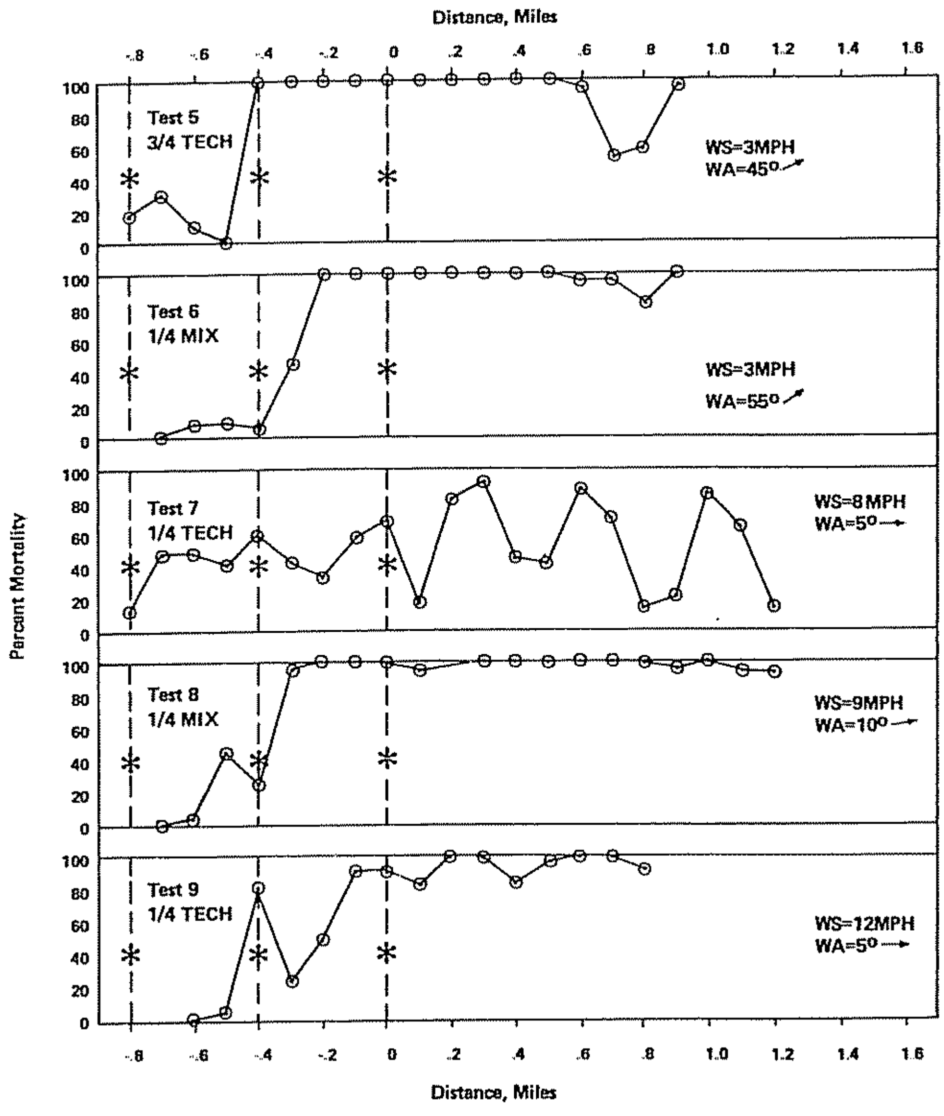

Fig. 3. Percent mortality vs. distance for aerial application tests 5–9 (asterisk indicates aircraft flight line, WS indicates wind speed at 250 ft altitude, and WA indicates the angle between wind direction at 250 ft altitude and the cage line).

fectiveness of Dibrom14 (naled) diluted in heavy aromatic naphtha (HAN), 1:5 ratio, with technical (undiluted) Dibrom 14. All applications were made with an Air Force UC-123K aircraft equipped with TeeJet nozzles (45 degrees forward) on a wing boom and flown at 150 mph. Spray altitude varied from ca 130 to 250 ft. Effectiveness was measured by bioassay with caged *Aedes taeniorhynchus* females (25/cage) placed on 4 ft high stakes at 0.1 mi intervals in a line perpendicular to the aircraft flight and parallel to wind direction. Applications were made with the dilute formulation at rates of 0.75 oz/acre (0.125 oz/acre Dibrom14) and 1.5 oz/acre (0.25 oz/acre Dibrom14) and with technical (undiluted) Dibrom14 at rates of 0.25 oz/acre and 0.75 oz/acre based on a 2000 ft swath width and 150 mph aircraft air speed. Numbers and size of nozzles, as well as pressure, were varied to obtain the desired flow. Results from single and multiple swath applications indicated that insecticide drift was more than adequate to cover 2000 ft. In tests with 3 swaths at 2000 ft intervals, the effectiveness indicated for each of the above treatments were, respectively, 56% (1 test), 92% (average of 3 tests), 70% (average of 2 tests), and 93% (1 test). These results indicate that the dilute formulation applied at 1.5 oz/acre (0.25 oz/acre Dibrom14) was more effective than 0.25 oz/acre of Dibrom14 undiluted and equal to 0.75 oz/acre Dibrom14 undiluted. The low kill with 0.75 oz/acre of the dilute formulation indicates that this dose was too low for effective mosquito control. These results cannot be considered totally conclusive due to the variability of atmospheric conditions between tests and the lack of replication for some tests. However, the results strongly suggest that dilution substantially improved the application efficiency and that the rate of 1.5 oz/acre of the 1:5 mixture will give excellent mosquito control. Use of this technique can result in considerable saving in chemical and application costs, as well as reduced environmental contamination. Additional research will be needed to determine the applicability of this technique under other environmental conditions and to verify the effect on natural populations.

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References Cited

Glancey, B. M., A. C. White, C. N. Husman and J. Salmela. 1966. Low volume applications of insecticides for control of adult mosquitoes. Mosq. News 26:356–359.

Mount, G. A. and C. S. Lofgren. 1967. Ultralow volume and conventional aerial sprays for control of adult salt-marsh mosquitoes, *Aedes sollicitans* (Walker) and *Aedes taeniorhynchus* (Wiedemann), in Florida. Mosq. News 27:473–477.

Mount, G. A., C. T. Adams, C. S. Lofgren and D. E. Weidhaas. 1970. Altitude and drift of ultralow volume aerial sprays of technical malathion for mosquito control. Mosq. News 30:580–584.

Sutherland, D. J., R. Kent and J. Downing. 1978. The effect of aerial ULV adulticiding with malathion and naled on field populations of *Aedes sollicitans*. Mosq. News 38:488–491.

1982 Parsons, R. E.
Effect of Ground Ultra Low Volume Insecticide Applications on Natural Mosquito Populations
Journal of the Florida Anti-Mosquito Association 53: 31-35 (Amvac Ref. #1398)

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1348

Effect of Ground Ultra Low Volume Insecticide Applications on Natural Mosquito Populations

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ABSTRACT

Ground ultra low volume (ULV) evaluations were conducted in Polk County, Florida, to determine the effectiveness of naled and malathion against natural mosquito populations. Dose rate, application methods, and insecticide were varied during the six treatments. No material or dose rate tested was effective in controlling natural mosquito populations in the test area. Discussion of the future needs for ground ULV research is presented.

INTRODUCTION

The use of ultra low volume (ULV) ground aerosol for controlling mosquitoes is the most common technique of adulticiding used today. Considerable research and development has been done on the materials and equipment we use in our ULV programs, yet, our knowledge is still very limited on the effect of these systems on natural populations of mosquitoes.

Mount et al., in 1972, 1974 and 1978, working in Arkansas, the Florida Keys and Cresent Beach, Florida, demonstrated that *Psorophora columbiae*, and *Aedes taeniorhynchus* could be temporarily controlled using ground ULV. However, Mount concluded that control could only be achieved for the night of application and the area should be re-treated nightly. The reason given for this limited control was reinfestation.

We have conducted evaluations on natural populations of mosquitoes in Polk County for 2 years. This paper describes the work conducted from September to November, 1981. The general objectives of the evaluation included:

1. To determine the effectiveness of label rates of naled against natural populations.
2. To determine if reinfestation was the primary reason mosquito populations were not reduced the night after treatment.
3. To develop better methods of evaluating ground ULV control procedures.
4. To compare malathion and naled against natural mosquito populations.

MATERIALS AND METHODS

The evaluations were all conducted in Fort Meade, Florida (Figure 1). This small community, located about 5 miles south of Bartow, was chosen because it had a street system well-designed for ULV application and a high mosquito population. Eleven CDC light traps were used to evaluate the

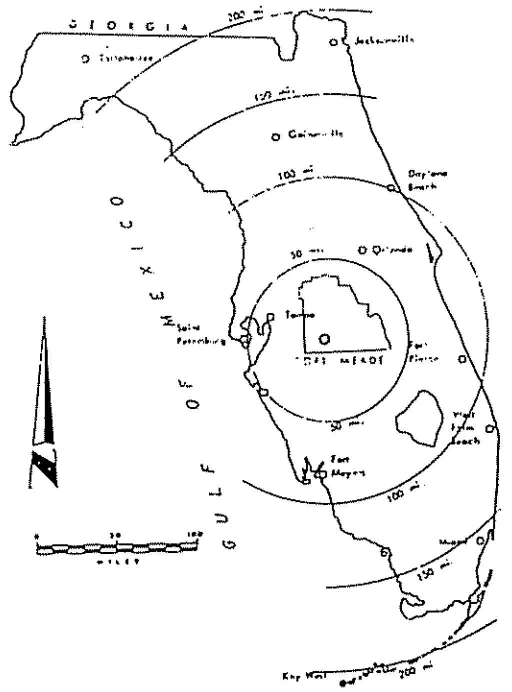

Figure 1

effect of treatment on natural populations. Figure 2 shows the light trap locations. Each trap site had 2 CDC light traps baited with 5 lbs. of dry ice. Two light traps were used at each location because if one malfunctioned then data from that location would still be available. Nine locations were inside the treatment area and 2 controls were located outside the treated area. The traps were located in such a manner to try to determine reinfestation rate. Our idea was to use location 11 (See Figure 2), the site at ca. the center of the treatment area, as the main indicator of reinfestation.

Truck traps as described by Bidlingmayer (1966) were used during 3 of the tests. The truck made 2–1 mile runs in a north-south direction and 2–1 mile runs in

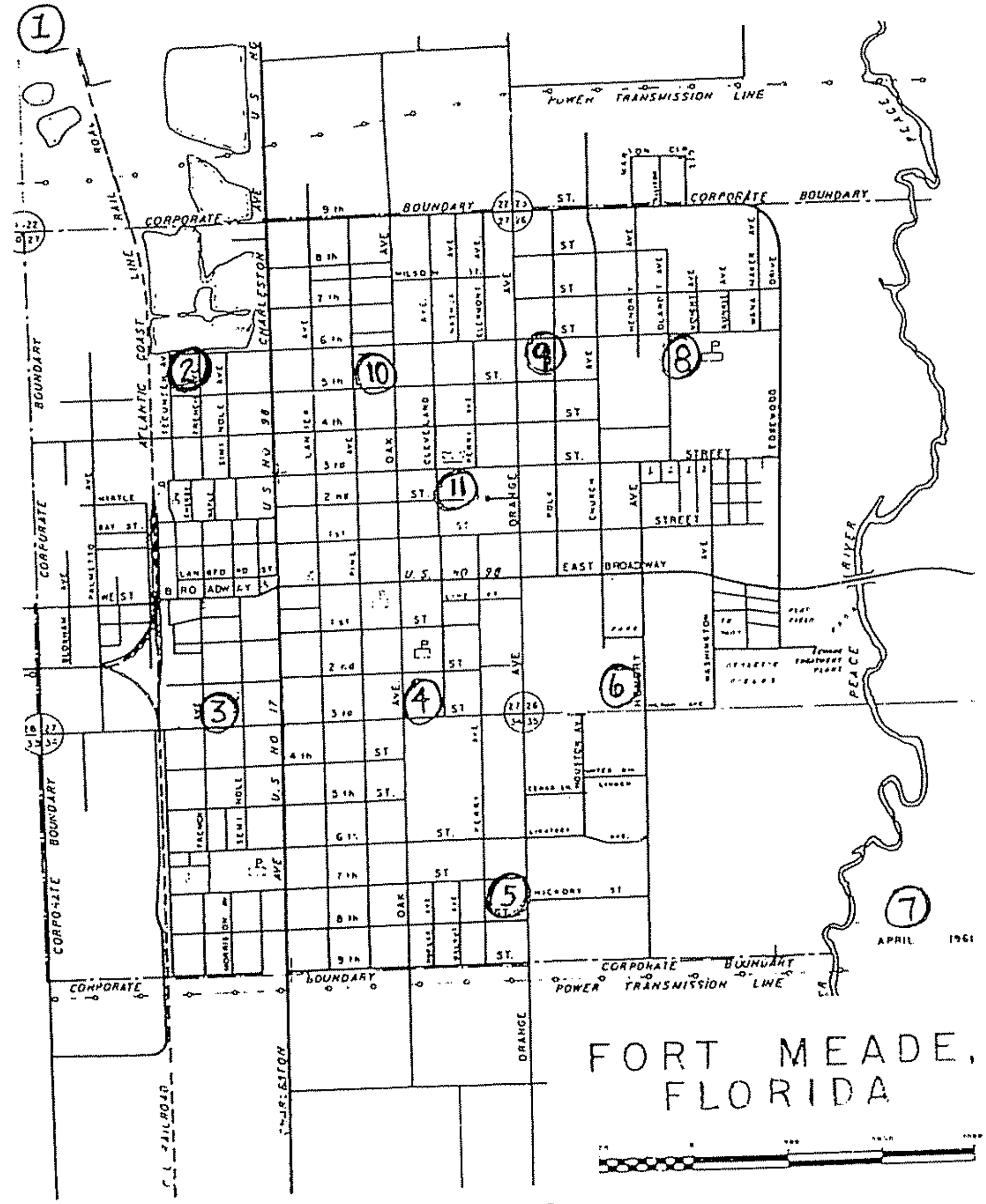

Figure 2.

an east-west direction. Truck speed was 20 mph. Previous, unpublished tests comparing 5, 10, 15 and 20 mph demonstrated that 20 mph was the most effective speed for sampling adult mosquitoes in this area. The trucks were run before ULV application on the treatment night and the night after treatment.

A LECO HD ULV aerosol generator operating at 4 psi was used for all the tests except one. This exception was one test with a LECO thermal fogger. Three tests were done with naled concentrate applied at 1.2 oz/min. at 10 mph. One test was run at 2.0 oz/min. at 10 mph and one thermal application with a 3% naled—15% HAN mix applied at the rate of 20 gal/hr. at 5 mph. One test was run with 2 trucks each applying 4.3 oz/min. of 95% Cythion (malathion) concentrate at 10 mph. One truck ran a north-south route and the other a east-west route. Weather conditions varied some but none of these tests were run in winds over 10 mph. Data from 2 tests were not included due to inclement weather conditions.

RESULTS AND DISCUSSION

Table 1 gives the overall results of the evaluations. None of the tests demonstrated any degree of control. The test on September 22 showed a 61% reduction in light trap collections but the controls were down more than 50%. Truck trap collections showed a 40% reduction on September 15, but again, controls were also lower. The results indicated considerable work needs to be done on the methods of evaluating natural mosquito populations.

Table 2 provides a breakout of the actual data collected during the week of September 28. This data is presented to provide the reader with the results that might be encountered during a treatment regime and to show the extreme variability between light traps during any one test.

The objectives for the evaluation were only partly answered. The first objective was to determine the effectiveness of label rates of naled against natural mosquito populations.

1. The label recommendations and even

Table 1. Results of ULV insecticide aerosol tests against natural mosquito populations in Polk County, FL. using light traps and truck traps as evaluation methods.

Date		Percent reduction or increase			Material and application rate
		Day 0[b]	Day 1[b]		
		LT[c]	LT[c]	TT[c]	
1 Sept[a]	Treatment	−54	−34		Naled, 1.2 oz/min at 10 mph
	Control	−85	−75		
8 Sept	Treatment	−44	−42	−39	Naled, 2.0 oz/min at 10 mph
	Control	−52	−30		
15 Sept.	Treatment	−52	− 4	−40	Naled, 1.2 oz/min at 10 mph
	Control	−32	−23		
22 Sept.	Treatment	−61	−52		Naled-thermal 15% HAN 3% naled, 20 gal/hr at 5 mph
	Control	−59	−70		
28 Sept.	Treatment	−50	−29	+85	Naled 1.2 oz/min at 10 mph
	Control	−43	+80		
4 Nov	Treatment	−33	− 3		Malathion, 2 trucks, each applying 43 oz/min at 10 mph
	Control	−67	−53		

[a]Nine locations—7 treatment, 2 control were used for this test, all other tests had 9 treatment and 2 control locations.
[b]Day 0 = night of treatment: Day 1—night after application
[c]LT = light trap
TT = truck trap—pre-catch on night of treatment compared to night after application.

Table 2. Example of data collected during one ground ULV aerosol application of naled at 1.2 oz/min at 10 mph.

Location		Average number of mosquitoes per location[a]			
	28 Sept.	29 Sept.[b]	% Change	30 Sept.	% Change
Control 1	1,816	810	−55	2,024	+11
Treatment 2	2,092	474	−73	2,069	− 1
Treatment 3	328	187	−43	127	−61
Treatment 4	363	214	−41	152	−58
Treatment 5	90	25	−72	261	+190
Treatment 6	652	239	−60	259	−60
Control 7	918	760	−17	2,884	+214
Treatment 8	376	119	−68	209	−44
Treatment 9	1,619	624	−61	1,043	−36
Treatment 10	1,547	1,166	−25	790	−49
Treatment 11	2,278	1,612	−29	1,686	−26
	Averages of total numbers and per cent change				
Control	1,367	785	−43	2,454	+80
Treatment	1,038	517	−50	733	−29

[a]Two CDC light traps baited with dry ice were set at each location.
[b]Treatment night.

0.5 oz/min. more than the label rate did not adequately control the mosquitoes. I believe this is strictly a matter of not enough volume of insecticide to get to the mosquito. Dr. Roberts of the USDA Insects Affecting Man and Animals Laboratory placed caged mosquitoes at the light trap locations and several other sites in the treatment areas. His results, which will be presented elsewhere, tend to support the idea the material is not reaching the mosquitoes.

2. The second objective was to determine if reinfestation was the primary reason mosquito populations were not reduced the night after treatment. Data was not collected to support this idea. Even the collections in innermost traps were not reduced to a degree to demonstrate good control. We don't know if this was due to reinfestation or poor coverage of the area by the insecticide. My personal vote would go with the latter.
3. The third objective was to develop better methods of evaluating ground ULV control procedures. Considerable progress was made in this area, yet, more work needs to be done. It is apparent that a single measure of ULV efficacy, such as light traps, is not sufficient to determine control effectiveness. I believe at least 3 methods, with one being caged insects, should be used when evaluating ground ULV applications against natural mosquito populations. Other methods could include: Light traps, landing rates, truck traps, suction traps etc.
4. The fourth objective was to compare malathion and naled against natural mosquito populations. Only one test was conducted on this objective and the results indicated neither material gave good control. Let me reiterate a point—I'm not saying these materials are not effective; if sufficient volume of the insecticide hits the mosquito it will be killed. To me, this means one of two things, volume, application techniques, equipment modification, or all, need to be improved or changed. Secondly, you might not be able to control mosquitoes under average natural conditions. The latter I don't believe but considerable research needs to be done to work out these problems.

In summary, our evaluations provided us the following information:

1. Mosquitoes were not adequately controlled during any

of the evaluations conducted at Ft. Meade.

2. New methods of accessing control of natural mosquito populations are needed.
3. More work needs to be done on volume and droplet size as related to control of natural mosquito populations.
4. Finally, I put forth a challenge to all operational, research and commercial groups. Let's work together in obtaining the information required to use ground ULV systems more efficiently and to get away from programs conducted by gut-feeling and show-the-flag concepts.

LITERATURE CITED

Mount, G. A., M. V. Meish, J. T. Lee, N. W. Pierce, and K. F. Baldwin. 1972. Ultralow volume ground aerosols of insecticides for control of rice field mosquitoes in Arkansas. Mosq. News 32:444-446.

Mount, G. A. and N. W. Pierce. 1974. Ultralow volume ground aerosols of naled for control of *Aedes taeniorhynchus* (Wiedemann) in the Florida Keys. Mosq. News 34:268-269.

Mount, G. A., N. W. Pierce, K. F. Baldwin and F. Washington. 1978. Control of *Aedes taeniorhynchus* at Cresent Beach, Florida, with aerosols of propoxur (Baygon RMOS) and naled (Dibrom R14). Mosq. News 38:54-56.

Bidlingmayer, W. L. 1966. Use of the truck trap for evaluating adult mosquito populations. Mosq. News 26:139-143.

The Status of *Aedes aegypti* in Western Collier County

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ABSTRACT

Ovipositional traps were used to determine the distribution and breeding foci of *Aedes aegypti* in western Collier County. Greatest activity was found adjacent to U. S. Highway 41 and near Pine Ridge Rd. Breeding sites consisted of trashy yards and tire dumps. Tire dumps contributed to *Ae. aegypti* in atypical, upper income neighborhoods

INTRODUCTION

Recently, south Florida has been subject to the immigration of Haitian and Cuban refugees. These countries, along with most other areas of the Caribbean, are endemic for dengue fever. The primary vector of dengue in the Caribbean, *Aedes aegypti*, is also prevalent in Florida (Carpenter and LaCasse, 1955; Darsie and Ward, 1981). Thus, knowledge of the status of *Ae. aegypti* in Florida communities can not be over emphasized.

The discovery of *Ae. aegypti* larvae in a bucket containing hibiscus cuttings prompted this surveillance project. Of particular interest was the distribution of the mosquito in a community characterized by a high standard of living and a clean urban environment. Tinker (1964) found that *Ae. aegypti* indices were constantly higher in substandard housing areas. Interestingly, the original source of *Ae. aegypti* was in a region of middle and upper income housing.

MATERIALS AND METHODS

The objective of the survey was to determine the distribution of potential *Ae. aegypti* breeding foci in western Collier County. Traps were set throughout populated areas of western Collier County. However, an emphasis was made to situate traps in areas containing containers which might breed *Ae. aegypti* (e.g. industrial parks, substandard housing complexes). Traps were relocated if negative for three con-

1982 Rathburn, Jr., C. B., A. H. Boike, Jr., L. A. Sizemore, and M. W. Peters
Laboratory Tests of Mosquito Adulticides
J. Florida Anti-Mosquito Association 92-96 (Amvac Ref. #1394)

LITERATURE CITED

Boike, A. H. Jr., C. B. Rathburn, Jr., C. F. Hallmon, and S. G. Cotterman. 1978. Insecticide susceptibility tests of *Aedes taeniorhynchus* and *Culex nigripalpus* in Florida, 1974-1976. Mosquito News 38(2):210-217.

Boike, A. H. Jr., C. B. Rathburn, Jr., C. F. Hallmon, and S. G. Cotterman. 1979. Insecticide susceptibility levels of some Florida mosquitoes for 1977-78. Proc. Fla. Anti-Mosq. Assn. 50:62-67.

Boike, A. H. Jr., C. B. Rathburn, Jr., C. F. Hallmon, and R. L. Welles. 1980. Monitoring for resistance in mosquitoes from several selected areas in Florida in 1979. Proc. Fla. Anti-Mosq. Assn. 51: 47-51.

Helson, B. V., G. A. Surgeoner and W. E. Ralley. 1979. Susceptibility of *Culex* spp. and *Aedes* spp. larvae (Diptera: Culicidae) to temephos and chlorpyrifos in southern Ontario. Proc. Ent. Soc. of Ontario 110:79-83.

Rathburn, C. B. Jr. and A. H. Boike, Jr. 1967. Studies of insecticide resistance in Florida mosquitoes. Mosquito News 27(3):377-382.

Sutherland, D. J. and E. S. Evans, Jr. 1976. Insecticide resistance in New Jersey mosquitoes: a five-year summary. Proc. New Jersey Mosq. Exter. Assn. 63:176-181.

Laboratory Tests of Mosquito Adulticides

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ABSTRACT

Non-thermal aerosol sprays of several pyrethroids, several organophosphates and one carbamate were tested as adulticides against *Aedes taeniorhynchus* (Wied.), *Culex nigripalpus* Theobald and *Culex quinquefasciatus* Say in a laboratory wind tunnel. Bendiocarb, chlorpyrifos, fenthion, naled and fenitrothion were more toxic to the three mosquito species than malathion used as a standard. The pyrethroids, flucythrinate, fluvalinate, permethrin, phenothrin and pyrethrum plus piperonyl butoxide were more toxic than the standard resmethrin when tested against *Ae. taeniorhynchus* but allethrin was significantly less toxic. When tested against *Cx. nigripalpus*, permethrin was more toxic and allethrin was less toxic than the standard resmethrin. Although not all pyrethroids were tested against *Cx. quinquefasciatus*, those tested against this species resulted in a toxicity similar to that obtained with *C. nigripalpus*.

INTRODUCTION

The West Florida Arthropod Research Laboratory conducts laboratory wind tunnel tests of promising, safe, and environmentally acceptable mosquito adulticides in a continuing program to develop new insecticides for use in the adult mosquito control programs in the State. Adulticides which show promise in these tests are further evaluated in field tests prior to being recommended for use. This report contains the results of laboratory non-thermal aerosol tests of 14 insecticides against three species of mosquitoes.

MATERIALS AND METHODS

All tests were conducted in a laboratory wind tunnel similar to that described by Rathburn (1969) with the exception that the heater and condensation tube of the thermal aerosol generator were not used. Test methods were similar to those described in Rathburn and Boike (1972) and Boike and Rathburn (1975). Treatment consisted of spraying 0.5 ml of an insecticide solution, diluted to a predetermined concentration in acetone, into a wind tunnel containing a cage of 25 adult female mosquitoes. The aerosol was drawn through the wind tunnel, which contained the 15 cm. diameter screen test cage, by means of a fan at an air velocity of 1.3 m/sec. Each replication of each insecticide consisted of one cage of mosquitoes for each of a series of 5 insecticide dilutions and the control. The control cages were exposed in the same manner to an aerosol of acetone only. Each test consisted of at least 2 replications or cages of each dosage and the control. Three to 6 tests were conducted with each insecticide. All insecticide dilutions were prepared the same day they were tested. Following treatment, the mosquitoes were anesthetized with carbon dioxide and transferred to clean holding cages. Knockdown was assessed at 1/2, 1, and 4 hrs and final mortality was determined at 24 hrs posttreatment. The LC_{50}, LC_{90} dosages, and the 95% confidence limits were determined by probit analysis.

Three species of mosquitoes were used in the tests and all were from established laboratory colonies. The *Aedes taeniorhynchus* and *Culex nigripalpus* were similar in susceptibility to field strains but, because of wide variations in the susceptibility of field strains of *Culex quinquefasciatus* throughout Florida, some tests of this species were conducted with two strains of different susceptibilities. All mosquitoes used in the tests were from 3 to 8 days old and were fed only a 10% sugar solution on cotton pads prior to and following the tests.

RESULTS

The tests of the pyrethroid adulticides are shown in Table 1. Against *Ae. taeniorhynchus*, permethrin was the most toxic being 7 times more toxic at the LC_{50} and 9 times more toxic at the LC_{90} dosage than the standard resmethrin. All the other pyrethroids tested except allethrin were from 2 to 3 times more toxic at the LC_{50} and 1 to 4 times more toxic at the LC_{90} dosage than the standard resmethrin. *Cx. nigripalpus* showed similar response to all pyrethroids tested except for permethrin and allethrin. Permethrin was 1 1/2 and 2 times more toxic and allethrin was 8 and 8 times less toxic than the standard resmethrin at the LC_{50} and LC_{90} dosage, respectively. Permethrin was slightly less toxic to *Cx. quinquefasciatus* than to *Cx. nigripalpus*, but allethrin and phenothrin were

Table 1. Laboratory spray tests of several pyrethroid adulticides against three species of mosquitoes.

Insecticide	Trade name	Lethal concentration in milligrams AI per milliliter LC_{50}	95% C.L.[1]	LC_{90}	95% C.L.[1]	Slope	Standard error
		Aedes taeniorhynchus					
allethrin	Pyrellin	0.258	0.241-0.276	0.610	0.539-0.690	3.43	0.21
flucythrinate	Payoff	0.077	0.069-0.086	0.291	0.239-0.354	2.23	0.13
fluvalinate	Mavrik	0.070	0.062-0.087	0.519	0.395-0.681	1.47	0.09
permethrin	Ectoban	0.024	0.023-0.025	0.059	0.053-0.065	3.27	0.13
phenothrin	Sumithrin	0.097	0.091-0.104	0.267	0.234-0.304	2.92	0.16
pyrethrum[2]	Pyrocide	0.059	0.054-0.064	0.139	0.125-0.177	1.19	0.27
resmethrin (std.)	SBP-1382	0.179	0.143-0.221	0.557	0.405-0.979	2.59	0.39
		Culex nigripalpus					
allethrin	Pyrellin DI	0.215	0.199-0.232	0.612	0.537-0.699	2.82	0.17
flucythrinate	Payoff	0.026	0.023-0.029	0.113	0.092-0.139	2.00	0.11
fluvalinate	Mavrik	0.021	0.019-0.023	0.090	0.076-0.107	2.00	0.12
permethrin	Ectoban	0.013	0.012-0.014	0.050	0.044-0.057	2.22	0.10
phenothrin	Sumithrin	0.031	0.028-0.034	0.106	0.091-0.124	2.39	0.15
pyrethrum[2]	Pyrocide	0.030	0.028-0.033	0.080	0.067-0.095	3.06	0.23
resmethrin (std.)	SBP-1382	0.027	0.025-0.029	0.074	0.066-0.084	2.92	0.34
		Culex quinquefasciatus					
allethrin[3]	Pyrellin DL	0.795	0.732-0.862	1.630	1.369-1.940	4.11	0.39
permethrin	Ectoban	0.033	0.031-0.037	0.086	0.073-0.100	3.13	0.19
phenothrin[3]	Sumithrin	0.262	0.248-0.278	0.558	0.493-0.632	3.91	0.24

[1]Confidence limits from probit analysis.
[2]Synergized with piperonyl butoxide @1:5.
[3]Tests were conducted with Sebring strain. Tests of permethrin were conducted with Cottondale strain of *Cx. quinquefasciatus*.

much less effective against *Cx. quinquefasciatus*.

The tests of the organophosphate and carbamate adulticides are shown in Table 2. Against *Ae. taeniorhynchus*, all insecticides were more toxic than the malathion standard at both the LC_{50} and LC_{90} dosage levels. Fenthion was the most toxic, being about 5 times more toxic than malathion at both the LC_{50} and LC_{90} dosages. In tests of *Cx. nigripalpus*, all insecticides were more toxic than the malathion standard at both the LC_{50} and LC_{90} dosages with the exception of the malathion-flucythrinate combination which was about the same toxicity as malathion alone. Bendiocarb was the most toxic, being 16 and 27 times more toxic at the LC_{50} and LC_{90} dosages, respectively than the standard malathion. All insecticides tested were more toxic to *Cx. quinquefasciatus* than the malathion standard at both the LC_{50} and LC_{90} dosages. Bendiocarb was the most toxic, being 3 times more toxic than the standard malathion at both the LC_{50} and LC_{90} dosages.

Several pyrethroids were also observed for their knockdown efficacy. Shown in Table 3 is the knockdown efficacy of three pyrethroids as compared to resmethrin and malathion as standards. Phenothrin was slightly more effective and allethrin was about the same effectiveness as resmethrin against *Ae. taeniorhynchus* at 1/2 hr posttreatment. Fluvalinate was considerably less effective than the resmethrin standard. At 4 hrs posttreatment, phenothrin was still more effective than resmethrin, but both allethrin and fluvalinate were less effective. As expected, malathion showed little knock-

Table 2. Laboratory spray tests of several organophosphate and one carbamate adulticide against three species of mosquitoes.

Insecticide	Trade name	Lethal concentration in milligrams AI per milliliter				Slope	Standard error
		LC_{50}	95% C.L.[1]	LC_{90}	95% C.L.[1]		
		Aedes taeniorhynchus					
bendiocarb	Ficam	0.037	0.035-0.039	0.068	0.062-0.074	4.85	0.28
chlorpyrifos	Dursban	0.048	0.045-0.051	0.087	0.081-0.093	4.95	0.39
fenitrothion	Sumithion	0.044	0.040-0.049	0.112	0.099-0.127	3.19	0.28
fenthion	Baytex	0.026	0.024-0.028	0.057	0.051-0.064	3.76	0.23
naled	Dibrom	0.079	0.072-0.086	0.161	0.140-0.187	4.11	0.38
mala-flucythrinate	Cythion-Payoff	0.093	0.085-0.103	0.252	0.196-0.325	2.96	0.34
malathion (std.)	Cythion	0.142	0.136-0.148	0.320	0.295-0.346	3.63	0.14
		Culex nigripalpus					
bendiocarb	Ficam	0.028	0.027-0.029	0.055	0.050-0.061	4.33	0.26
chlorpyrifos	Dursban	0.068	0.065-0.070	0.111	0.104-0.118	5.93	0.37
fenitrothion	Sumithion	0.129	0.123-0.136	0.325	0.291-0.363	3.19	0.15
fenthion	Baytex	0.064	0.060-0.068	0.140	0.123-0.159	3.78	0.24
naled	Dibrom	0.057	0.054-0.060	0.110	0.102-0.119	4.46	0.24
mala-flucythrinate	Cythion-Payoff	0.401	0.380-.0466	0.510	1.240-1.839	2.31	0.15
malathion (std.)	Cythion	0.450	0.422-0.479	1.503	1.364-1.656	2.45	0.10
		Culex quinquefasciatus					
bendiocarb	Ficam	0.034	0.032-0.036	0.072	0.065-0.081	3.90	0.24
chlorpyrifos	Dursban	0.067	0.065-0.070	0.137	0.126-0.149	4.12	0.24
fenthion	Baytex	0.051	0.049-0.055	0.139	0.127-0.153	3.00	0.15
naled[3]	Dibrom	0.098	0.088-0.109	0.266	0.233-0.303	2.97	0.24
naled	Dibrom	0.071	0.069-0.073	0.118	0.112-0.125	5.76	0.29
malathion (std.)[3]	Cythion	0.657	0.616-0.701	2.225	1.964-2.521	2.42	0.10
malathion (std.)	Cythion	0.113	0.109-0.118	0.225	0.207-0.243	4.30	0.23

[1]Confidence limits from probit analysis.
[2]100:1 ratio.
[3]Tests were conducted with Sebring strain. Tests of other adulticides were conducted with Cottondale strain of *Cx. quinquefasciatus*

Table 3. Knockdown efficacy of several adulticides against three species of mosquitoes.

Insecticide	Trade name	Posttreatment time in hours[1]	Lethal concentration in milligrams AI per milliliter: LC_{50}	95% C.L.[2]	LC_{90}	95% C.L.[2]	Slope	Std. error
			Aedes taeniorhynchus					
allethrin	Pyrellin DL	1/2	0.053	0.043-0.065	0.171	0.149-0.198	2.50	0.25
		4	0.226	0.209-0.245	0.538	0.467-0.621	3.40	0.25
fluvalinate	Mavrik	1/2	0.251	0.200-0.316	2.393	1.355-4.227	1.31	0.11
		1	0.186	0.157-0.220	1.346	0.881-2.060	1.49	0.12
		4	0.124	0.109-0.141	0.719	0.529-0.979	1.67	0.12
phenothrin	Sumithrin	1/2	0.030	0.025-0.036	0.102	0.089-0.118	2.41	0.24
		4	0.055	0.052-0.060	0.129	0.116-0.143	3.49	0.22
resmethrin	SBP-1382	1/2	0.066	0.058-0.073	0.164	0.148-0.184	3.25	0.31
		1	0.061	0.040-0.079	0.182	0.138-0.292	2.68	0.37
		4	0.115	0.105-0.125	0.325	0.290-0.374	2.85	0.35
malathion	Cythion	1/2	>3.35[3]	—	—	—	—	—
		4	0.199	0.183-0.215	0.500	0.421-0.594	3.20	0.22
			Culex nigripalpus					
allethrin	Pyrellin DL	1/2	—	—	0.064[4]	—	—	—
		4	0.091	0.083-0.099	0.200	0.179-0.223	3.75	0.28
fluvalinate	Mavrik	1/2	0.038	0.033-0.044	0.223	0.166-0.299	1.67	0.12
		1	0.033	0.029-0.037	0.215	0.160-0.291	1.57	0.12
		4	0.020	0.016-0.024	0.170	0.120-0.242	1.36	0.12
phenothrin	Sumithrin	1/2	0.011	0.010-0.014	0.034	0.029-0.039	2.74	0.25
		4	0.015	0.013-0.017	0.039	0.034-0.045	3.13	0.26
resmethrin	SBP-1382	1/2	0.009	0.008-0.011	0.040	0.034-0.048	2.05	0.49
		1	0.010	0.008-0.011	0.033	0.028-0.041	2.40	0.42
		4	0.016	0.014-0.017	0.040	0.035-0.045	3.15	0.32
malathion	Cythion	1/2	>1.68[3]	—	—	—	—	—
		4	0.432	0.393-0.474	1.379	1.196-1.591	2.54	0.16
			***Culex quinquefasciatus*[5]**					
allethrin	Pyrellin DL	1/2	0.129	0.119-0.139	0.229	0.210-0.251	5.11	0.35
		4	0.575	0.539-0.613	1.057	0.940-1.187	4.85	0.35
phenothrin	Sumithrin	1/2	0.057	0.050-0.064	0.141	0.128-0.157	3.22	0.22
		4	0.080	0.072-0.087	0.184	0.167-0.203	3.52	0.24
malathion	Cythion	1/2	>1.68[3]	—	—	—	—	—
		4	0.788	0.713-0.849	2.225	1.940-2.551	2.84	0.15

[1] Time interval from treatment to mortality determination.
[2] Confidence limits from probit analysis.
[3] Highest dosage tested-mortality below 10%.
[4] Lowest dosage tested-mortality 91%.
[5] Tests were conducted with Sebring strain.

down effectiveness at 1/2 hr, but gave surprisingly good mortality at 4 hrs posttreatment.

At 1/2 hr posttreatment, allethrin and phenothrin were about the same effectiveness as resmethrin against *Cx. nigripalpus* but fluvalinate was considerably less effective. At 4 hrs posttreatment, phenothrin was equal to resmethrin in effectiveness but both allethrin and fluvalinate were less effective. Normally, malathion gives poorer kill of *Cx. nigripalpus* than *Ae. taeniorhynchus* requiring approximately twice the dosage to effect the same degree of kill. This was true in these tests also. Allethrin, phenothrin, and malathion were all less effective against *Cx. quinquefasciatus* than *Cx. nigripalpus* at both 1/2 and 4 hrs post-treatment.

DISCUSSION

Although reproduceability between tests in this study was excellent, the data obtained were not comparable to data obtained in previous studies (Rathburn and Boike, 1972 and Boike and Rathburn, 1975) because of changes in testing procedures. The data in the 1972 study were obtained using a laboratory thermal aerosol generator and the data obtained in the 1975 study were obtained with a non-thermal aerosol. Malathion, naled, and resmethrin were the only insecticides used in all three studies. Comparing the data obtained in the 1972 study with that obtained in 1975, there was a 24 and 13 fold decrease with malathion, a 6 and 3 fold decrease with naled and a 13 and 12 fold decrease with resmethrin in the LC_{50} and LC_{90} dosages respectively against *Ae. taeniorhynchus* in the 1975 study. Except for resmethrin, which is significantly more toxic to *Cx. nigripalpus* than *Ae. taeniorhynchus*, the differences obtained with *Cx. nigripalpus* were similar to those obtained with *Ae. taeniorhynchus*. The differences in toxicity obtained between the 1972 and 1975 laboratory studies demonstrate the greater effectiveness of non-thermal aerosol sprays as compared to thermal aerosols, which is probably due to droplet size since all other testing conditions remained the same.

The study reported here and the 1975 study were both conducted with non-thermal aerosols; however, in this study, in order to refine the testing techniques, the time the mosquitoes remained in the treated cages following treatment and before they were transferred into clean cages was standardized to 20 minutes. This 20 minute time interval was established by a separate study (unpublished) in which the mortality of a single dosage was determined for various time intervals from 0 to 120 minutes. Although different insecticides produced different time-mortality curves, the 20 minute time interval was selected since near maximum mortality of all insecticides was observed at this exposure time in treated cages. Although this change in technique generally increased the time the mosquitoes remained in treated cages and, as a result, increased the mortality slightly, it resulted in much more reproduceable data. The LC_{50} and LC_{90} dosages of malathion, naled, and resmethrin against both *Ae. taeniorhynchus* and *Cx. nigripalpus* in this study decreased only slightly ranging from no decrease to 1.6 fold decrease.

LITERATURE CITED

Boike, A. H., Jr. and C. B. Rathburn, Jr. 1975. Laboratory non-thermal aerosol tests of insecticides for the control of adult mosquitoes. Mosquito News 35(4):488-490.

Rathburn Carlisle B., Jr. 1969. A laboratory thermal aerosol generator for the testing of insecticidal aerosols. Mosquito News 29(1):1-6.

Rathburn. C. B., Jr. and A. H. Boike, Jr. 1972. Laboratory thermal aerosol tests of new insecticides for the control of adult mosquitoes. Mosquito News 32(2):179-183.

1981 Kline, D. L., D. G. Haile, and K. F. Baldwin
Wind Tunnel Tests with Seven Insecticides Against Adult Culicoides mississippiensis
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WIND TUNNEL TESTS WITH SEVEN INSECTICIDES AGAINST ADULT *CULICOIDES MISSISSIPPIENSIS* HOFFMAN[1,2,3]

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ABSTRACT. The effectiveness of 7 insecticides, which included 4 synthetic pyrethroids (NRDC-161[4], permethrin, resmethrin and *d*-phenothrin) and 3 organophosphorous (OP) compounds (fenthion, malathion and naled), was tested against field-collected adult female *Culicoides mississippiensis* in a laboratory wind tunnel. Knockdown (1 hr posttreatment mortality) and 24-hr mortalities were determined for each compound to indicate relative effectiveness. The pyrethroids were more effective than the OP compounds tested. NRDC-161 was the most effective pyrethroid, followed by permethrin, resmethrin and *d*-phenothrin. Of the OP compounds, naled was slightly more effective than malathion, and fenthion was the least effective.

Some *Culicoides* spp. (biting midges) are extremely annoying pests in coastal areas. However, very little research effort has been directed toward control of these insects with adulticide applications. This is partially due to difficulties of conducting definitive research with an insect of such small size.

We feel that compounds already proven effective for ULV applications against mosquitoes will also give effective temporary local reductions of biting midges. This was indicated by Giglioli et al. (1980) in aerial application tests with fenitrothion against adult biting midges in Grand Cayman, West Indies. Presently, there is a need for data on the relative effect of various candidate chemicals against adult *Culicoides*. This paper reports the methods developed for conducting wind tunnel tests with *Culicoides mississippiensis* Hoffman and the results of tests with 7 insecticides, including 4 synthetic pyrethroids (NRDC-161, permethrin, resmethrin and *d*-phenothrin) and 3 organophosphorous (OP) compounds (fenthion, malathion and naled).

METHODS AND MATERIALS

The wind tunnel system of testing used in this study was basically that described by Mount et al. (1976). The major change involved use of a fine mesh screen in the exposure cages to contain the small adult *Culicoides*; 15.7-mesh per cm (40-mesh per in.) screen was used instead of the 6.3-mesh per cm (16-mesh per in.) screen used for mosquitoes. Thus, the screened area in the tunnel cross-section that surrounds the cage support bracket was also changed to 15.7-mesh per cm to insure uniform airflow through the tunnel and cage. The fabricated atomizing nozzle was also replaced with a commercially-available air atomizing nozzle (#12891 1/8 JJ, Spraying Systems Co., Chicago, Illinois).

The wind tunnel consisted of a cylindrical tube 15.5 cm in diameter and 88 cm in length. A variac controlled blower was used to force air through a plenum chamber into the tunnel, where air ve-

[1] Diptera: Ceratopogonidae.

[2] This paper reports the results of research only. Mention of a pesticide does not constitute a recommendation for use by the USDA nor does it imply registration under FIFRA as amended. Also, mention of a commercial or proprietary product does not constitute an endorsement by the USDA.

[3] This research was supported in part by the Office of Naval Research, Microbiology Program, Naval Biology Project, under contract N00014-79-F-0070, NR 133-997.

[4] (*S*)-[cyano(3-phenoxyphenyl)methyl] (1*R*)-*cis*-3-(2,2-dibromoethenyl)-2,2-dimethylcyclopropanecarboxylate.

locity was maintained at 1.78 m/sec. The treatment sample of biting midges was confined in cardboard exposure cages, 8.6 cm in diameter and 5.0 cm high with 15.7-mesh per cm brass screen ends, which were placed in the center of the tube for exposure. One-fourth ml of the desired concentration of the technical insecticide in acetone (wt A.I./volume diluent, expressed as % concentration) was atomized at the tunnel entrance with an air pressure of 10.3 kpa (105.5 g/cm²), and the insects were exposed momentarily as the aerosol passed through the cage. We used an automatic pipette to introduce the insecticide solution into the nozzle for convenience and efficiency.

Immediately following exposure, the insects were lightly anesthetized with CO_2 and transferred to new 8.6 × 5.0 cm cardboard holding cages covered with fine mesh cloth screen tops. A cotton pad, soaked in a 10% sucrose solution was placed on each holding cage to provide food for the caged insects. The cages were then placed into large styrofoam chests, containing a moistened layer of cotton to maintain a high humidity environment. Mortality was checked 1 hr after treatment to determine knockdown capability and 24 hr mortality was recorded as overall effectiveness. Checks were exposed to contact sprays containing acetone only and handled in the same manner.

In our testing procedure to establish an effective range of concentrations for LD-50 determination the candidate insecticides were first tested at concentrations of 0.25% (wt/v), then the concentration was successively reduced by one-half until the 24-hr mortality fell below 50%. After an effective range was established, tests with serial dilutions of a given insecticide were made sequentially from low to high concentrations without cleaning the wind tunnel. However, the tunnel was cleaned at the beginning and end of each test series and before each new insecticide was tested.

Because we do not have a laboratory colony of biting midges, field collections of adult females of *C. mississippiensis* were made with CO_2-baited suction traps. The biting midges were transported to the laboratory, knocked down in a cold room at ca. 2°C and transferred to exposure cages with ca. 25/cage. Duplicate cages were used at each concentration tested, and at least 4 concentrations of each insecticide were used in each test. At least 3 replicates were made of each test. All tests were conducted within 6 hrs from time of collection.

A probit analysis using log-transformed dosage data was applied to the results to determine the LC-50 and LC-90 of each compound. The 95% fiducial limits for LC-50 and LC-90 values are used to indicate variability of the test procedures. Check mortality ranged from 5–8%, and therefore no correction for check mortality was made.

This testing procedure is not intended to yield results that can be compared closely; however, it does eliminate those insecticides that are not toxic enough to warrant further testing, and it identifies the range of concentrations that are highly effective.

RESULTS AND DISCUSSION

The 24-hr mortality data (LC-50's and LC-90's and their respective 95% fiducial limits) are presented in Table 1 along with the LC-50 for knockdown (1 hr) mortality. The compounds are ranked in order of decreasing toxicity (based on LC-90 of 24-hr mortality) to *C. mississippiensis*. The synthetic pyrethroids were more effective than the OP compounds with NRDC-161 the most toxic followed by permethrin, resmethrin and *d*-phenothrin. Of the OP compounds tested, naled was slightly more effective than malathion, and fenthion was least effective.

Quick knockdown is a desirable characteristic for biting midge adulticides, since immediate relief from biting is helpful and reinvasion from untreated areas is

Table 1. Effectiveness of 7 insecticides (% concentration) in laboratory wind tunnel tests against field-collected adult female *Culicoides mississippiensis*.

Insecticide	1 hr knockdown (LC-50)	24-hr mortality LC-50	95% Fiducial limits lower	95% Fiducial limits upper	LC-90	95% Fiducial limits lower	95% Fiducial limits upper
NRDC-161	00001	.00005	.00004	.00006	.00087	.00063	.00136
Permethrin	00017	.00034	.00020	.00049	.00487	.00310	.00983
Resmethrin	00115	.00115	.00071	.00159	01134	.00832	.01781
d-Phenothrin	.00062	.00224	.00016	.00125	.03027	.01156	.03688
Naled	03523	.01143	00820	.01488	.07379	.05123	.12876
Malathion	.03339	.02395	.01469	.03336	.21206	.13198	.49897
Fenthion	2.15851	.02903	.02435	.03461	.35899	.25343	.56174

very probable. The knockdown LC-50 for all the pyrethroids was equal to or less than the 24 hr mortality and was much better than the OP compounds. Some recovery from knockdown was indicated for NRDC-161, permethrin, and *d*-phenothrin, since the knockdown LC-50 was less than the 24-hr LC-50. Of the OP compounds, naled and malathion had approximately equal knockdown capability. Fenthion demonstrated practically no knockdown capability and gave the lowest 24-hr mortality.

The data derived from these wind tunnel tests will be useful in the design of field application experiments. Plans are currently being formulated to test several of these candidate insecticides in ground and aerial application experiments.

References Cited

Giglioli, M. E. C., E. J. Gerberg and R. G. Todd. 1980. Large scale field tests and environmental assessments of Sumithion® (fenitrothion) against adult biting midges in Grand Cayman, West Indies. Mosq. News 40:1–5.

Mount, G. A., N. W. Pierce and K. F. Baldwin. 1976. A new wind-tunnel system for testing insecticidal aerosols against mosquitoes and flies. Mosq. News 36:127–131

1981 Rathburn Jr., C. B., A. H. Boike, Jr., C. F. Hallmon and R. L. Welles
Field Tests of Insecticides Applied as ULV Sprays by Ground Equipment for the Control of Adult Mosquitoes
Mosquito News 41: 132-135 (Amvac Ref. #1399)

1399

tions and parous rates of anthropophilic blackflies in Guatemala, with reference to the transmission of *Onchocerca volvulus*. Tropen. Med. Parasit. 26:169–182.

Malaise, R. 1937. A new insect trap. Ent. Tidskr. 58:148–160.

Service, M. W. 1977. Methods for sampling adult Simuliidae, with special reference to the *Simulium damnosum* complex. Center for Overseas Pest Research, Trop. Pest Bull. No. 5, 48 pp.

Townes, H. K. 1962. Design for a Malaise trap. Proc. Entomol. Soc. Wash. 64(4):253–262.

Travis, B. V., M. Vargas V., and J. C. Swartzwelder. 1974. Bionomics of black flies (Diptera:Simuliidae) in Costa Rica. I. Species biting man, with an epidemiological summary for the Western Hemisphere. Rev. Biol. Trop. 22(1):187–200.

Vargas, L. and Díaz Nájera. 1957. Simulidos Mexicanos. Rev. Inst. Salubrid. Enferm. Trop. 17(4):143–399.

Wilton, D. P. and R. C. Collins. 1978. An entomologic and parasitologic survey for onchocerciasis in western El Salvador. Amer. J. Trop. Med. Hyg. 27(3):499–502

FIELD TESTS OF INSECTICIDES APPLIED AS ULV SPRAYS BY GROUND EQUIPMENT FOR THE CONTROL OF ADULT MOSQUITOES

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ABSTRACT. Field tests of several insecticides applied as ULV sprays by ground equipment were conducted using caged adult *Aedes taeniorhynchus* (Wiedemann) and *Culex nigripalpus* Theobald. Satisfactory mortalities of both species were obtained with chlorpyrifos (Dow MFC), fenitrothion (Sumithion Concentrate); phenthoate (Cidial ULV); propoxur (Baygon 1 MOS); and 3% naled (Dibrom 14) in various diluents including heavy aromatic naphtha (HAN); Chevron 400 solvent, and diesel oil plus 3% Ortho Additive. Resmethrin (20% SBP-1382 18.5MF in Klearol) gave excellent mortality of *Cx. nigripalpus* but poor kill of *Ae. taeniorhynchus*.

This research is part of a continuing program to establish effective dosages of insecticides and insecticide formulations presently labeled as ULV sprays and for other insecticides which have shown promise in laboratory spray tests against the adults of two important species of Florida mosquitoes. The tests were conducted over a 5-year period from 1974–1979.

MATERIALS AND METHODS

All tests were conducted in the early evening hours after sunset. Temperatures ranged from 64 to 85°F and averaged 78.8°F and wind velocities ranged from 1 to 10 mph and averaged 5.3 mph for the tests. The test plot was a fairly open beach residential area with few houses and a few large pine trees but with little ground vegetation.

Four cages of mosquitoes, 2 of *Aedes taeniorhynchus* (Wiedemann) and 2 of *Culex nigripalpus* Theobald, each containing 25 females, were attached to a metal pole. One cage of each species was placed at 6 ft. and another at 2 ft. above ground level. The poles with cages attached were placed at 165 and 330 ft. downwind and perpendicular to the line of travel of the first swath of the aerosol generator. A second and third swath were applied at 1 and 2 blocks (300 and 600 ft.) upwind of the first swath. Each test, or replicate, consisted of the cages of mosquitoes from 3 sets of poles (165 and 330 ft.) placed one block (600 ft.) apart, or a total of 12 cages of each species. The cages were 6 in. in diameter and 1 in. deep with 14 X 18 mesh screen on both circular surfaces and were hung vertically with the screened surfaces facing into the wind. A like number of cages were used as untreated controls for each test.

All mosquitoes used in the test were from organophosphorous susceptible laboratory colonies and were between 2 and 8 days old. After exposure, the mosquitoes were anesthetized with carbon dioxide and transferred to clean holding cages which were identical to the treatment cages. All cages of mosquitoes were held with access to a 10% sucrose solution on cotton pads for 12 to 15 hrs. at which time mortality counts were made.

The tests were conducted with a Leco HD ULV® cold aerosol generator mounted on a flat-bed truck and the aerosol was discharged at an upward angle of 45°. Because of proposed label requirements, the tests of resmethrin (SBP-1382 18.5MF) were conducted at a vehicle speed of 5 mph. All other tests were conducted at a vehicle speed of 10 mph. The equipment was calibrated for each formulation prior to testing and the insecticide was measured before and after each test to determine actual discharge rates. Tests in which the actual discharge varied more than 10% were discarded. Spraying time was recorded by means of a stop watch and varied from 15–18 min. depending on the length of run necessary to completely cover the test area.

RESULTS

The average percent mortalities for the two species of mosquitoes at the stated discharge rates of the various insecticides and formulations are shown in Table 1. All percentage formulations shown are expressed as volume to volume. The average percent mortalities for each test were corrected for the check mortality of that test. Overall check mortalities averaged 1.1% for *Ae. taeniorhynchus* and 0.7% for *Cx. nigripalpus*.

Good results were obtained with Dow MFC (chlorpyrifos) against *Ae. taeniorhynchus* at a discharge rate of 0.63 gallon per hour (gph) and a formulation pressure of 4.0 psi; however, 1.0 gph was required for satisfactory mortality of *Cx. nigripalpus*. Since research by Mount and Pierce (1972) demonstrated an increase in mortality of a formulation of Dibrom 14 in HAN when the formulation (air) pressure was reduced to 1.5 psi, Dow MFC was further tested at a formulation pressure of 2.0 psi. At this pressure, the discharge rate of 0.63 gph gave satisfactory mortality of both species of mosquitoes.

Dibrom 14 Concentrate (naled) at 3% and a discharge rate of 10 gph resulted in good mortality of both species of mosquitoes when diluted in either Chevron 400 solvent or diesel oil plus 3% Ortho Additive at a formulation pressure of 4.0 psi and when diluted in heavy aromatic naphtha (HAN) at a pressure of 1.5 psi. The 2% Dibrom 14 diluted in diesel oil plus 2% Ortho Additive applied at 10 gph and a formulation pressure of 4.0 psi did not give satisfactory mortality of *Ae. taeniorhynchus*. Formulation studies conducted prior to testing to determine the stability of formulations of Dibrom 14 in diesel oil showed that Ortho Additive in equal proportions to Dibrom 14 were required to eliminate sludge formation for a period of one week.

Satisfactory mortality of *Cx. nigripalpus* was obtained with 20% SBP-1382 18.5MF (resmethrin) in Klearol at 4.3 gph, but very poor kill was obtained with *Ae. taeniorhynchus*. These tests substantiated previous research (Rathburn and Boike 1972 and 1973) with essentially the same dosage of undiluted SBP-1382 40MF which resulted in 28% mortality of *Ae. taeniorhynchus* and 93% with *Cx. nigripalpus*. The 18.5MF (18.5% wt./wt.) formulation was introduced by the manufacturer because of better low temperature stability than the 40MF (40% wt./wt.) formulation.

Other data in Table 1 show that excellent results were obtained with 1.0 gph of Sumithion Concentrate (fenitrothion),

Table 1. The mortality of caged adult *Aedes taeniorhynchus* and *Culex nigripalpus* obtained with several insecticides applied as ULV sprays by ground equipment.

Insecticide	Formulation: trade name	Formulation: percent	Formulation: diluent	Dschg. rate gph	Form. press. psi	No. tests	Average % mortality: *Aedes*	Average % mortality: *Culex*
chlorpyrifos	Dow MFC	—	none	1.0	4.0	5	100	94
				0.75	4.0	4	96	84
				0.63	4.0	5	99	72
				1.00	2.0	3	97	92
				0.63	2.0	3	95	90
fenitrothion	Sumithion Conc.	—	none	1.00	4.0	5	100	96
naled	Dibrom 14 Conc.	3.0	HAN	10.0	1.5	3	97	99
		3.0	Chevron 400	10.0	4.0	3	99	100
		3.0	diesel oil[1]	10.0	4.0	4	94	100
		2.0	diesel oil[1]	10.0	4.0	4	81	95
phenthoate	Cidial ULV	—	none	1.5	4.0	1	100	92
propoxur	Baygon 1 MOS	—	none	4.0	4.0	6	99	98
resmethrin	SBP-1382 18.5MF	20	Klearol	4.3	4.0	5	30	95

[1] Plus Ortho Additive.

1.5 gph of Cidial ULV (phenthoate), and 4.0 gph of Baygon 1 MOS (propoxur) all applied at a formulation pressure of 4.0 psi.

At present, Dow MFC is labeled for use as ULV sprays by ground equipment at 0.67 to 1.33 fl oz/min. (0.31 to 0.63 gph) In addition, there is a Florida 24C (or local need) label for use at 2.1 fl. oz./min. (1.0 gph) for the control of *Cx. nigripalpus*. It appears from the results of the preceding tests that if the formulation pressure is reduced to 2.0 psi, satisfactory control of *Cx. nigripalpus* can be obtained at the highest labeled rate under the national label. At present, the formulation of 3.125% Dibrom 14 in HAN, Chevron 400 or diesel oil plus 3.125% Ortho Additive is only labeled for use in Florida, but there is a national label for 10% Dibrom 14 in soybean oil or HAN for application as ULV sprays by ground equipment. SBP-1382 40MF is labeled at 8.9% in Klearol as a ULV spray, but at present the 18.5 MF formulation does not have an EPA label. Sumithion Concentrate, Cidial and Baygon 1 MOS are also not presently labeled for use as ULV sprays. Therefore, it is recommended that potential users of these, and any other insecticides, consult appropriate state agencies or manufacturer's representatives for currently approved recommendations.

References Cited

Mount, G. A. and H. W. Pierce 1972. Adult mosquito kill and droplet size of ultra low volume ground aerosols of insecticides. Mosquito News 32(3):354–357.

Rathburn, C. B. Jr. and A. H. Boike, Jr. 1972. Ultra low volume tests of SBP-1382 applied by ground equipment for the control of adult mosquitoes. Mosquito News 32(3):334–337.

Rathburn, C. B. Jr. and A. H. Boike, Jr. 1973. Ultra low volume tests of several insecticides applied by ground equipment for the control of adult mosquitoes. Mosquito News 35(1):26–29.

1979 Boike, A. H., Jr., C. B. Rathburn, Jr., C. F. Hallmon, and S. G. Cotterman
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1979

1392

SCIENTIFIC PAPERS

Insecticide Susceptibility Levels of Some Florida Mosquitoes for 1977-78

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ABSTRACT

First generation larvae and adults from several wild strains of *Aedes taeniorhynchus* (Wied.) and *Culex nigripalpus* Theob. were tested for insecticide susceptibility against malathion, naled, and fenthion and compared to the susceptible West Florida Arthropod Research Laboratory (WFARL) strains. F_1 larvae from a sample of *Ae. taeniorhynchus* from Flagler County were 37X less susceptible to malathion at the LC_{90} level as compared to the WFARL strain, and 104X less susceptible in the adult stage. No decrease in susceptibility was detected when larvae or adults from the malathion-resistant areas were tested against naled or fenthion. Two populations of *Cx. nigripalpus* from the central part of the state were almost as susceptible as the WFARL strain in tests against malathion and naled. Larvae from a Tampa, Hillsborough County, strain of *Culex quinquefasciatus* Say were less susceptible to all insecticides tested at an LC_{90} level as compared to a Cottondale, Jackson County, strain in the following order: temephos, 38X; malathion, 16.8X; fenthion, 10.8X; naled, 8.1X; and chlorpyrifos, 6.3X. Since the susceptibility level of the Cottondale strain to all insecticides tested was similar to the standard susceptible WFARL strains of *Ae. taeniorhynchus* and *Cx. nigripalpus*, the Tampa strain of *Cx. quinquefasciatus* is apparently the first reported instance of insecticide tolerance of a *Culex* species in the State of Florida.

INTRODUCTION

In a continuing insecticide resistance surveillance program in the State of Florida, four organophosphate insecticides were tested as larvicides and adulticides against three species of mosquitoes, *Aedes taeniorhynchus* (Wied.), *Culex nigripalpus* Theob., and *Culex quinquefasciatus* Say. With the possibility of the latter species becoming a vector of St. Louis encephalitis in Florida, a strain from Cottondale, Jackson County, was colonized during July, 1977 to establish a base-line. During October, 1978, another strain of *Cx. quinquefasciatus* from Tampa, Hillsborough County, was established to determine the susceptibility of a strain from another area of the state.

Preliminary tests have indicated a difference in tolerance between the two strains of *Cx. quinquefasciatus* which may require additional resistance surveillance of this species from several other areas of the state.

MATERIALS AND METHODS

Collections of wild mosquitoes from various areas of the state were shipped to the laboratory for rearing and both larvae and adults were tested according to the methods described by Rathburn and Boike (1967) and Boike et al. (1978). The two strains of *Cx. quinquefasciatus* were collected as larvae and egg rafts, colonized in the laboratory and tested. *Aedes taeniorhynchus* and *Cx. nigripalpus* adults and larvae from each area were pair tested with the susceptible WFARL strains. The susceptible *Cx. quinquefasciatus* strain from Cottondale was used for comparison with the Tampa strain.

RESULTS

Although the number of areas sampled during the present period was fewer than those previously reported by Boike et al. (1978), malathion tests against populations of *Ae. taeniorhynchus* from Flagler, Hillsborough and Monroe Counties continue to show resistance (Tables 1 and 2). Larvae from the Marineland, Flagler County, strain were about 13X less susceptible at the LC_{50} level and approximately 37X at the LC_{90}

Table 1. Susceptibility of *Aedes taeniorhynchus* (Wied.) larvae to malathion, naled, and fenthion, 1977-78.

County	Area	Reps.	Lethal concentration in µg/ml.				Slope	Std. error
			LC_{50}	95% C.L.[1]	LC_{90}	95% C.L.[1]		
				malathion—1977				
Monroe	Key Largo	21	0.053	0.050-0.057	0.187	0.167-0.209	2.36	0.13
WFARL strain		18	0.041	0.039-0.042	0.067	0.063-0.073	5.89	0.29
Hillsborough	Picnic Is.	11	0.234	0.220-0.249	0.571	0.496-0.656	3.22	0.24
WFARL strain		11	0.032	0.031-0.033	0.055	0.051-0.059	5.44	0.34
Hillsborough	Ruskin	15	0.295	0.271-0.321	1.383	1.117-1.711	1.91	0.12
WFARL strain		11	0.050	0.048-0.053	0.086	0.077-0.095	5.54	0.38
				malathion—1978				
Monroe	Geiger Key	10	0.312	0.283-0.343	1.340	1.080-1.650	2.03	0.13
WFARL strain		6	0.029	0.028-0.031	0.056	0.051-0.063	4.47	0.31
Hillsborough	Ruskin	10	0.180	0.160-0.202	1.120	0.868-1.440	1.61	0.11
WFARL strain		8	0.033	0.032-0.034	0.046	0.043-0.048	8.75	0.75
Flagler	Marineland	12	0.396	0.358-0.438	1.920	1.500-2.460	1.87	0.12
WFARL strain		14	0.030	0.029-0.031	0.052	0.048-0.056	5.25	0.31
				naled—1977				
Monroe	Key Largo	20	0.067	0.065-0.070	0.152	0.138-0.169	3.61	0.18
WFARL strain		16	0.075	0.072-0.077	0.144	0.133-0.155	4.50	0.23
Hillsborough	Picnic Is.	10	0.074	0.071-0.077	0.120	0.112-0.128	6.09	0.38
WFARL strain		11	0.112	0.106-0.117	0.193	0.173-0.216	5.37	0.42
				naled—1978				
Monroe	Geiger Key	8	0.088	0.083-0.093	0.169	0.147-0.194	4.51	0.44
WFARL strain		4	0.075	0.071-0.080	0.127	0.115-0.139	5.62	0.48
Monroe	Suragloaf Key	10	0.071	0.067-0.075	0.133	0.121-0.148	4.64	0.38
Monroe	No Name Key	12	0.084	0.080-0.088	0.180	0.164-0.198	3.86	0.22
WFARL strain		4	0.084	0.079-0.089	0.138	0.124-0.152	6.00	0.55
Flagler	Marineland	10	0.049	0.046-0.052	0.098	0.091-0.106	4.21	0.26
WFARL strain		7	0.066	0.062-0.070	0.124	0.114-0.135	4.64	0.32
				fenthion—1977				
Monroe	Key Largo	20	.00165	0.00155-0.00175	.00323	0.00280-0.00374	4.39	0.34
WFARL strain		12	.00145	0.00140-0.00150	.00229	0.00213-0.00245	6.46	0.41
				fenthion—1978				
Indian River	Vero Beach	8	0.00205	0.00198-0.00213	0.00341	0.00317-0.00365	5.83	0.36
WFARL strain		8	0.00118	0.00113-0.00123	0.00199	0.00186-0.00213	5.65	0.33

[1]Confidence Limits.

Table 2. Susceptibility of *Aedes taeniorhynchus* (Wied.) adults to malathion and naled. 1977-78.

County	Area	Reps.	LC_{50}	95 % C.L.[1]	LC_{90}	95% C.L.[1]	Slope	Std. error
				Lethal concentration in mg/ml.				
				malathion—1977				
Monroe	Key Largo	12	0.100	0.080-0.126	1.188	0.874- 1.615	1.19	0.10
WFARL strain		14	0.077	0.074-0.080	0.146	0.137- 0.155	4.65	0.17
Hillsborough	Picnic Is.	6	1.063	0.889-1.271	7.382	5.157-10.568	1.52	0.11
WFARL strain		4	0.056	0.052-0.060	0.103	0.094- 0.113	4.80	0.43
				malathion—1978				
Monroe	Geiger Key	2	5.030	3.930-6.450	20.300	9.180-44.700	2.12	0.50
WFARL strain		2	0.117	0.108-0.127	0.174	0.150- 0.203	7.42	1.01
Flagler	Marineland	4	1.200	0.899-1.610	11.200	6.350-19.900	1.32	0.16
WFARL strain		4	0.061	0.058-0.064	0.108	0.099- 0.117	5.16	0.35
				naled—1977				
Monroe	Key Largo	7	0.072	0.066-0.078	0.150	0.133- 0.169	3.40	0.35
WFARL strain		7	0.073	0.070-0.076	0.123	0.115- 0.132	5.67	0.31

[1]Confidence Limits.

level as compared to the WFARL strain. Adults from Flagler County were 20X less susceptible at the LC_{50} level and approximately 104X at the LC_{90} level. The various populations of *Ae. taeniorhynchus* exposed to naled showed little difference in susceptibility as compared with those of the WFARL strain at the LC_{50} and LC_{90} values, indicating the species continues to be susceptible to naled. Two strains of *Ae. taeniorhynchus* from Monroe and Indian River Counties exposed to fenthion showed similar tolerance as compared to the WFARL strain.

Two populations of *Cx. nigripalpus* were tested for susceptibility to malathion and naled (Table 3). Larvae exposed to both insecticides showed little difference (< 2X) in susceptibility to either insecticide as compared to the WFARL strain; however, adults from Orange County were slightly more than 3X less susceptible to malathion.

Using the Cottondale strain as the susceptible *Cx. quinquefasciatus* strain, the results shown in Table 4 indicate the Tampa strain to be resistant to the following organophosphate insecticides at the

Table 3. Susceptibility of *Culex nigripalpus* Theob. larvae and adults to malathion and naled, 1977.

County	Area	Reps	LC_{50}	95% C.L.[2]	LC_{90}	95% C.L.[2]	Slope	Std. error
				Lethal concentration[1]				
				Larvae—malathion				
Polk	Waverly	13	0.037	0.036-0.037	0.049	0.047-0.051	9.96	0.64
Orange	W. Orlando	12	0.038	0.038-0.039	0.054	0.052-0.057	8.64	0.46
WFARL strain		12	0.025	0.025-0.026	0.035	0.034-0.036	8.99	0.50
				Adults—malathion				
Polk	Waverly	10	1.370	1.260-1.500	4.080	3.420-4.870	2.71	0.18
Orange	W. Orlando	6	1.710	1.450-2.020	5.250	3.300-8.350	2.63	0.44
WFARL strain		10	0.551	0.521-0.583	1.400	1.290-1.530	3.16	0.13
				Larvae—naled				
Polk	Waverly	14	0.053	0.052-0.054	0.072	0.069-0.075	9.72	0.53
Orange	W. Orlando	8	0.048	0.047-0.049	0.067	0.062-0.068	9.78	0.64
WFARL strain		14	0.046	0.045-0.047	0.062	0.060-0.064	10.00	0.51

[1]Larval data in μg/ml.; adult data in mg/ml.
[2]Confidence Limits.

Table 4. Susceptibility of *Culex quinquefasciatus* Say larvae to malathion, naled, temephos, fenthion, and chlorpyrifos, 1978.

County	Area	Reps.	Lethal concentration in μg/ml. LC_{50}	95% C.L.[1]	LC_{90}	95% C.L.[1]	Slope	Std. error
				malathion				
Hillsborough	Tampa	20	0.610	0.575-0.646	1.950	1.700-2.240	2.54	0.11
Jackson	Cottondale	20	0.081	0.079-0.082	0.116	0.112-0.120	8.11	0.35
				naled				
Hillsborough	Tampa	20	0.210	0.198-0.223	0.745	0.644-0.863	2.33	0.10
Jackson	Cottondale	17	0.070	0.068-0.071	0.092	0.090-0.095	10.49	0.51
				temephos				
Hillsborough	Tampa	26	0.00321	0.00296-0.00349	0.02763	0.02334-0.03272	1.37	0.05
Jackson	Cottondale	26	0.00055	0.00054-0.00056	0.00073	0.00072-0.00075	10.33	0.31
WFARL strain*		7	0.00043	0.00041-0.00046	0.00071	0.00067-0.00076	5.94	0.51
WFARL strain†		20	0.00068	0.00066-0.00070	0.000116	0.00110-0.00121	5.53	0.23
				fenthion				
Hillsborough	Tampa	16	0.01452	0.01357-0.01566	0.06263	0.05346-0.07338	2.02	0.09
Jackson	Cottondale	20	0.00378	0.00369-0.00386	0.00580	0.00562-0.00599	6.87	0.22
				chlorpyrifos				
Hillsborough	Tampa	24	0.00254	0.00243-0.00264	0.00716	0.00665-0.00771	2.84	0.10
Jackson	Cottondale	24	0.00079	0.00077-0.00080	0.00113	0.00110-0.00116	8.11	0.30

[1]Confidence limits.
**Culex nigripalpus*
†*Aedes taeniorhynchus*

following LC_{50} and LC_{90} levels, respectively: chlorpyrifos, 3.2X and 6.3X; naled, 3.0X and 8.1X; fenthion, 3.8X and 10.8X; malathion, 7.5X and 16.8X; and temephos 5.8X and 37.8X.

DISCUSSION

Results on the tolerance of *Ae. taeniorhynchus* and *Cx. nigripalpus* to malathion, naled, and fenthion are a continuation of surveillance studies previously reported by Rathburn and Boike (1967), and Boike et al. (1978). *Ae. taeniorhynchus* continues to be resistant to malathion according to the data reported herein, with the exception of a strain from Key Largo tested in 1977. According to information obtained from the district, susceptibility of this population to malathion could be attributed to the migration of malathion susceptible mosquitoes into the Key Largo area from the Everglades. All of the malathion-resistant *Ae. taeniorhynchus* strains tested were almost as tolerant to naled and fenthion as the WFARL susceptible strain.

The results obtained in this study, together with previous information, indicate that *Cx. nigripalpus* in Florida is still susceptible to malathion and naled.

The *Cx. quinquefasciatus* strains from two different and widely separate areas have been exposed to different insecticide pressures. The Cottondale strain originated from an area where there are no mosquito control operations while the Tampa strain has been exposed to extensive mosquito control practices for a number of years. The susceptibility of the Cottondale strain is comparable to the *Ae. taeniorhynchus* and *Cx. nigripalpus* WFARL strains, which have never been exposed to insecticides, while the Tampa strain of *Cx. quinquefasciatus* showed varying degrees of tolerance to malathion, naled, temephos, fenthion, and chlorpyrifos. Larval tolerance of the Tampa strain to temephos at the LC_{90} level was surprisingly high (38X) since this insecticide has never been used in the area; however, since the Tampa strain was 17X more tolerant to malathion than the Cottondale strain, this may represent cross resistance as reported by Georghiou et al. (1969) on a malathion-resistant population of *Cx. tarsalis* being resistant to parathion, methyl parathion, fenthion, chlorpyrifos and temephos.

Whether the tolerance of the Tampa strain to all five organophosphate insecticides tested represents true resistance or a natural level of susceptibility cannot be definitely stated until several other strains of *Cx. quinquefasciatus* from comparable areas practicing mosquito control are tested. The possibility of this species becoming tolerant to insecticides has been reported by Micks and Rougeau (1977) where 20 strains of *Cx. quinquefasciatus* were collected from two mosquito control districts in Texas that showed tolerance to several organophosphates when compared to a standard susceptible laboratory strain. Palmisano et al. (1976) reported that populations of *Cx. pipiens quinquefasciatus* collected from southern Louisiana parishes, that had mosquito control programs were significantly less susceptible to organophosphate insecticides than those from parishes that had no control programs.

Also, Moseley et al. (1977) showed that the *Culex pipiens* complex in Memphis became resistant to malathion, fenthion, and naled after applying malathion as an adulticide for a period of eight summers.

Since *Cx. quinquefasciatus* is one of the main urban vectors of St. Louis encephalitis in the United States (U. S. Department of Health, Education, and Welfare, 1976), information on its susceptibility to various insecticides would not only be useful but important to mosquito control districts in determining a control program should this species become associated with an outbreak of St. Louis encephalitis in Florida.

ACKNOWLEDGMENTS

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LITERATURE CITED

Boike, A. H., Jr., C. B. Rathburn, Jr., C. F. Hallmon, and S. G. Cotterman. 1978. Insecticide Susceptibility tests of *Aedes taeniorhynchus* and *Culex nigripalpus* in Florida, 1974-1976. Mosquito News 38(2):210-216.

Georghiou, G. P., P. A. Gilles, and D. J. Womeldorf.

1969. *Culex tarsalis* Coquillett: Detection of resistance to parathion, methyl parathion, fenthion, Dursban, and Abate in a malathion-resistant population. Calif. Vector News 16(12):115-118.

Micks, D. W. and D. Rougeau. 1977. Organophosphorous tolerance in *Culex quinquefasciatus* in Texas. Mosquito News 37(2):233-239.

Moseley, K., J. Mullenix, and R. T. Taylor. 1977. Organophosphorus resistance in the Memphis, Tennessee *Culex pipiens* complex. Mosquito News 37(2):271-275.

Palmisano, C. T., C. D. Steelman, and P. E. Schilling. 1976 Relative effects of insecticide usage in Louisiana mosquito control programs on the susceptibility of adult female *Culex pipiens quinquefasciatus* populations. Mosquito News 36(4):521-527.

Rathburn, C. B., Jr. and A. H. Boike, Jr. 1967. Studies of insecticide resistance in Florida mosquitoes. Mosquito News 27(3):377-382.

Control of St. Louis Encephalitis, Vector Topics No. 1. 1976. U. S. Dept. Health, Educ. and Welfare, PHS, CDC, Atlanta, GA 35 pp.

Mosquito Control for St. Louis Encephalitis Vectors in Western Volusia County

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ABSTRACT

"Homemade" CDC light traps and power aspirator proved to be an effective and inexpensive means of monitoring adult *Culex nigripalpus* populations in western Volusia County. The use of the vector potential concept, number of parous vector mosquitoes in an area over a period of time, was used to set adulticiding priorities when large numbers of *Cx. nigripalpus* adults were found over hundreds of square miles of western Volusia County. Adulticiding was done with a Beecomist spray system and Leco HD aerosol generators with Dibrom 14 Concentrate and Baytex Liquid Concentrate used in each system respectively. The Beecomist spray system proved to be very effective in killing large numbers of *Cx. nigripalpus* adults when used shortly after dark with good weather conditions. Costs for surveillance and spraying for the period May 1, to December 31, 1978 totaled $25,714.32.

INTRODUCTION

Geographically, western Volusia County is separated from the eastern portion of the County by the Tomoka Wildlife Management Area and the Farmton Wildlife Management Area. The western boundary of Volusia County is formed by the St. Johns River. Western Volusia County has an abundance of lakes and fresh water marshes. The topography consists of ridges and depressions.

There are nine population centers within western Volusia County. Census figures for the area in 1977 showed a total population of 59,000 people. Two areas, DeLand and Deltona contain approximately 80% of the total population. Deltona is a retirement community with approximately 18,000 people—60% are over 65 years old. This retirement community is built around numerous small lakes and few of the 500 miles of roads are straight.

Prior to December, 1977, mosquito control in western Volusia County consisted of surveillance for larvae and adult mosquitoes. In December, 1977, St. Louis Encephalitis (SLE) claimed the life of a resident, and at this time adulticiding for *Cx. nigripalpus* began in the vicinity where the victim lived. Due to this death, an emergency fund was set aside by the Volusia County Council to survey and treat *Cx. nigripalpus* in 1978. The East Volusia Mosquito Control District supplied the materials and personnel to survey and treat *Cx. nigripalpus* populations.

MATERIALS AND METHODS

Since *Cx. nigripalpus* flight patterns are influenced by numerous environmental factors (Bidlingmayer 1974), wind direction, wind velocity, temperature and relative humidity readings were taken at CDC trap sites and during adulticiding operations. A

1979 Focks, D. A., D. A. Dame, A. L. Cameron, and M. D. Boston
Susceptibility of Toxorhynchites Rutilus Rutilus to Five Adulticides Currently Used for Mosquito Control
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SUSCEPTIBILITY OF *TOXORHYNCHITES RUTILUS RUTILUS* TO FIVE ADULTICIDES CURRENTLY USED FOR MOSQUITO CONTROL[1]

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ABSTRACT. One pyrethroid and four organophosphorous (OP) insecticides were evaluated as contact aerosols in wind tunnel tests against adult *Toxorhynchites rutilus rutilus* (Coquillett). The data indicate that *Tx. r. rutilus* and *Culex quinquefasciatus* Say were not significantly different in susceptibility to malathion (*O,O*-dimethyl phosphorodithioate of diethyl mercaptosuccinate), fenthion (*O,O*-dimethyl *O*-[4-(methylthio)-*m*-tolyl] phosphorothioate), naled (1,2-dibromo-2,2-dichloroethyl dimethyl phosphate), and chlorpyrifos (*O,O*-diethyl *O*-(3,5,6-trichloro-2-pyridyl) phosphorothioate). Resmethrin [5(phenylmethyl)-3-furanyl]methyl 2,2-dimethyl-3-(2-methyl-1-propenyl)cyclo propanecarboxylate (approx. 70% *trans*, 30% *cis*-isomers)) was ca. 1.4X more toxic to *C. quinquefasciatus* than to *Tx. r. rutilus*. *Aedes aegypti* (L.) was ca. 2X more susceptible than *Tx. r. rutilus* to 3 of the 4 OP's tested and ca. 16X more susceptible to resmethrin. Chlorpyrifos was equally toxic to *Ae. aegypti* and *Tx. r. rutilus*. Male and female *Tx. r. rutilus* did not differ significantly in their response to the insecticides tested.

Interest in the predaceous genus of mosquito *Toxorhynchites* (Theobald) has recently been renewed (Brown 1973, Furmizo et al. 1977, Focks et al. 1977, and Gerberg and Visser 1978), partly because of the existence of endemic dengue fever in the Caribbean and the role played by the container-breeding mosquito *Aedes aegypti* (L.) in transmission of the disease. Computer simulations of an integrated control strategy that would incorporate releases of adult *Toxorhynchites rutilus rutilus* (Coquillett) and the use of adulticides suggest that in certain situations it may be possible to use the strategy to eliminate populations of these vectors (Focks et al. 1978). Because of this potential of *Tx. r. rutilus* as a biocontrol agent and the need to integrate biological and chemical control techniques, we undertook studies to determine the relative effectiveness of 5 commonly used mosquito adulticides against adult male and female *Tx. r. rutilus*.

METHODS AND MATERIALS

The *Tx. r. rutilus* adults tested were taken from our laboratory colony; the original material came from Gainesville and Vero Beach, Florida. The rearing techniquies employed have been described previously (Focks et al. 1977). The mosquitoes were ca. 14 days old at the time of the test. Both sexes were used in approximately equal numbers. The data were analyzed to determine if there were any sex related differences in response to the insecticides.

Four organophosphates (OP) were tested: malathion (*O,O*-dimethyl phosphorodithioate of diethyl mercaptosuccinate), naled (1,2-dibromo-2,2-dichloroethyl dimethyl phosphate), chlorpyrifos (*O,O*-diethyl *O*-(3,5,6-trichloro-2-pyridyl) phosphorothioate), and fenthion (*O,O*-dimethyl *O*-[4-(methylthio)-*m*-tolyl] phosphorothioate). The one synthetic pyrethroid tested was resmethrin [5(phenylmethyl)-3-furanyl]methyl 2,2-dimethyl-3-(2-methyl-1-propenyl(cyclopropanecarboxylate (approx. 70% *trans*, 30% *cis*-isomers).

[1] This paper reports the results of research only. Mention of a pesticide in this paper does not constitute a recommendation for use by the U.S. Department of Agriculture nor does it imply registration under FIFRA as amended.

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All compounds were tested as contact sprays in a wind tunnel (Mount et al. 1976). This device consisted of a cylindrical tube 15.5 cm in diameter through which a column of air (ca. 23°C and ca. 50% RH) was blown at a rate of 1.8 m/sec (ca. 4 mph). Adult mosquitoes (10/cage) were confined in cardboard exposure cages, 8.6 cm in diameter and 5.0 cm high, with 16-mesh galvanized wire screen ends; the cages were held in the center of the wind tunnel tube for exposure. Upwind of the insects, a 0.1 ml solution of the desired concentration of insecticide in acetone (wt. AI/vol. diluent and expressed as % concentration) was atomized at a pressure of 105 g/cm^2.

Following exposure, the insects were anesthetized with carbon dioxide and transferred to new 8.6 X 5.0-cm cardboard holding cages covered with nylon screen tops. Insects in each cage were provided with a 10% sucrose solution on cotton. The holding cages were held at ca. 23°C and ca. 50% RH. Knockdown was checked 60 min after treatment, and mortality was recorded 24 hr after treatment. Controls were exposed to contact sprays containing acetone only and handled in the same manner.

Each insecticide was initially tested once with 10 mosquitoes at each of 2 doses slightly above and 2 doses slightly below the average LC-90 for *Ae. aegypti* and *Cx. quinquefasciatus*. The estimated LC-10, -25, -50, -75, and -90's obtained from a log-transformed probit analysis of the resulting data were used as the 5 test dosages at which each compound was subsequently tested. In this manner, virtually all the doses used were discriminating and 3 replicates of 5 doses each (30 mosquitoes/dose) were conducted for each of the 5 compounds. The dose-response relationship was determined by probit analysis of the log-transformed mortality data. Abbott's formula was applied to correct for control mortality (the average control mortality was less than 0.2%).

RESULTS AND DISCUSSION

The 24 hr LC-50's and LC-90's and their respective 95% fiducial limits are presented in Table 1. The compounds are ranked in order of decreasing toxicity (LC-90) to *Tx. r. rutilus*. The LC-90's for the same compounds against *Ae. aegypti* and *Cx. quinquefasciatus* are included for comparison (Mount and Pierce 1973, 1975).

The results indicate that *Ae. aegypti* was nearly twice as susceptible to malathion, naled, and fenthion as *Tx. r. rutilus* and not significantly different (p=0.05) in susceptibility to chlorpyrifos. Resmethrin

Table 1. Toxicity of aerosols of insecticides (% concentration) to caged adult *Toxorhynchites rutilus rutilus* (Coquillett) of both sexes. of *Aedes aegypti* (L.) and *Culex quinquefasciatus* (Say) exposed in a wind tunnel.

	Tx. r. rutilus				*Ae. aegypti*	*Cx. quinquefasciatus*
Insecticide	24 hr LC-50	95% Fiducial limits	24 hr LC-90	95% Fiducial limits	24 hr LC-90	24 hr LC-90
Fenthion	0.0061	0.0056–0.0067	0.0142	0.0125–0.0169	0.008[b]	0.016[b]
Chlorpyrifos	.0070	.0065– .0076	.0152	.0135– .0179	.012[c]	.011[c]
Naled	.0139	.0129– .0148	0212	0192– .0248	.012[b]	.020[b]
Resmethrin	0063	.0045– .0087	.0258	.0168– .0563	001[c,d]	.019[c,d]
Malathion	.0166	.0135– .0199	.0525	.0407– .0767	.026[b]	.070[b]

[a] ca. 14 days old.
[b] Data from Mount and Pierce (1973).
[c] Data from Mount and Pierce (1975).
[d] Values reported are the average LC-90 for *d-cis-* and *d-trans*-resmethrin.

appeared to be ca. 16X more toxic to *Ae. aegypti* than to *Tx. r. rutilus*. None of the OP compounds tested revealed significant differences (p=0.05) between susceptibility of *Tx. r. rutilus* and *Cx. quinquefasciatus*. Resmethrin was ca. 1.4X more toxic to *Cx. quinquefasciatus* than to *Tx. r. rutilus*.

Resmethrin and naled produced relatively quick knockdown (within 1 hr) at concentrations near that required for 24-hr kill. Fenthion and chlorpyrifos demonstrated no knockdown within 1 hr, and malathion showed only moderate knockdown.

When 2 of the 4 replicates were analyzed for differences in response by sex, no difference was found (n=919 mosquitoes, χ^2 (corrected) = 0.58).

Except for the use of resmethrin, there seems to be little possibility of applying an insecticidal dose sufficient to control prey adults without affecting the predaceous adult population. The difference in susceptibility to resmethrin between *Ae. aegypti* and *Tx. r. rutilus* may be great enough that a discriminating dose could be applied in the field during a release program. Monitoring adult predator releases has indicated that laboratory-reared adults die at ca. 20% per day in the field (Focks et al. 1979). This would suggest the optimal times for adulticiding to be immediately prior to and several days after a predator release. The proportion of predator adults alive on any particular day subsequent to a release is given by the expression: S_a^t where S_a is the adult daily survival (ca. 80%) and t being the number of days after the release. Using this expression for field mortality, one would expect ca. 32% of the adults released to be alive 5 days after a release and only 10% alive 10 days after a release.

References Cited

Brown, H. 1973. Mosquito Control. Some perspectives for developing countries. Natl. Acad. Sci., Wash., D.C. 63 pp.

Focks, D. A., D. W. Hall and J. A. Seawright. 1977. Laboratory colonization and biological observations of *Toxorhynchitres rutilus rutilus*. Mosquito News:751–755.

Focks, D. A., J. A. Seawright and D. W. Hall. 1978. Deterministic model for simulating the predation of *Toxorhynchites rutilus rutilus* on *Aedes aegypti*. USDA-ARS-S-178. 25 pp.

Focks, D. A., J. A. Seawright, and D. W. Hall. 1979. Field survival, migration and ovipositional characteristics of laboratory reared *Toxorhynchites rutilus rutilus* (Coquillett) (Diptera: Culicidae). J. Med. Entomol. (In Press.)

Furmizo, R. T., W. H. Cheong and A. Rudnick. 1977. Laboratory studies of *Toxorhynchites splendens*. Part I. Colonization and laboratory maintenance. Mosquito News 37:664–667.

Gerberg, E. J., and W. M. Visser. 1978. Preliminary field trial for the biological control of *Aedes aegypti* by means of *Toxorhynchites brevipalpis*, a predatory mosquito larva. Mosquito News 38:197–200.

Mount, G. A., and N. W. Pierce. 1973. Toxicity of selected adulticides to six species of mosquitoes. Mosquito News 33:368–370.

Mount, G. A. and N. W. Pierce. 1975. Toxicity of pyrethroid and organophosphorous adulticides to five species of mosquitoes. Mosquito News 35:63–66.

Mount, G. A., N. W. Pierce and K. F. Baldwin. 1976. A new wind-tunnel system for testing insecticidal aerosols against mosquitoes and flies. Mosquito News 36:127–131.

CBE STYLE MANUAL

1978 Boike, A. H., Jr., C. B. Rathburn, Jr., C. F. Hallmon, and S. G. Cotterman
Insecticide Susceptibility Tests of Aedes Taeniorhynchus and Culex Nigripalpus in Florida, 1974-1976
Mosquito News 38: 210-217 (Amvac Ref. #1384)

INSECTICIDE SUSCEPTIBILITY TESTS OF *AEDES TAENIORHYNCHUS* AND *CULEX NIGRIPALPUS* IN FLORIDA, 1974–1976[1]

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ABSTRACT. F_1 larvae and adults from wild populations of *Aedes taeniorhynchus* (Wied.) and *Culex nigripalpus* Theob. in Florida were tested against malathion, naled, and fenthion, and compared to the susceptible laboratory strains. The areas tested were based on previous results and also included new areas for additional susceptibility information. Both larval and adult forms of *Ae. taeniorhynchus* were found to be resistant to malathion. F_1 adults from one of the Florida Keys were 40 times more tolerant to malathion at the LC_{50} level based on paired tests with the laboratory susceptible strain. No resistance was detected when larvae or adults from some of these resistant areas were tested against naled or fenthion. F_1 larvae of *Cx. nigripalpus* were as susceptible as the laboratory strain when tested against malathion and naled; however, adults from some areas were up to 5X less susceptible to malathion.

INTRODUCTION

In a continuing effort to control 2 principal mosquito species in Florida, knowledge of their susceptibility to various insecticides is essential. Susceptibility levels of *Aedes taeniorhynchus* (Wied.) and *Culex nigripalpus* Theob. to several insecticides have been reported by Rogers and Rathburn (1964), Rathburn and Boike (1967), Boike and Rathburn (1968, 1969, 1972, 1975), Gahan et al. (1966), and Mount et al. (1971). This paper includes additional studies on the tolerance of first generation larvae and adults of these 2 species to malathion, naled, and fenthion for the years 1974–76

MATERIALS AND METHODS

Samples of wild adult mosquitoes from various areas in the state were sent to this laboratory where both F_1 larvae and adults were tested for insecticide resistance according to the methods previously described by Rathburn and Boike (1967), Boike and Rathburn (1969, 1972, 1975). Test results from each area were statistically analyzed by probit analysis in order to obtain the LC_{50} and LC_{90} values, their 95% confidence limits, and the slope and standard error of the regression line.

RESULTS

Results of larval tests are shown in Tables 1 and 2 and adult tests in Tables 3 and 4. In both larval and adult tests, each area was pair tested with the susceptible laboratory strain; however, since little variation occurred with the laboratory strain and in the interest of space, all replications were combined for a given year. Areas tested are arranged in the tables in increasing LC_{50} values. The resistant ratios cited in the text were based on paired tests and not on the average LC_{50} and LC_{90} values shown in the tables.

MALATHION vs *Ae. taeniorhynchus*. During the 3-year period, populations of *Ae. taeniorhynchus* showed a continuing lack of susceptibility to malathion, especially in the coastal areas of Florida and the Keys. This was observed previously by Boike and Rathburn (1975) and noted again during 1975 and 1976 (Tables 1 and 3). In 1975, F_1 larvae from Charlotte County were 11X less susceptible than the laboratory strain at the LC_{50} level and 16X at the LC_{90} level. During 1976, F_1 larvae of adult mosquito populations sampled from the southwestern coastal area (Longboat Key,

[1] Presented at the New Orleans meeting, April, 1977.

Table 1. Susceptibility of *Aedes taeniorhynchus* (Wied.) larvae to malathion, naled, and fenthion 1974–76.

County	Area	Reps.	LC_{50}	95% C.L.	LC_{90}	95% C.L.	Slope	Std. error
				Malathion–1974				
Laboratory strain		28	0.019	0.019–0.020	0.038	0.036–0.040	4.27	0.18
Dade	Cutler Ridge	11	0.053	0.046–0.062	0.371	0.290–0.475	1.52	0.12
Indian River	Indian R. Shores	6	0.131	0.117–0.146	0.439	0.364–0.528	2.44	0.18
Indian River	Vero Bch.	4	0.147	0.131–0.165	0.398	0.321–0.495	2.96	0.28
				Malathion–1975				
Laboratory strain		44	0.025	0.025–0.026	0.055	0.052–0.058	3.82	0.15
St. Lucie	Ft. Pierce	7	0.092	0.084–0.101	0.319	0.268–0.380	2.38	0.16
Volusia	Tomoka	16	0.138	0.128–0.148	0.531	0.451–0.625	2.19	0.12
Volusia	Oak Hill	4	0.167	0.146–0.189	0.594	0.441–0.800	2.32	0.22
Hillsborough	Ruskin	14	0.180	0.162–0.199	0.932	0.730–1.191	1.79	0.10
Hillsborough	Port Tampa	10	0.186	0.170–0.205	0.530	0.461–0.611	2.82	0.20
Charlotte	Punta Gorda	4	0.322	0.278–0.373	1.290	0.909–1.820	2.13	0.22
				Malathion–1976				
Laboratory strain		64	0.013	0.013–0.014	0.034	0.033–0.036	3.15	0.07
Hillsborough	Ruskin	14	0.046	0.042–0.050	0.159	0.138–0.182	2.38	0.17
Hillsborough	Port Tampa	12	0.068	0.062–0.074	0.237	0.210–0.268	2.36	0.11
Flagler	Flagler Bch.	13	0.079	0.074–0.085	0.339	0.284–0.404	2.03	0.11
Broward	Dania	24	0.090	0.084–0.096	0.518	0.427–0.627	1.68	0.08
Sarasota	Longboat Key	8	0.098	0.088–0.109	0.315	0.272–0.366	2.53	0.15
Manatee	Perrico Is.	10	0.119	0.105–0.133	0.638	0.505–0.805	1.76	0.10
Monroe	No Name Key	19	0.143	0.132–0.155	0.708	0.605–0.828	1.84	0.09
Sarasota	Manasota Bch.	9	0.209	0.189–0.230	0.740	0.583–0.940	2.33	0.17
Monroe	Sugarloaf Key	26	0.210	0.193–0.228	1.301	1.031–1.665	1.61	0.09
				Naled–1974				
Indian River	Indian R. Shores	3	0.032	0.025–0.040	0.091	0.072–0.116	2.81	0.50
Indian River	Wabasso	8	0.048	0.046–0.049	0.079	0.074–0.085	5.75	0.34
Laboratory strain		40	0.057	0.056–0.058	0.127	0.120–0.135	3.67	0.13
Dade	Cutler Ridge	7	0.060	0.056–0.065	0.132	0.113–0.154	3.79	0.42

Table 1. (continued)

County	Area	Reps.	Lethal concentration in µg/ml.				Slope	Std. error
			LC_{50}	95% C.L.	LC_{90}	95% C.L.		
			Naled–1975					
Hillsborough	Port Tampa	7	0.043	0.041–0.046	0.077	0.070–0.084	5.14	0.45
Volusia	Tomoka	2	0.046	0.041–0.051	0.105	0.082–0.135	3.54	0.49
Volusia	Oak Hill	3	0.066	0.055–0.079	0.210	0.121–0.365	2.55	0.47
Laboratory strain		9	0.070	0.067–0.073	0.123	0.112–0.136	5.20	0.38
			Naled–1976					
Monroe	Sugarloaf Key	12	0.032	0.030–0.034	0.068	0.063–0.073	3.97	0.22
Flagler	Flagler Bch.	16	0.034	0.032–0.036	0.080	0.075–0.085	3.43	0.18
Hillsborough	Port Tampa	8	0.038	0.036–0.040	0.079	0.073–0.085	4.04	0.22
Monroe	No Name Key	14	0.040	0.038–0.042	0.094	0.086–0.104	3.39	0.20
Laboratory strain		48	0.041	0.040–0.042	0.092	0.088–0.096	3.65	0.13
Broward	Dania	16	0.044	0.042–0.046	0.086	0.080–0.092	4.42	0.24
Sarasota	Manasota Bch.	8	0.068	0.064–0.071	0.133	0.116–0.152	4.39	0.38
			Fenthion–1974					
Laboratory strain		16	0.00091	0.00088–0.00094	0.00169	0.00160–0.00179	4.78	0.20
Indian River	Wabasso	16	0.00124	0.00120–0.00129	0.00230	0.00213–0.00247	4.81	0.25
			Fenthion–1976					
Broward	Dania	11	0.00093	0.00089–0.00097	0.00160	0.00150–0.00171	5.41	0.34
Laboratory strain		25	0.00095	0.00093–0.00098	0.00180	0.00171–0.00188	4.66	0.15
Monroe	No Name Key	10	0.00101	0.00096–0.00107	0.00216	0.00194–0.00240	3.91	0.27
Sarasota	Manasota Bch.	8	0.00114	0.00107–0.00121	0.00239	0.00209–0.00275	3.96	0.38
Monroe	Sugarloaf Key	16	0.00201	0.00193–0.00210	0.00366	0.00332–0.00404	4.94	0.34

Table 2. Susceptibility of *Culex nigripalpus* Theob. larvae to malathion and naled, 1974–1976.

County	Area	Reps.	Lethal concentration in μg/ml. LC$_{50}$	95% C.L.	LC$_{90}$	95% C.L.	Slope	Std. error
			Malathion–1974					
Laboratory strain		40	0.023	0.022–0.024	0.047	0.045–0.049	4.15	0.16
Pasco	New Pt. Richey	20	0.033	0.032–0.034	0.055	0.053–0.057	5.89	0.30
Bay	St. Andrew St. Pk.	7	0.040	0.039–0.041	0.057	0.055–0.060	8.43	0.48
Bay	Panama City Bch.	21	0.053	0.052–0.054	0.076	0.074–0.079	8.16	0.30
			Malathion–1975					
Laboratory strain		14	0.029	0.028–0.030	0.047	0.044–0.051	6.01	0.38
Polk	Lakeland	6	0.035	0.034–0.037	0.051	0.047–0.056	7.80	0.86
Volusia	Oak Hill	15	0.048	0.047–0.049	0.072	0.068–0.076	7.34	0.35
			Malathion–1976					
Laboratory strain		16	0.034	0.033–0.035	0.049	0.047–0.050	8.29	0.38
Manatee	Perrico Is.	8	0.045	0.044–0.047	0.067	0.063–0.071	7.44	0.46
Sarasota	Longboat Key	8	0.046	0.045–0.048	0.074	0.070–0.079	6.13	0.36
Broward	Dania	16	0.052	0.051–0.053	0.073	0.070–0.076	8.78	0.43
Sarasota	Manasota Bch.	8	0.055	0.054–0.057	0.082	0.077–0.088	7.40	0.45
Polk	Bartow	4	0.060	0.057–0.063	0.095	0.085–0.106	6.36	0.52
			Naled–1974					
Laboratory strain		12	0.037	0.036–0.038	0.054	0.052–0.056	8.03	0.45
Pasco	New Pt. Richey	16	0.068	0.067–0.070	0.091	0.088–0.094	10.30	0.52
			Naled–1975					
Laboratory strain		4	0.054	0.052–0.057	0.073	0.066–0.080	10.16	1.16
Volusia	Oak Hill	6	0.061	0.059–0.063	0.082	0.078–0.086	10.16	0.83
			Naled–1976					
Laboratory strain		34	0.052	0.051–0.053	0.071	0.069–0.074	9.40	0.33
Manatee	Perrico Is.	8	0.059	0.058–0.061	0.075	0.072–0.078	12.63	0.71
Sarasota	Longboat Key	8	0.064	0.063–0.065	0.084	0.081–0.087	11.08	0.67
Sarasota	Manasota Bch.	4	0.066	0.064–0.069	0.093	0.087–0.099	8.85	0.69
Broward	Dania	8	0.074	0.073–0.075	0.089	0.087–0.091	15.85	0.99

Table 3. Susceptibility of *Aedes taeniorhynchus* (Wied.) adults to malathion and naled, 1974–76.

County	Area	Reps.	Lethal concentration in mg/ml. LC_{50}	95% C.L.	LC_{90}	95% C.L.	Slope	Std. error
			Malathion–1974					
Laboratory strain		25	0.130	0.124–0.137	0.358	0.331–0.338	2.91	0.12
Indian River	Indian R. Shores	4	0.367	0.231–0.582	2.144	0.957–4.806	1.67	0.38
Dade	Cutler Ridge	5	3.201	2.215–4.625	28.589	9.183–88.982	1.35	0.27
Indian River	Wabasso	6	5.041	3.463–7.338	37.256	13.999–99.129	1.48	0.25
			Malathion–1975					
Laboratory strain		20	0.160	0.152–0.168	0.429	0.390–0.472	2.98	0.12
Hillsborough	Ruskin	5	0.331	0.281–0.391	1.810	1.329–2.464	1.74	0.17
Volusia	Tomoka	3	1.531	1.299–1.806	9.927	6.654–14.182	1.58	0.15
Hillsborough	Port Tampa	3	1.577	1.247–1.993	4.152	3.021–5.706	3.05	0.50
St. Lucie	Ft. Pierce	3	2.473	1.735–3.526	12.078	5.102–28.596	1.86	0.45
			Malathion–1976					
Laboratory strain		34	0.220	0.211–0.229	0.763	0.705–0.826	2.37	0.06
Sarasota	Longboat Key	4	1.159	0.919–1.462	7.357	5.110–10.593	1.60	0.15
Broward	Dania	10	2.276	1.998–2.592	21.612	14.942–31.261	1.31	0.10
Hillsborough	Port Tampa	8	2.834	2.482–3.236	17.366	11.337–26.595	1.63	0.19
Monroe	No Name Key	8	4.740	3.912–5.744	39.337	21.772–71.072	1.39	0.17
Sarasota	Manasota Bch.	6	5.732	5.105–6.437	20.663	15.646–27.290	2.30	0.27
Monroe	Sugarloaf Key	8	10.280	7.695–13.734	181.447	73.181–451.752	1.03	0.12
Flagler	Flagler Bch.	4	10.445	4.167–26.182	95.104	10.612–852.118	1.34	0.40
			Naled–1976					
Broward	Dania	4	0.085	0.077–0.093	0.182	0.158–0.210	3.87	0.34
Laboratory strain		14	0.161	0.154–0.168	0.380	0.343–0.421	3.43	0.16
Monroe	Sugarloaf Key	6	0.190	0.178–0.203	0.317	0.282–0.356	5.77	0.56
Monroe	No Name Key	3	0.196	0.162–0.237	0.427	0.281–0.648	3.78	0.69
Sarasota	Manasota Bch.	2	0.212	0.184–0.244	0.354	0.260–0.481	5.77	1.14

Table 4. Susceptibility of *Culex nigripalpus* Theob. adults to malathion and naled 1974–76.

County	Area	Reps.	Lethal concentration in mg./ml.				Slope	Std. error
			LC_{50}	95% C.L.	LC_{90}	95% C.L.		
			Malathion–1974					
Laboratory strain		34	0.673	0.645–0.703	2.058	1.905–2.224	2.64	0.08
Pasco	New Pt. Richey	9	0.928	0.826–1.043	3.107	2.576–3.748	2.44	0.19
Bay	Panama City Bch.	10	1.251	1.132–1.382	3.280	2.756–3.905	3.06	0.24
Bay	St. Andrews St. Pk.	6	1.338	1.177–1.521	3.229	2.562–4.070	3.35	0.37
Dade	Cutler Ridge	2	1.445	1.233–1.692	2.974	2.294–3.858	4.09	0.68
			Malathion–1975					
Laboratory strain		4	0.207	0.166–0.258	0.823	0.635–1.067	2.14	0.28
Volusia	Oak Hill	7	0.914	0.822–1.017	3.185	2.669–3.800	2.36	0.16
Polk	Lakeland	2	1.072	0.748–1.536	2.639	1.519–4.586	3.27	0.71
			Malathion–1976					
Laboratory strain		22	0.451	0.425–0.479	1.740	1.573–1.923	2.19	0.08
Broward	Dania	9	1.071	0.939–1.221	9.482	6.607–13.766	1.35	0.11
Manatee	Perrico Is.	8	1.370	1.226–1.532	5.518	4.396–6.925	2.12	0.15
Sarasota	Longboat Key	10	1.443	1.313–1.586	5.673	4.642–6.933	2.16	0.13
Sarasota	Manasota Bch.	6	1.466	1.297–1.657	6.361	4.860–8.325	2.01	0.15
Orange	Orlando	4	2.075	1.780–2.419	6.294	4.378–9.045	2.66	0.35
Polk	Bartow	2	2.157	1.436–3.241	10.537	3.200–34.690	1.86	0.52
			Naled–1976					
Laboratory strain		10	0.090	0.085–0.096	0.247	0.217–0.279	2.93	0.15
Broward	Dania	4	0.097	0.088–0.108	0.187	0.163–0.214	4.54	0.51
Sarasota	Longboat Key	3	0.138	0.128–0.149	0.253	0.221–0.291	4.86	0.48
Manatee	Perrico Is.	4	0.189	0.140–0.254	0.976	0.300–3.174	1.80	0.53

Perrico Island and Manasota Beach) and the Florida Keys (No Name Key and Sugarloaf Key) were 6X to 13X less susceptible than the laboratory strain at the LC_{50} level and 8X to 31X at the LC_{90} level. During 1974, F_1 adults from Dade and Indian River counties were 25X and 38X more resistant respectively at the LC_{50} level when compared to the laboratory strain. During 1976, F_1 adults from the Florida Keys (No Name Key and Sugarloaf Key) were as much as 16X and 40X respectively less susceptible than the laboratory strain at the LC_{50} level.

NALED vs *Ae. taeniorhynchus*. F_1 larvae from all areas tested during the 3-year period were as susceptible (<2X) to naled as to the laboratory strain (Table 1). When adults from malathion resistant areas in 1976 were tested for susceptibility to naled, very little difference was noted when compared to the susceptible laboratory strain (Table 3).

FENTHION vs *Ae. taeniorhynchus*. A limited number of fenthion tests were performed mainly during 1976 (Table 1). F_1 larvae from 4 areas sampled during this period were found to be as susceptible (<2X) as the laboratory strain.

MALATHION vs *Cx. nigripalpus*. First generation larvae sampled during 1974–76 were almost as susceptible to malathion as those of the laboratory strain (Table 2). Adults tested from some areas during the same period were 2X to 5X less susceptible than the laboratory strain at the LC_{50} level and from 2X to 6X at the LC_{90} level (Table 4).

NALED vs *Cx. nigripalpus* Larvae from all 6 areas sampled during 1974–76 were as tolerant to naled as the laboratory strain (Table 2). Adults were tested from areas sampled during 1976 only and were found to be 2X and 4X less tolerant than the laboratory strain at the LC_{50} and LC_{90} levels respectively.

DISCUSSION

Previous results on the susceptibility of Florida mosquitoes to insecticides have been reported by Rathburn and Boike (1967) and Boike and Rathburn (1968, 1969, 1972) and included mostly larval data, while a recent report (Boike and Rathburn 1975) contained mainly larval data and some adult tests. The data reported herein contain substantially more adult testing and in many instances both larval and adult results can be compared for a given area. The data also indicate that *Ae. taeniorhynchus* continues to be resistant to malathion in the state, with apparently the highest degree of tolerance noted in adults from the lower Florida Keys. Although no resistance to malathion was noted in larval samples of *Cx. nigripalpus*, some adult populations were 6X less susceptible to malathion than the susceptible laboratory strain. This could be significant; however, it probably represents vigor tolerance in the adult stage.

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References Cited

Boike, Arthur H., Jr. and Carlisle B. Rathburn, Jr. 1968. Tests of the susceptibility of Florida mosquitoes to insecticides, 1967. Mosquito News 28(3):313–316.

Boike, Arthur H., Jr. and Carlisle B. Rathburn, Jr 1969. Laboratory tests of the susceptibility of mosquito larvae to insecticides in Florida, 1968 Mosquito News 29(3):392–395.

Boike, Arthur H., Jr. and Carlisle B. Rathburn, Jr. 1972. The susceptibility of mosquito larvae to insecticides in Florida, 1969–1971. Mosquito News 32(3):328–331.

Boike, Arthur H., Jr. and Carlisle B. Rathburn, Jr. 1975. Laboratory susceptibility tests of some Florida strains of *Aedes taeniorhynchus* (Wied.) and *Culex nigripalpus* Theob. to malathion and naled. 1972–1974. Mosquito News 35(2):137–140.

Gahan, James B., Carroll N. Smith and B. Michael Glancy. 1966. Resistance in Florida and countermeasures involving chemicals. Mosquito News 26(3):330–337.

Mount, G. A., D. A. Dame and C. S. Lofgren. 1971. Susceptibility of a Florida strain of *Aedes taeniorhynchus* (Wied.) to insecticides. Mosquito News 31(3):438–440.

Rathburn, Carlisle B., Jr. and Arthur H. Boike, Jr. 1967. Studies of insecticide resistance in Florida mosquitoes. Mosquito News 27(3):377–382.

Rogers, Andrew J. and Carlisle B. Rathburn, Jr. 1964. Present status of insecticides for mosquito control in Florida. Mosquito News 24(3):286–291.

LABORATORY OBSERVATIONS ON THE MATING BEHAVIOR OF *CULEX TRITAENIORHYNCHUS* GILES

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ABSTRACT. Male insemination capacity and the incidence of multiple insemination was studied using a wild-type, laboratory strain and a recessive eye color mutant of *Cx. tritaeniorhynchus*. Sexually mature, wild-type males inseminated an average of 5.1 mature females during a 4-day test period with most inseminations occurring the 2nd night. Multiple insemination was detected in 8 of 389 fertile egg rafts and occurred most frequently in small cages having high pair densities. No preferential mating was observed among the mutant males and females, and progressively more wild-type matings occurred at lower pair densities and in larger cages.

Studies of *Culex tritaeniorhynchus* Giles mating behavior have recently been initiated to provide background information as a prelude to genetical control experiments in nature. Information on phenomena such as male insemination performance, the incidence of multiple insemination and preferential mating are critical in planning releases. Observations on *Cx. tritaeniorhynchus* mating behavior in nature (Kawai et al. 1967, Reisen et al. 1977) and during colonization attempts (Newson and Blakeslee 1957, Sasa et al. 1967; Shirasaka et al. 1968, Baker and Sakai 1974) have been restricted to the time and place of mating and the incidence of successful mating under laboratory conditions. In fact, there are relatively few detailed studies of many aspects of the mating behavior of *Culex* mosquitoes, in general, with the exception of *Cx. p. fatigans* (e.g. Kitzmiller and Laven 1958, Sebastian and de Meillon 1967) and to a lesser extent *Cx. tarsalis* (Asman 1975) and *Cx. nigripalpus* (Lea and Edman 1972).

The present paper describes male insemination performance, the incidence of multiple insemination, and preferential mating in *Cx. tritaeniorhynchus* under laboratory conditions.

METHODS AND MATERIALS

STRAINS. The Balloki, Pakistan, strain of *Cx. tritaeniorhynchus* was used throughout and has been under continuous culture at our laboratories for the past 6 years (Baker and Sakai 1974). A recessive, sex-linked, heat sensitive, eye color mutant, rose eye (Baker and Sakai 1973), was used in the multiple insemination and preferential mating experiments. This mutant, originally isolated from the Balloki strain, expresses itself well in the larval stage as red eye color at 28°C, becoming paler to

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AG-CAT ULV SPRAY SYSTEM DEVELOPMENT, CALIBRATION, AND FIELD TESTS USING NALED

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ABSTRACT. An aerial ULV spray system was developed for use with a Grumman Ag-Cat using Dibrom® 14 (1,2-dibromo-2,2-dichloroethyl dimethyl phosphate). The entire system utilizes a 26 volt electric motor directly coupled to a brass gear pump. The design affords simplified attachment and changeover from the conventional system, an incorporated flushing system, pressure gauges located at the nozzles, disposable insecticide tank, and safety for the pilot from insecticide exposure. The system was calibrated and field tested to determine flow rate, swath width, particle size, and its ability to kill mosquitoes. The system has proven to be a valuable tool in combating *Culex salinarius* (Say) and *Aedes sollicitans* (Walker).

INTRODUCTION

The advent of ULV aerial treatment has brought about a decrease in cost and an increase in effectiveness of mosquito adulticiding. The Douglas DC-3 ULV spray system, developed and calibrated at New Orleans Mosquito Control (NOMC) has proven to be an effective tool for large areas over 4,000 ha (Machado et al. 1969a, Machado et al. 1969b). Using this aircraft for short periods on small areas increases the cost per hectare of treatment considerably.

A single-engine aircraft is desirable for treatment of areas less than 2,000 ha. NOMC equipped a Grumman Ag-Cat with an electrical pump-driven ULV system for use with Dibrom® 14 (naled). After installation, the system was calibrated in accordance with label recommendations. The optimum swath width of the system, its effectiveness and limitations under field conditions were then determined.

SYSTEM DESCRIPTION

The nozzles are located on a small boom on each lower-wing tip. The total number of nozzels can vary using 2, 3, or 4. The pressure gauge is located on one wing tip just forward of the nozzles. The hoses are routed through the wings (inside a plastic tube) to a brass gear pump with a diaphragm by-pass. The insecticide tank is a 57 liter Dibrom can and liner, mounted in the hopper by cargo straps. The tank can be replaced after treatment or refilled from larger Dibrom containers. Also mounted in the hopper is a 23 liter polyethylene can containing isopropanol for flushing the system. The gear pump is driven by a 26 volt electric motor powered by the aircraft's electrical system.

MATERIALS

a) Motor- EEMCO 26 volt, D-709
b) Gear pump- Brass Oberdorfer #4000
c) By-pass valve- Spray Systems type 9840
d) Nylon hose- Synflex® #3130-06, ⅜" i.d.
e) Teejet nozzles- Spray Systems #8001
f) Brass swivel and pipe
g) Tube- Polyethylene- 1" i.d.
h) Insecticide tank- 57 liter (15 gal) Dibrom can and liner
i) Flushing tank- 23 liter (6 gal) polyethylene can
j) Solenoid- 24 volt and wires
k) Plastic clamps- Thomas and Betts Ty-527-M
l) Tank harness- Aircraft cargo type
m) Ball valves- (2)- Hayward ⅜" PVC
n) Tank cradle- Plywood insulated with foam rubber
o) Strainer- Spray Systems "T" type, 100 mesh
p) Pressure gauge- 5.9 cm diam, 0-160 psi, Ashcroft

INSTALLATION AND USE

Changeover from the conventional system is simple, and requires 2 man-hours of work. Once the spray booms and nozzles are mounted on the wing tips, they need never be taken off aside from maintenance. All hoses are permanently mounted through the wing and connected with swivel type couples. The pump is attached by 4 bolts and receives power from the electrical system with one wire. The cost of the entire system is less than $1,000.

The system is adjusted on the ground before takeoff with no in-flight pressure or flowrate adjustments needed. The pilot operates the entire system with an on-off toggle switch.

DETERMINATION OF SWATH WIDTH. An unused road in NOMC area W-20 was selected for swath width determination. Dibrom dye cards (Koundahjian 1965) were numbered and placed on the ground every 3 m for 366 m downwind and 9 m upwind of the flight path The Ag-Cat was flown at 145 kph, perpendicular to the wind, at an altitude of 7 6 m spraying Dibrom at 1200 ml/min. The droplet-exposed cards were collected after 15 min. Cards with droplet densities of less than 3 spots/cm^2 were considered to be beyond the effective swath.

With wind speeds up to 8 kph, the swath width was 100 m, displaced downwind up to 100 m. With wind speeds above 8 kph, the swath width was very dispersed and difficult to determine.

CALIBRATION OF FLOW RATE. A dosage rate of between 36.5 ml and 73.0 ml/ha (0.5 to 1.0 oz/acre by label) of Dibrom was used for all treatments. It was calculated that a flow rate of 800 ml/min is necessary to produce a dosage rate of 36.5 ml/ha with a 100 m swath width.

The spray system was operated with the Ag-Cat stationary with an engine speed of 2000 rpm. The Dibrom sprayed from each of the two nozzles for 2 min was collected through plastic tubes into buckets and the volume measured. The pressure of the system was adjusted to obtain the desired flow rates (Table 1).

DETERMINATION OF PARTICLE SIZE. Eight spinners (modified from Rathburn 1970) with Teflon® coated slides were placed 15 m apart downwind of the flight path, 1 m above the surface, beginning directly below the flight path.

The Ag-Cat sprayed Dibrom from two #8001 Teejet nozzles mounted at a 45° forward angle, slightly aft of the wing tips, at 800 ml/min and 4.8 atm (70 psi) pressure. The particles were allowed to impinge on the Teflon slides for 15 min. The average number median diameter (NMD) (Yeomans 1949) was 20 μm. Ninety-five percent of the particles were below 80 μm, and 87% below 30 μm.

The procedure was repeated under the same conditions using two #8002 Teejet nozzles. The NMD was 53 μm, with 95% of the particles below 80 μm, and 65% below 30 μm. From the data collected, it was decided that the standard spray configuration for all treatments would be as in Table 1, column a.

Table 1. Calibrated flow rates of Dibrom 14 through an Ag-Cat ULV system.

	a.	b.
Teejet #	(2) #8001	(2) #8002
Pressure	4.8 atm (70 psi)	4.8 atm (70 psi)
Flow Rate	804 ml/min	1495 ml/min
Dosage*	36.5 ml/ha (0.50 oz/acre)	68.6 ml/ha (0.94 oz/acre)
Droplet Size (Number Median Diameter)	20.2 μm	53.4 μm

* at 145 kph with a 100 m swath width and 7.6 m altitude.

KILL TESTS ON CAGED MOSQUITOES

Mosquitoes from natural populations of *Aedes sollicitans* (Walker) and *Culex salinarius* (Say) were placed in screen cages 7 cm in diam by 18 cm long, and kept in ice chests with moistened paper towels.

Eight cages, each containing 10 to 15 female mosquitoes of each species were placed atop 1 m poles in the center of the treatment area. These were placed at 15 m intervals, parallel to the wind direction, starting below the flight path. The treatment area, approximately 125 ha, was treated using the standard Ag-Cat configuration. Cage and spinner placements were on one of two unused cross-roads in a *Spartina patens* marsh. The cages remained in position for 15 min after treatment and were returned to the ice chests until they were examined for mosquito mortality. Controls were employed outside the treatment area, and handled in the same manner as the treated cages. In all cases, 100% of the treated mosquitoes died after 1.5 hr, while only 2% of the control mosquitoes died after 10 hr.

FIELD TESTS ON THE MOSQUITOES OF THE NATURAL POPULATION

A large population of *Ae. sollicitans* and *Cx. salinarius* afforded a good opportunity to test the operational aspects of the system. The population was sampled 1 night pre-treatment, treatment night, and 1 night post-treatment.

The mosquitoes were monitored before and after the treatment using CO_2 enhanced 3 min landing rates, and truck trap collections from a 4.8 km route. All landing rates were taken by two groups of observers, at the same 14 stations, over a 2 hr period starting at sunset. Truck trap collections were made 30 min after sunset.

By using the standard Ag-Cat spray configuration with four #8001 Teejet nozzles (this doubles the dosage rate while keeping the pressure and particle size the same), the 800 ha area was treated 1 hr before sunset.

Based on landing rate and truck trap data from two trials, *Ae. sollicitans* were reduced an average of 71% and *Cx. salinarius* were reduced an average of 88%. The amount of reinfestation which occurred can only be estimated, but due to the small size of the test area, it is believed that some did occur.

CONCLUSIONS

All tests indicate the system works well at 145 kph, 7.6 m altitude, with a 100 m swath width, spraying Technical Grade Dibrom 14 (at label recommendations) from #8001 Teejet nozzles at 4.8 atm. The only operational limitation is wind condition. Wind speeds in excess of 8 kph displace the swath too far downwind. The system, in operation for 3 years, has performed almost flawlessly.

The Ag-Cat spray system is proving to be an effective tool in situations where use of large aircraft is not feasible. With 57 liters of Dibrom 14, it can treat 810 ha in about 1 hr with 73 ml/ha (1 oz/acre). This is very effective against both *Cx. salinarius* and *Ae. sollicitans*, since the system can treat a relatively large infested area in a short time just before the dusk or after the dawn activity period.

Literature Cited

Koundakjian, T. H. 1965. The detection and measurement of Dibrom LV concentrate aerospray droplets. Calif. Chem. Co., Ortho Div., Res. and Devel. Dept., Richmond, Calif. (File no. 721:101):6pp.

Machado, W. C., Blake, A. J., Bordes, E. S. Jr. and Carmichael, G. T. 1969a. Evaluation of a multi-engine aircraft in the ULV application of Dibrom. Mosquito News 29(1):47–52.

Machado, W. C., Bordes, E. S. Jr., Blake, A. J. and Carmichael, G. T. 1969b. A technique for ULV insecticide application from high altitudes. Mosquito News 29(3):353–360.

Rathburn, C. B. 1970. Methods of assessing droplet size of insecticidal sprays and fogs. Mosquito News 30(4):501–513.

Yeomans, A. H. 1949. Directions for determining particle size of aerosols and fine sprays. USDA Bur. Entomol. Pl. Quar. ET-267:7pp.

1978 Hester, P. G., B. W. Clements, Jr., J. C. Dukes, and W. N. Swenson
Effects of Dibrom Applied as Aerial Sprays on Non-Target Salt Marsh Organisms in Northwest Florida
Proceedings of the Florida Anti-Mosquito Association 3-5 (Amvac Ref. #1388)

1978

(1388)

Table 2. Laboratory tests of the effectiveness of selected larvicides against a wild strain of *A. aegypti* as compared to a laboratory strain of *A. taeniorhynchus*, 1977.

Insecticide	Species	Reps	Lethal concentrations in μg/ml				Slope	Std error
			LC_{50}	95% C.L.[1]	LC_{90}	95% C.L.[1]		
methoprene	*A. aegypti*	4	0.0037	0.0030-0.0047	0.0863	0.0606-0.1229	0.94	0.05
	A. taeniorhynchus	4	0.0030	0.0021-0.0044	0.0174	0.0128-0.0237	1.69	0.18
diflubenzuron	*A. aegypti*	4	0.0012	0.0011-0.0012	0.0028	0.0025-0.0032	3.28	0.21
	A. taeniorhynchus	4	0.0004	0.0004-0.0005	0.0013	0.0011-0.0015	2.58	0.20

[1]Confidence Limits.

taeniorhynchus to all the adulticides and larvicides tested. These differences, however, may not hold true for all *A. aegypti* populations, even though previous larvicide tests (Boike and Rathburn 1968 and 1969, Rathburn and Boike 1969) with other strains of *A. aegypti* also showed a reduction in susceptibility to malathion, naled, fenthion, and temephos when compared to the laboratory colony *A. taeniorhynchus*.

ACKNOWLEDGEMENTS

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LITERATURE CITED

Boike, A. H., Jr. and C. B. Rathburn, Jr. 1968. Tests of the susceptibility of Florida mosquitoes to insecticides, 1967. Mosquito News 28(3):313-16.

Boike, A. H., Jr and C. B. Rathburn, Jr. 1969. Laboratory tests of the susceptibility of mosquito larvae to insecticides in Florida, 1968. Mosquito News 29(3):392-5.

Rathburn, C. B., Jr. and A. H. Boike, Jr. 1969. A study of factors affecting the susceptibility of mosquito larvae to insecticides in laboratory resistance tests. Mosquito News 29(3):395-401.

Effects of Dibrom Applied as Aerial Sprays on Non-Target Salt Marsh Organisms in Northwest Florida

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ABSTRACT

Aerial sprays of 25% Dibrom by volume in soybean oil were applied at the rate of 0.063 lb A.I. (active ingredient)/acre upwind of a salt marsh and allowed to drift over the area. Selected organisms exposed in the tests included the blue crab, *Callinectes sapidus* Rathbun; fiddler crab, *Uca pugnax* Smith; grass shrimp, *Palaemonetes* sp.; large shrimp, *Penaeus* sp.; sheepshead minnow, *Cyprinodon variegatus* Lacepede; and longnose killifish, *Fundulus similis* (Baird and Girard). In addition to the selected organisms, the salt marsh was observed for any gross adverse effects. High mortality of caged adult stable flies, *Stomoxys calcitrans* (L.), placed in each marsh area showed that coverage of spray over the salt marsh was complete. No adverse effects were observed, in terms of the criteria applied, in any non-target organism or the natural macrofauna of the marsh.

A study was initiated to determine the effects of aerial sprays of Dibrom on non-target organisms. The aerial spray method and formulation used in this study was previously described by Rogers et al (1972) for the control of stable flies, *Stomoxys calcitrans*, in northwest Florida. The stable fly, commonly known as the dog fly, migrates to the Gulf beaches from inland breeding sites on northerly winds during the late summer and fall of each year. During this period, large numbers of flies invade the beaches creating a serious economic impact on tourism in this area.

Although the beach habitat is normally sprayed to control the dog fly, test plots were established in a salt-marsh. The marsh habitat contained more stable water conditions and the types of resident non-target organisms were similar to those in the beach habitat. Various species of salt-marsh organisms commonly found in Florida's brackish-water marshes, as substantiated by others (Zilberberg, 1966; Wood, 1967; Nixon and Oviatt, 1973; Subrahmanyam and Drake, 1975) were selected for use as indicator, non-target organisms in this study. The test organisms included the following: blue crab, *Callinectes sapidus* (measuring one to two inches from point to point); fiddler crab, *Uca pugnax;* grass shrimp, *Palaemonetes* sp. (approximately 2.5 cm long); large shrimp, *Penaeus* sp. (length 5.0 to 10.2 cm); sheepshead minnow, *Cyprinodon variegatus;* and longnose killifish, *Fundulus similis*.

MATERIALS AND METHODS

Aerial applications of 25% Dibrom by volume on soybean oil were drifted over a salt marsh located on Breakfast Point, Bay County, Florida. Flight centers for spraying were marked at 61 m intervals beginning 610 m inland from the bayshore. Four spray swaths were made with the last being 793 m landward and upwind of the bayshore. Based on the above measurements, the first swath was located 244 m inland of the normal high tide elevation in the marsh. The upper marsh stations were located at the normal high tide level, the middle marsh stations at 366 m, and the lower marsh stations 488 m.

Test organisms were collected and placed in large holding cages prior to spraying except for two fish species, which were seined in the marsh and placed directly into test pens approximately 24 hr prior to spraying. The test fish that were dead or appeared abnormal were removed just before spraying. Blue crabs and shrimps were exposed in 3.2 mm mesh wire cages measuring 7.6 x 30.5 x 46 cm. The top side of each cage was suspended one inch under the water surface by attaching styrofoam floats on the outer edges of the cage. Fish were exposed in 3.2 mm mesh open top wire cages four feet in diameter and fiddler crabs in 30.5 cm diameter metal pens fitted with 3.2 mm mesh wire tops, to prevent predation or escape. Caged adult stable flies from the laboratory colony were placed on stakes one to two meters above the ground at stations adjacent to the non-target species, for bioassay studies and spray coverage.

In addition to evaluating the effects of Dibrom aerial sprays on the selected test organisms, the entire macrofauna of the salt marsh was visually observed for any gross adverse effects of the pesticide. All tidal channels and open shallow pools, as well as areas heavily vegetated with black rush (*Juncus roemerianus* Scheele), were inspected after each spray application. Similar stations containing representative test organisms and caged stable flies were established in another salt marsh on the bay to serve as untreated checks.

Caged organisms, both treated and checks, were counted at 1, 24, and 48 hr post-treatment. To avoid putting undue stress on the organisms by removal of the cages from the water, only the dead specimens were counted at 1 and 24 hr; the live specimens were not counted until 48 hr after treatment. The natural macrofauna of the marsh also was monitored during these time periods.

Aerial sprays of 25% Dibrom by volume in soybean oil were applied by a twin-engine aircraft operated at a speed of 240 kph on 61 m swath centers and at an altitude of 46 m. In each test, a total of 840 acres was treated at a volume of 2.3 fl oz of 25% Dibrom (28.6 g or 0.063 lb A.I./acre).

RESULTS AND DISCUSSION

A summary of the efficacy of 25% Dibrom spray on non-target organisms is presented in Table 1 and a summary of physical data for the four tests is shown in Table 2. The data show that there were no adverse effects, as measured in terms of gross mortality, of the Dibrom spray on any of the non-target organisms. During, immediately after, and 24 and 48 hr post-treatment, thousands of fiddler crabs were feeding on

Table 1. Average percent mortality of caged non-target salt marsh organisms and stable flies, *Stomoxys calcitrans*, in four tests of 25% Dibrom by volume in soybean oil applied as aerial spray, 1976-77.

Test organism	Marsh area	Treated No. organisms	Treated % mortality[1]	Treated range	Check No. organisms	Check % mortality[1]	Check range
Fiddler crab	Upper	50	1.5	0-4.0	50	5.5	0-10.0
Stable fly[2]		194	91.0	73-100	300	2.7	0- 6.7
Longnose killifish	Middle	42	1.2	0-4.5	44	3.4	0-12.0
Sheepshead minnow		48	0	—	44	0	—
Blue crab		6	0	—	6	4.2	0-16.7
Stable fly[3]		124	91.5	83-100	300	2.7	0- 6.7
Blue crab	Lower	12	0	—	12	2.1	0- 8.3
Grass shrimp[2]		42	0.8	0-2.0	41	0	—
Large shrimp[2]		20	1.7	0-6.7	20	0	—
Stable fly		275	85.0	70-100	300	2.7	0- 6.7

[1]Mortality counts at 48 hr for non-target organisms and 24 hr for stable flies.
[2]Tests are average of three replications.
[3]Tests are average of two replications.

the open flats of the marsh and showed no apparent ill effects of the spray. No obvious adverse effects were noted to any of the marsh inhabiting organisms except for several dead tiger beetles, which are scavengers and plentiful in the marsh.

Table 2. Physical data recorded during four aerial spray tests to determine effects of 25% Dibrom on non-target salt marsh organisms, 1976-77.

Type of sample	Average	Range
Water depth (cm)		
Marsh		
Upper	2.2	0.8- 2.5
Middle	7.8	6.4-10.0
Lower	24.0	18.0-31.0
Water temperature (°C)		
Marsh:		
Upper	34.5	31.0-37.0
Middle	34.0	31.0-36.5
Lower	32.5	28.0-35.5
Water salinity—lower marsh (o/oo)[1]	30.2	29.6-30.8
Water pH—lower marsh[2]	8.2	—
Air temperature (°C)	31.5	26.0-34.5
Relative humidity (%)	56.8	52.0-62.2
Wind speed (kph)	11.8	11.0-13.0

[1]Results of two replications.
[2]Only one replication.

The bioassay studies against caged adult stable flies revealed that spray coverage over the salt marsh was complete. The fly mortality in the four tests averaged 89.1% with a range of 70-100%.

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LITERATURE CITED

Nixon, S.W. and E. A. Oviatt. 1973. Ecology of a New England salt marsh. Ecol. Monogr. 43: 464-98.

Rogers, A. J., B. W. Clements, Jr., C. B. Rathburn, Jr., A. H. Boike, Jr., and N. E. Thomas, Jr. 1972. Strip spraying of naled by aircraft for control of adult stable flies and mosquitoes. Florida Anti-Mosq. Assoc., Rep. Annu. Mtg. 43:28-32.

Subrahmanyam, C. B. and S. H. Drake. 1975. Studies on the animal communities in two North Florida salt marshes, Part I. Fish Communities. Bull. mar. Sci. 25(4):445-65.

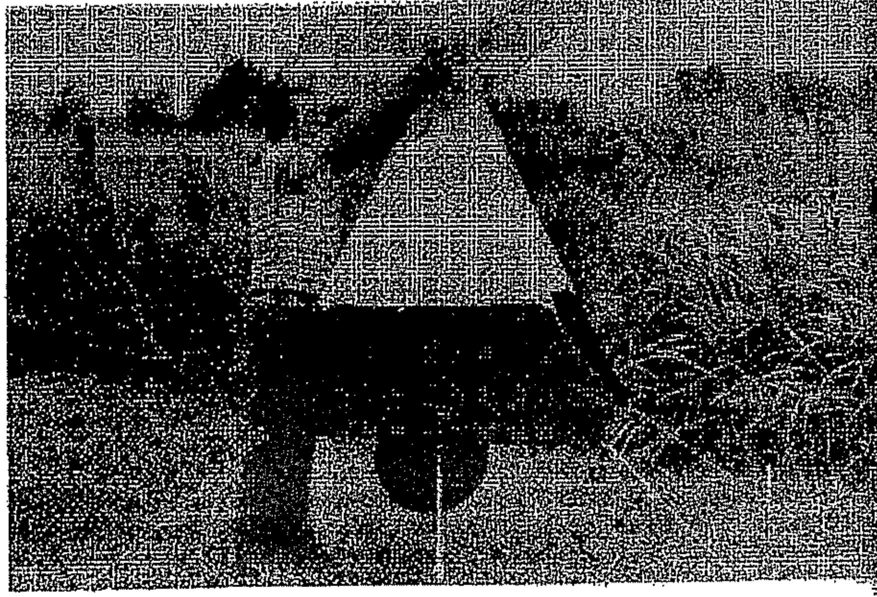
Wood, C. E. 1967. Physioecology of the grass shrimp, *Palaemonetes pugio*, in the Galveston Bay Estuarine System. Contr. mar. Sci. Univ. Tex. 12:49-79.

Zilberberg, M. H. 1966. Seasonal occurrence of fishes in a coastal marsh of northwest Florida. Publs. Inst. mar. Sci. Univ. Tex. 11:126-34.

1978 Meek, L., G. Faget, and T. Morganti
Horse Flies Target Of Insecticide Tests
Louisiana Agriculture 21: 14-15 (Amvac Ref. #1386)

1978
Louisiana Agriculture
21:14-15

(1386)



Canopy traps were used in collecting horse flies for the tests.

Horse flies target of insecticide tests

LAMAR MEEK, GUY FAGET AND TOM MORGANTI[1]

HORSE FLIES and deer flies, known collectively as tabanids, are among the most annoying and aggressive blood-sucking flies that attack man and his livestock. They also act as vectors for many animal diseases such as anaplasmosis and swamp fever (equine infectious anemia), both of which are relatively common in Louisiana. In spite of their irritation and annoyance to livestock and their involvement in disease transmission, very little effort in the past has been directed toward an effective yet economical control program for these flies.

The insecticides malathion and naled (dibrom) have been used successfully in recent years for area control of adult mosquitoes by Louisiana's mosquito control districts. These materials have shown promise for tabanid control; however, the extent of tabanid control that is secondarily produced with these compounds during mosquito spraying is relatively unknown.

Adult horse flies, *Tabanus nigrovittatus*, were collected by LSU entomologists for use in insecticide trials. This species, often referred to as a salt marsh greenhead, was collected along the coastal marsh of Cameron Parish with a series of canopy traps. Trapping wild specimens was necessary because there is no established technique for colonizing any horse fly species in the laboratory.

Experimental Procedure

All captured flies were taken to the headquarters of the mosquito control district in Cameron and placed in screened tubular cages (12 x 4 inches) at the rate of 10 flies per cage. The cages were then suspended approximately 3 feet above the ground from stakes located in an open field. The stakes were aligned in rows of six stakes per row. The rows were set 50 feet apart and arranged perpendicular to the spray route.

The cages within the rows were spaced at 50-foot intervals up to 300 feet from the route of the spray truck. A distance of 300 feet is generally considered the effective swath width attainable with ultra-low-volume (ULV) sprayers when controlling mosquitoes. For the malathion test there were six rows with 12 cages in each row. For the naled test 3 weeks later there were four rows with 12 cages in each row.

Prior to the tests, the truck-mounted ULV sprayer was calibrated to deliver the appropriate dosage rate and droplet size of malathion and naled. During the tests the spray truck was driven at 15 mph along a route perpendicular to and upwind of the rows of cages. Following the tests, the cages were removed from the stakes and taken to the headquarters of the mosquito control district and the flies were checked for mortality at 1 and 6 hours post-treatment.

Tests involving naled and malathion contained 8 and 12 replications, respectively. Results were compared with those obtained with horse flies from cages that were not sprayed with insecticides.

Climatic Conditions

Uniformity of climatic conditions was also of concern during insecticide applications. For this reason tests were conducted in the late evening hours when the ground surface heat was minimal and the wind had subsided to about 5 mph. These conditions allowed the fine mist of insecticide droplets to drift relatively evenly over the test area. This is also the time of day normal operations are conducted for mosquito control by ULV spraying.

In tests using 95 percent malathion (Cythion), the insecticide flow rate from the sprayer was maintained at [illegible] ounces per minute. At this flow rate and a truck speed of 15 mph, the dosage rate of malathion was equivalent to 0.5 ounce per acre. In tests conducted with 10 percent naled, the flow rate was increased to 12 ounces per minute. At this flow rate and a truck speed of [illegible] mph, the dosage level was equal to [illegible] ounce of active ingredient per acre.

Results

As shown in Table 1, malathion consistently produced very poor mortality at 1 hour post-treatment. Although the test included 12 replicates, significant reduction of the horse fly adults was achieved as close as 50 feet to the spray route. There were instances where

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mortality did occur throughout the test arrangement, but no definite trends were established on a per-row basis. Much higher mortality was observed 6 hours after treatment with malathion.

As shown in Table 2, outstanding horse fly mortality was achieved with 10 percent naled. The effective swath width of naled applied with the ULV sprayer extended out to 300 feet from the spray route. Unlike malathion, significant reductions with naled did occur at 1 hour post-treatment and after 6 hours all treated horse flies had died.

Although more field tests with these and other compounds are scheduled, these results indicate that naled is far superior to malathion in producing high mortality of horse flies in a relatively short period of time with dosage rates commonly used for mosquito control.

The encouraging results obtained with naled in these caged tests may not be duplicated with unrestrained tabanid populations. Other ULV tests are needed to assess the effectiveness of this insecticide against horse flies under more realistic conditions. Furthermore, residual control of horse flies may not be achieved in a given area with just one swath from a truck-mounted ULV sprayer.

Because of the ability of these insects to fly long distances, the amount of acreage treated in one contiguous block will determine how quickly an area will become reinfested; consequently, the more acreage sprayed, the more time required for fly populations to return to pretreatment levels. This principle has been demonstrated regarding populations of mosquitoes attacking livestock.

Presently, no information is available concerning the time required for horse flies to reinfest an area treated with insecticides by ULV equipment. Research into this and other segments of tabanid biology is needed before organized control programs can be established.

Table 1.—Percent mortality of caged horse fly adults exposed to 95% malathion applied by ULV sprayer[1]

Distance from sprayer (ft)	% mortality: Replications 1	2	3	4	5	6	7	8	9	10	11	12	Avg. (%)
	1 hour post-treatment												
50	0	0	60	70	30	0	0	0	0	20	60	10	20.8
100	10	0	10	10	10	20	10	0	40	0	0	20	9.1
150	0	10	0	10	10	10	0	0	0	10	10	10	5.8
200	0	0	10	0	0	10	0	40	0	10	0	0	5.8
250	0	20	10	0	0	10	0	10	0	0	0	0	4.1
300	0	0	10	0	0	0	10	10	0	0	0	0	2.5
Control	0	0	0	0	0	0	0	0	0	0	0	0	0
	6 hours post-treatment												
50	90	40	100	100	100	90	70	70	70	100	100	100	85.8
100	50	90	100	90	100	100	70	50	100	100	100	80	85.8
150	30	50	90	80	50	80	90	80	80	50	90	10	65.0
200	30	60	50	80	40	30	70	80	60	60	40	30	52.5
250	90	60	80	90	80	90	70	90	0	0	80	90	68.3
300	40	60	70	90	100	90	90	60	40	60	40	90	69.2
Control	10	10	0	0	0	10	0	10	0	10	10	0	5.0

[1] Applied at rate of 0.5 ounce of active ingredient per acre.

Table 2.—Percent mortality of caged horse fly adults exposed to 10% naled applied by ULV sprayer[1]

Distance from sprayer (ft)	% mortality: Replications 1	2	3	4	5	6	7	8	Avg. (%)
	1 hour post-treatment								
50	100	100	100	100	100	100	100	100	100
100	100	100	100	100	100	100	100	100	100
150	100	100	100	100	100	100	100	100	100
200	100	100	90	100	100	100	100	100	98.7
250	100	100	100	100	100	90	100	100	98.7
300	80	80	100	90	100	60	90	80	85
Control	0	0	0	0					0
	6 hours post-treatment								
50	100	100	100	100	100	100	100	100	100
100	100	100	100	100	100	100	100	100	100
150	100	100	100	100	100	100	100	100	100
200	100	100	100	100	100	100	100	100	100
250	100	100	100	100	100	100	100	100	100
300	100	100	100	100	100	100	100	100	100
Control	0	0	0	0					0

[1] Applied at rate of 0.13 ounce of active ingredient per acre.

Mineral content...

(Continued from Page 12)

as a regular part of the mineral supplement program.

Iron content of the forage during all months (Fig. 7) was at least eight times greater than the minimum requirement. The large peak was a result of legumes present in the pastures at that time of year. Legumes tend to be high in iron content.

The copper values (Fig. 8) indicate a highly significant difference among months. Values during November, December, January and February were adequate, while those for the rest of the year fell below the requirement. This indicates that during spring and summer months copper should be included in the mineral supplement to eliminate the possibility of a deficiency.

The cobalt content (Fig. 9) appeared to be slightly higher than those reported in the literature as average values. Legumes tend to contain more cobalt than non-legumes, which is reflected in the March and April values.

Although mineral content of pastures is highly variable and is affected by many conditions, the data presented give an indication of the concentration of these minerals throughout the year. Under the conditions of this study, it was found that phosphorus, calcium, copper, zinc and possibly magnesium should be supplemented at certain periods of the year. Analyses of the forage indicated that sufficient quantities of cobalt, manganese and iron were present throughout the year.

1978 Meisch, M. V.
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(1387)

ULTRALOW VOLUME AERIAL APPLICATION OF INSECTICIDES FOR MOSQUITO CONTROL IN ARKANSAS RICELAND COMMUNITIES.[1]

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ABSTRACT. Insecticides were aerially applied by ULV to each of three 16 sq. mi. areas in Lonoke County. The center of a small town was the locus of the control zone. Insecticides used were naled at 1.0 fl. oz/acre, and malathion at 3.0 and 1.5 fl. oz/acre. An LV application of fenthion (0.1 lb ai/acre) was made to 2000 acres surrounding an additional community. The latter treatment was similar to that most commonly used over Arkansas communities. The mosquitoes in the area were primarily *Psorophora columbiae* (Dyar & Knab) with some *Anopheles quadrimaculatus* Say also present. Percentage reduction of the mosquito population was measured by light trap and landing rate. Good control was achieved for about 24 hrs with all ULV treatments except 1.5 oz. malathion. When compared to the standard LV application, the ULV technique produced very similar results. There appeared to be little difference between 3 oz ai/acre malathion and 1.0 oz ai/acre of naled.

Since the summer of 1969, entomologists at the University of Arkansas have been involved with a research-oriented pilot mosquito control program in Lonoke County, Arkansas, an area typical of many counties in the rice producing areas of the state. The primary pest mosquitoes in Lonoke County are the dark ricefield mosquito, *Psorophora columbiae* (Dyar and Knab) and the common malaria mosquito, *Anopheles quadrimaculatus* Say (Meisch and Coombes 1975). Communities in the rice country are surrounded by many rice and soybean fields along with some cotton fields. Both pest species develop very well in association with rice culture. Since ricefields are flooded intermittently throughout the growing season by each individual farmer, synchronized flights of mosquitoes do not occur except after general rainfall. Therefore, mosquito control has been initially directed at the larval stage.

For adulticiding in these towns, ultralow volume (ULV) aerosol generators are used, a technique which has proved effective in Arkansas (Mount et al. 1972). When mosquito populations are particularly heavy, aerial low volume (LV) applications of insecticides are applied. LV sprays are used because ULV equipped aircraft are not readily available in the state. Robinette, Arkansas State Health Department, reported successful mosquito control in an Arkansas rice producing area in 1970 by use of aerial ULV spraying (Personal communication). The University of Arkansas does not endorse routine widespread application of insecticide over large acreages, since the rice and soybean acreage is relatively free of insecticides. Widespread insecticide usage may create unfavorable residues, pollute the environment, and build insecticide resistant insect populations on crops that are relatively insecticide free. Although progress is being made in Arkansas mosquito control, there still exists a mosquito problem. It was deemed pertinent to undertake an experiment with aerial

[1] Approved for publication, Director, Ark. Agricultural Experiment Stations. This paper reflects the results of research only. Mention of a pesticide, commercial or proprietary product does not constitute a recommendation or an endorsement of this product by the United States Department of Agriculture. Also it does not imply registration under FIFRA as amended.

ULV insecticides to determine their effectiveness in riceland mosquito control.

MATERIALS AND METHODS

Insecticides were applied by the aerial ULV technique to the Carlisle, England, and Humnoke communities in Lonoke County. Carlisle was treated with naled (Dibrom® 14) at the rate of 1.0 fl. oz/acre. England and Humnoke were treated with 3.0 and 1.5 fl. oz/acre. of malathion (95%) respectively. The insecticides were applied over 16 sq. mi. with the center of town as the locus of the control zone. One-half of the England community treatment was made at ca 7:00–8:00 a.m. on July 1, and the remainder treated from ca 7:00–8:00 a.m. on July 2. Approximately one-half of Humnoke community was treated at 8:00–9:00 p.m. on July 2, and the remainder treated 7:00–8:00 p.m. on the same day. The Carlisle community was scheduled to receive an application of naled on approximately these dates; however, the application was cancelled due to mechanical difficulties with the aircraft. On the evening of July 30, from 7:00–8:00 p.m., Carlisle was treated with naled (Dibrom® 14) at the rate of 1 fl. oz/acre.

The England and Humnoke communities were treated with a twin engine Beechcraft 18 aircraft, while Carlisle was treated with a DC 3 aircraft. Aircraft flew at 150 mph and at an altitude of 150 feet, providing a swath of 350 feet.

Flat fan Tee Jet® nozzles (8004) at 165 psi were used for the malathion applications. Four nozzles were used for the 3 fl. oz. rate, and 2 were used for the 1.5 fl. oz. rate. Naled was applied with 4 hollow cone Tee Jet® nozzles (D-3) at 60 psi.

Temperatures for all evening tests were 80±5°F, while the morning applications were 70±5°F. Winds were predominantly southwesterly at ca 5 mph with gusts up to 10 mph during all application periods.

In addition to the ULV treatments an LV application of fenthion (0.1 lb ai/acre) was applied to 2000 acres in the Lonoke community (also in Lonoke Co.) on July 1, 1976. This application is similar to the type treatment normally performed by Arkansas communities against adult mosquitoes. Three Grumman Ag Cat #600 aircraft flying simultaneously applied the fenthion at 0.1 ai/acre in 0.5 gal of water at 65–70 psi with 14–45 nozzles from ca 6:30–7:30 p.m. on July 1. Aircraft flew at 120 mph and at an altitude of 100 ft, providing a swath of 120 ft. Of the 2000 acres sprayed, most of the area consisted of the town proper; however, some peripheral areas were sprayed, including pasture land and ricefields which bordered the city.

Mosquito populations in the treatment areas were assessed by New Jersey light traps and mosquito landing rates. Six light traps were operated within each of the towns except Humnoke where 3 traps were used. All traps were randomly spaced within city limits and therefore were in the center of the treatment zone. In addition, light traps outside the treatment zone were used as control traps. Traps were operated the night prior to treatment, the night of treatment, and 1 day and 5 days post-treatment.

Intensive landing rate data were taken on the same time schedule as the light traps. Two men took landing rates at each of the 4 towns. The men wore blue denim workshirts and trousers. Thirty-two landing rate stations were established for each community. Counts were started at the center of town and continued at each ½ mile interval for all 4 directions away from town. After going 3 miles or 6 stations, the 3.5 mile reading was omitted and a 4 mile observation taken. The east to west axis was done first, followed by the north to south. The 2 men counted the total number of mosquitoes landing on their persons for the duration of 1 minute. Counts taken for the first 4 stations from the town center were within the treatment zone (total of 17 stations), while 2.5, 3.0, and 4.0 mile readings (all 4 directions) were outside the treatment area (total of 12 stations).

The percentage reduction of the mosquito population measured by light traps and landing rates was estimated by comparing counts from within the spray zone of the communities with counts from outside the spray zone.

RESULTS AND DISCUSSION

In Humnoke, malathion at 1.5 oz/acre provided only a 40% reduction of mosquito populations as determined from the light traps on the night of treatment and 57% control 24 hrs post treatment (Table 1). After 5 days, a 62% reduction in mosquito numbers was observed; however, rain occurred on this night and doubtless influenced the data. Even poorer control was observed by landing rate monitoring. A 26% reduction occurred on the night of treatment and no control was obtained 24 hrs later. The landing rates were not taken on the 5th day due to rain.

When the malathion dosage was increased to 3.0 oz/acre and applied to the England community, a 79% reduction in mosquito numbers taken in New Jersey light traps was observed on the night of treatment. This reduction was more pronounced after 24 hrs when a 97% reduction occurred. After 5 days percentage reduction was only 66%. When landing rates were used to monitor populations, percentage reduction of mosquito numbers was 30%, 85%, and 37% respectively for the night of treatment, and 24 hrs and 5 days posttreatment. It would appear that this dosage became ineffective between 24 hrs and 5 days posttreatment.

Naled at 1.0 oz/acre reduced mosquito numbers by 89% and 92% on the night of treatment as measured by light trap and landing rate captures respectively. Landing rate data indicated a 76% reduction, and a 50% reduction occurred in the light trap captures 24 hrs and 5 days post-treatment.

Fenthion at 1.3 oz ai/acre reduced light trap captures 86% on the night of treatment, and reduced landing rate numbers 82%. This was better control than that observed by Coombes (1977, unpublished Ph.D. dissertation, University of Arkansas) who reported a 20% reduction on the night of application under similar test conditions. Light trap numbers indicated a continued good control of 80% 24 hrs post-treatment; however, landing rates were reduced by only 66%. The latter percentage is in agreement with data reported by Coombes. Five days post-treatment, light trap collections were reduced 96%, and landing rates indicated a 94% reduction when compared to the 1 day post-treatment counts. This can be explained by the fact that ULV ground equipment was used in the area at 96 and 120 hours post-treatment. The Carlisle community also operated ULV ground equipment at the same time. Since Lonoke was treated over a much smaller area (2000 acres) than the Carlisle area (10,000 acres), this might account for the better control observed at Lonoke as a smaller "buffer zone" existed.

The ULV technique did not provide long-lasting mosquito control in the test area, but good control was achieved for

Table 1. Efficacy of ultralow volume and low volume application of adulticides for mosquito control in four communities in Lonoke County, Arkansas, 1976.

	Dosage		% Reduction of Natural Populations					
			Light Traps			Landing Rates		
Compounds	(oz ai/ acre)	Location	night of treat.	24 hr.	5 days	night of treat	24 hr.	5 days
Malthion (ULV)	3.0	England	79	97	66	30	85	37
Malthion (ULV)	1.5	Humnoke	40	57	62	26	0	a
Naled (ULV)	1.0	Carlisle	89	50	50	92	76	74
Fenthion (LV)	1.32	Lonoke	86	96	96	82	66	94

[a] Rained night of monitoring, samples not taken.

about 24 hrs in all ULV treatments except 1.5 oz malathion. When compared to the typical LV fenthion treatment, the ULV techniques produced very similar results. Overall there appeared to be little difference between 3 oz ai/acre malathion and 1.0 oz ai/acre of naled.

The communities of Lonoke and Carlisle had active larvicide and ULV ground adulticide programs. England, which had a smaller larviciding program and no ULV ground adulticiding program, did not show the percentage reduction of mosquito numbers 5 days post-treatment. From these data, use of these control methods in conjunction with aerial spraying would appear to offer improved mosquito control.

Literature Cited

Meisch, M. V. and L. E. Coombes. 1975. A pilot abatement district in the rice growing areas of Arkansas. Proc. N. J. Mosq. Control Assoc. 62:190–5.

Mount, G. A., M. V. Meisch, J. T. Lee, N. W. Pierce and K. F. Baldwin. 1972. Ultra low volume ground aerosols of insecticides for control of rice field mosquitoes in Arkansas. Mosquito News 32(3): 444–46.

MOSQUITO REPELLENTS: ALICYCLIC AMIDES AS REPELLENTS FOR *AEDES AEGYPTI* AND *ANOPHELES QUADRIMACULATUS*

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ABSTRACT. Of 30 amides synthesized from 5 alicyclic carboxylic acids, 6 were highly effective repellents for *Aedes aegypti* (L.) or *Anopheles quadrimaculatus* Say when tested on cloth. 1-1(Bicyclo[2.2.1]hept-5-en-2-ylcarbonyl) hexahydro-1*H*-azepine was the most effective repellent; it provided 128 and 111 days of protection against *Ae. aegypti* and *An. quadrimaculatus*, respectively.

INTRODUCTION

In a continuing effort to find and develop improved insect repellents for personal use, USDA scientists have synthesized and evaluated large numbers of candidate materials. This effort has intensified over the past few years because of the increased importance of alternate measures for insect control. We previously reported that a number of aliphatic amides and sulfonamides derived from heterocyclic amines were highly effective repellents for the yellow fever mosquito, *Aedes aegypti* (L.), when applied to cloth (McGovern et al. 1974, 1975). We now report data for 30 alicyclic carboxamides tested as repellents against *Ae. aegypti* and *Anopheles quadrimaculatus* Say.

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MATERIALS AND METHODS

CHEMICALS. The amides were synthesized by using the standard reaction between an alicyclic acid chloride and an appropriate amine and were purified by conventional procedures. The purity of the chemicals was > 95% by gas chromatographic analysis.

MOSQUITO REPELLENCY TESTS. Tests

1978 Mount, G. A., N. W. Pierce, K. F. Baldwin and F. Washington
Control Of Aedes Taeniorhynchus At Crescent Beach, Florida, With Aerosols Of Propoxur (Baygon® Mos) And Naled (Dibrom® 14)
Mosquito News 38: 54-56 (Amvac Ref. #1389)

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CONTROL OF *AEDES TAENIORHYNCHUS* AT CRESCENT BEACH, FLORIDA, WITH AEROSOLS OF PROPOXUR (BAYGON® MOS) AND NALED (DIBROM®$_{14}$)[1]

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ABSTRACT. Field trials with ultralow volume ground aerosols against native infestations of the black salt-marsh mosquito, *Aedes taeniorhynchus* (Wiedemann), showed that propoxur (Baygon® MOS) (*o*-isopropoxyphenyl methylcarbamate) was about equal to a naled standard (10% Dibrom®$_{14}$ in heavy aromatic naphtha) (1,2-dibromo-2,2-dichloroethyl dimethyl phosphate) The percentage control of the native mosquito population determined on the basis of human landing counts was about equal to the mortality of caged mosquitoes of the same species.

Alternate adulticides are needed to control *Aedes taeniorhynchus* (Wiedemann) in Florida that are resistant to malathion (diethyl mercaptosuccinate *S*-ester with *0,0*-dimethyl phosphorodithioate) (Seawright and Mount 1975). Previous laboratory wind tunnel tests by Mount et al. (1974) indicated that both naled (1,2-dibromo-2,2-dichloroethyl dimethyl phosphate) and propoxur (*o*-isopropoxyphenyl methylcarbamate) were equally effective against malathion-susceptible and -resistant strains of species of mosquitoes. Naled is currently registered by EPA for control of adult mosquitoes as 10% Dibrom®$_{14}$ diluted in heavy aromatic naphtha (HAN). This formulation of naled was tested against native infestations of malathion-resistant *Ae. taeniorhynchus* in the Florida Keys (Mount and Pierce 1974) and was compared with propoxur in tests at Crescent Beach, Florida. At the present time, propoxur is not registered for ultralow volume (ULV) aerosol use against adult mosquitoes. Also, aerosol tests of a Baygon® MOS (Mosquito Oil Spray) formulation of propoxur against caged adult female *Ae. taeniorhynchus* and *Anopheles quadrimaculatus* Say have been reported by Mount et al. (1975a).

During August and September of 1975 we made additional tests of aerosols of undiluted Baygon MOS and 10% Dibrom$_{14}$ in HAN against native infestations and laboratory-reared caged specimens of *Ae. taeniorhynchus* at Crescent Beach. Our objectives were to determine the effects of propoxur and naled aerosols against *Ae. taeniorhynchus* in a residential area on the coast of Florida and to compare the control of the native population with the mortality of caged adult females of the same species.

METHODS AND MATERIALS. The test site was the old residential section of Crescent Beach between the Intracoastal Waterway and Highway AIA. This area was chosen because it is representative of many residential areas along coastal Florida where aerosols are used as a supplement to source reduction and larviciding for control of salt-marsh mosquitoes. This section of Crescent Beach consists of ca. 50 acres that is normally treated with adulticides by the St. Johns Mosquito Control District.

The aerosols were applied by moving a truck-mounted aerosol generator over a network of streets and private roads that

[1] This paper reports the results of research only. Mention of a pesticide in this paper does not constitute a recommendation for use by the USDA nor does it imply registration under FIFRA as amended. Also mention of a commercial or proprietary product in this paper does not constitute an endorsement of this product by the USDA.

made up a total of ca. 2 miles. The application time was ca. 25 min, when the truck speed was 5 mph. This low truck speed was used because the private roads in the test area were very narrow and contained several sharp curves. Complete coverage was difficult because of erratic street spacings, shifting winds, and dense vegetation in some portions of the area.

A Leco® HD aerosol generator was used to disperse the adulticide formulations. The instrument panel for the generator was mounted in the cab of the dispersal truck so that liquid flow rate, liquid temperature, and nozzle air pressure could be monitored during application. The flowmeter was calibrated just before each application so the formulations could be applied at ca. the same temperature. Furthermore, the volume of each formulation was measured before and after each application to determine the actual amount applied. Nozzle air pressures used for Baygon MOS and 10% $Dibrom_{14}$ in HAN were 4 and 1.5 psi, respectively, since Mount and Pierce (1972) and Mount et al. (1975b) determined that the droplet sizes were 14 and 15 μm volume median diameter when the materials were atomized at these pressures.

The native infestations of salt-marsh mosquitoes were estimated by making landing counts on humans at 12 stations immediately before and 45 min after each treatment. These counting stations were selected on the basis of favorable mosquito habitat and were fairly well-distributed throughout the test area. Four additional stations were established in an untreated area just west of the Intracoastal Waterway and ca. 1.5 miles from Crescent Beach; counts were made therefore to determine any variations in density of salt-marsh mosquitoes due to natural causes. Also, adult female *Ae. taeniorhynchus*, 3–5 days old, from our OP-susceptible laboratory colony were placed in cages (25/cage) and hung 2–4 ft above the ground on shrubs and trees (which gave them some protection from the spray) at each of the counting stations. The cages were put in position just before each application and removed 45 min posttreatment. Before and after the exposure, the caged mosquitoes were protected in insulated chests containing moist cotton and canned ice, and after each test, they were returned to Gainesville and held for 24-hour mortality observations. Cages of mosquitoes placed at the counting stations in the untreated area were handled in exactly the same manner.

RESULTS AND DISCUSSION. The pretreatment counts showed a mean number of mosquitoes per plot of 74, indicating a relatively light density. Application data and test results are presented in Table 1. Percentage control of the native mosquito population was adjusted for variations in

Table 1. Efficacy of ground ULV aerosols against *Aedes taeniorhynchus* at Crescent Beach, Florida, 1975. Aerosols applied at 5 mph with a Leco HD generator operated at 4 psi for propoxur (Baygon MOS) and 1.5 psi for naled (10% $Dibrom_{14}$ in HAN).

Flow rate (fl oz/min)	Dose (lb AI/acre) Assumed (300 ft swath)	Actual	No. of tests	Percentage control* of native population	Percentage mortality of caged mosquitoes
		Baygon MOS (1 lb AI/gal)			
4.75	0.012	0.02	3	56	59
9.5	.024	.038	2	72	70
		10% $Dibrom_{14}$ in HAN (1.4 lb AI/gal)			
6	.02	.033	3	85	65

* Percentage control $= 100 - \left(\frac{\%\text{ of pretreatment in treated area}}{\%\text{ of pretreatment in untreated area}} \times 100\right)$.

density in the untreated area, which had a mean increase of 21%. The percentage mortalities of the caged mosquitoes were not adjusted since untreated caged mosquitoes had a mean mortality of only 2%.

The 4.75 fl oz/min flowrate of Baygon MOS at 5 mph dispersal speed was inadequate. The higher rate of Baygon and the treatment with 10% $Dibrom_{14}$ in HAN gave relatively low percentage control and percentage mortality (65–85%, respectively). However, these rates provided complete control and mortality at many count stations: The mean was low because of poor coverage at several stations attributable to very dense vegetation and/or shifts in the wind direction during application.

Overall, there was close agreement between percentage control of the native population of *Ae. taeniorhynchus* as determined by landing counts and percentage mortality of caged adult females of the same species (Table 1). However, the correspondence was closer with Baygon MOS than with $Dibrom_{14}$. We do not have a logical explanation for this difference and assume that it is caused by experimental error. Since Mount et al. (1974) showed that both propoxur and naled provided rapid knockdown of *Ae. taeniorhynchus* in laboratory aerosol tests, knockdown rate would not explain the 20% difference with $Dibrom_{14}$.

References Cited

Mount, G. A. and N. W. Pierce. 1972. Adult mosquito kill and droplet size of ultralow volume ground aerosols of insecticides. Mosquito News 32: 354–357.

Mount, G. A. and N. W. Pierce. 1974. Ultralow volume ground aerosols of naled for control of *Aedes taeniorhynchus* (Wiedemann) in the Florida Keys. Mosquito News 34: 268–269.

Mount, G. A., J. A. Seawright and N. W. Pierce. 1974. Selection response and cross susceptibility of a malathion-resistant strain of *Aedes taeniorhynchus* (Wiedemann) to other adulticides. Mosquito News 34: 276–277.

Mount, G. A., N. W. Pierce and K. F. Baldwin. 1975a. Ultralow volume ground aerosols of propoxur (Baygon® MOS) for control of adult mosquitoes. Mosquito News 35: 490–492.

Mount, G. A., N. W. Pierce and K. F. Baldwin. 1975b. Comparison of two aerosol generator nozzle systems: estimates of droplet size and caged mosquito assays. Mosquito News 35: 501–503.

Seawright, J. A. and G. A. Mount. 1975. Inheritance of malathion resistance in *Aedes taeniorhynchus* (Wiedemann). Mosquito News 35: 365–371.

1978 Sutherland, D. J., R. Kent and J. Downing
The Effect Of Aerial ULV Adulticiding With Malathion And Naled On Field Populations Of Aedes Sollicitans
Mosquito News 38: 488-491 (Amvac Ref. #1390)

THE EFFECT OF AERIAL ULV ADULTICIDING WITH MALATHION AND NALED ON FIELD POPULATIONS OF *AEDES SOLLICITANS*[1]

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ABSTRACT. Malathion and naled were applied as aerial ULV, and their effect on field populations of *Aedes sollicitans* (Walker) was studied. The application rate for malathion 91% was 219 ml/ha (3 oz./a) and for naled (Dibrom 14) 73 ml plus 146 ml heavy aromatic naphtha/ha (1 oz. plus 2 oz./a). Fifty separate applications were made, approximately 1600 ha (4000 a) per application. The effect on field populations was variable with a decrease in reduction levels over the 3 days post treatment. Based on actual mosquito landing counts malathion provided a more extended depression of populations. However, areas receiving naled application contained greater mosquito populations prior to treatment which prevents absolute comparison between the two insecticides.

INTRODUCTION

ULV adulticiding by aircraft is a control technique employed by many mosquito control agencies. Much of the research on the technique has depended on the use of caged mosquitoes. While this is a convenient test method, caging has 2 disadvantages in that (1) it confines the insect and may stimulate activity thereby causing increased droplet impact on the mosquitoes or (2) some droplets can impinge on the screen thereby reducing the numbers of droplets reaching the mosquitoes. In practical mosquito control caged mosquitoes can be of value in judging the ULV application itself. However, in order to seek ways to improve the efficiency of ULV adulticiding as well as justify its value as a control procedure, it becomes necessary to study its effect on natural mosquito populations. During 1977 the New Jersey State Airspray Program treated approximately 81,000 hectares (200,000 acres) with malathion and naled for the control of adult *Aedes sollicitans* (Walker). The purpose of this report is to describe the effect of such measures on field populations of this mosquito.

MATERIALS AND METHODS

The acreage treated was located in the shore counties of New Jersey, close to the salt marsh breeding habitat. Fifty individual airspray applications were conducted with an average of 1600 hectares (4000 acres) per application. Two-thirds of the applications used naled; one-third used malathion. Sites treated included mixtures of forest and field with sparse shrub and ground cover. Although caged mosquitoes were employed, major data gathered consisted of landing counts (numbers of mosquitoes landing per min), taken daily 3 days before and 3 days after an application. The data from the 3rd and 2nd day before the spray were used to justify the need for and timing of adulticiding. A total of 2400 landing counts were taken at an average of 8 sites within each area treated. Additional information was obtained from untreated areas. Data were analyzed on the basis of percent reduction and also actual landing counts.

The application aircraft was a twin-engine Piper Aztec, capable of application speed of 150 mph using 8–14 nozzles (size ranging from 80015 to 8005) at

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40–50 psi. The insecticides were applied at the following rates: malathion 91% at 219 ml/hectare (3 oz/acre), naled (Dibrom 14) 73 ml plus 146 ml heavy aromatic naphtha/hectare (1 oz Dibrom 14 plus 2 oz HAN/acre). We have found that naled topically applied to adult mosquitoes is approximately 3 times as toxic as malathion. For field application we dilute naled to increase the droplet numbers and to reduce the corrosive properties of naled.

RESULTS AND DISCUSSION

Figure 1 is a summary chart of information collected from the 50 applications. Data have been transposed into the percent decrease or increase in mosquitoes landing per min on days 1, 2, 3 post treatment as compared to the day before application. Categories established for such decrease or increase are 100–80, 80–60, 60–40, 40–20, 20–0 percent. The frequency that these categories occurred on day 1, 2 and 3 after treatment is indicated at the left of the chart. The percent reduction or increase occurring after the 50 applications was so highly variable that no statistically significant differences between insecticides on such a basis could be found. However, a closer examination of Figure 1 does reveal certain important points: (1) the effect on field populations was highly variable as expected, but sometimes an actual increase (reinfestation) of

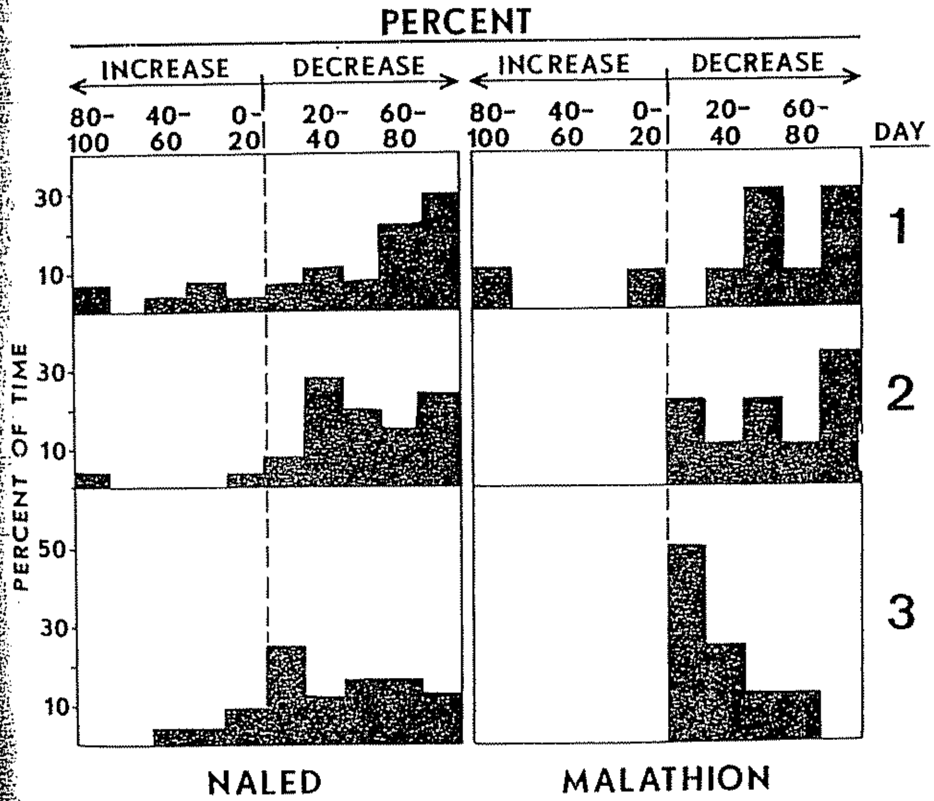


Figure 1. The frequency of various levels of increase or decrease of field populations of *Ae. sollicitans* during the 3 days after aerial ULV treatment with malathion and naled.

mosquitoes occurred in areas treated with either insecticide, (2) as expected with non-residual insecticides there is a general decrease over the 3 days of post treatment in the level of reduction, (3) on day 1 a higher frequency of upper reduction categories was evident after naled application, and (4) malathion always provided some level of reduction on the 2nd and 3rd days after application.

Data from which Figure 1 was derived are further summarized in Table 1, with numerical figures for the frequency (percent of time) when mosquito populations increased, decreased, and the decrease amounted to over 40% and over 60%. Both insecticides performed about equally on the basis of frequency of any level of reduction or increase on the 1st day after application. Frequency of the higher category of reduction (> 60%) was greater with naled. However, malathion on day 2 and 3 provided some level of population reduction. The droplet size of the malathion ULV was determined to be greater than that of naled, which could have enhanced malathion impact and residues on vegetation.

Since differences between insecticides could not be detected on the basis of percent reduction and increase of populations, subsequently all landing count data were transformed using $\sqrt{X}$ to reduce variability within plots (Zar 1974). The results of the ANOVA are given in Fig. 2. Significant differences ($P < .05$) occurred in landing counts in areas before treatment as well as on the 2nd and 3rd day after treatment. Areas selected for treatment with naled did have higher populations before treatment, and, therefore, naled was challenged to a greater degree than was malathion. One day after spraying, both insecticides had reduced populations to the same level. However, on days 2 and 3 post spray, landing counts in malathion-treated areas continued to decline while those in naled-treated areas rose. While the differences exceed those before treatment, it may still be argued that the insecticides were not equally challenged by the same population levels, environmental factors and conditions. Based on the use of caged mosquitoes during these studies, naled as applied in dilute form did penetrate canopied areas much better than did malathion, probably due to its smaller droplet size. However, while naled has the property of rapid knockdown, there was some indication of recovery from such knockdown.

The long flight range of *Ae. sollicitans* and its involvement in the transmission of eastern encephalitis (Crans 1977) make this species important in many areas. Current studies involving adulticiding of field populations of this mosquito indicate that ULV is a useful control measure, however variable, incomplete and temporary. Of great value is the knowledge derived from the studies that such adulticiding in 1977 reduced mosquito populations

Table 1. Percent of time during each of 3 days after aerial adulticiding when an increase or reduction in mosquitoes occurred, 1977.

		Percent of time			
Insecticide	Day	Increase occurs	Reduction occurs	Reduction >40%	Reduction >60%
naled	1	22.2	77.7	59.2	51.8
	2	8.0	92.0	56.0	36.0
	3	16.6	83.4	45.9	29.2
malathion	1	20.0	80.0	70.0	40.0
	2		100	66.7	44.4
	3		100	25.0	12.5

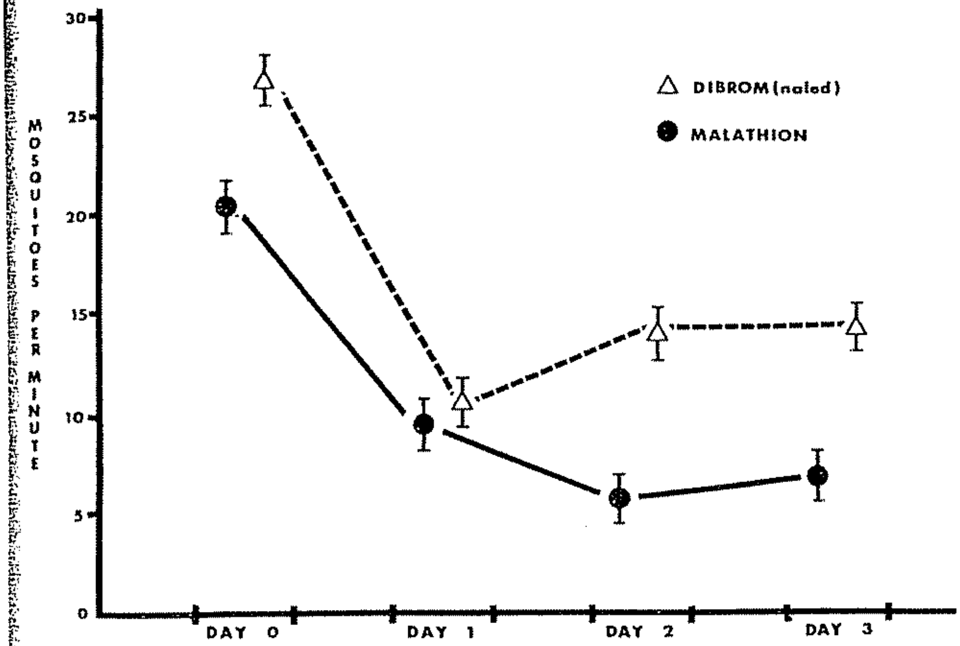


Figure 2. Mean landing counts (numbers of mosquitoes landing per min ± confidence intervals, $P < .05$) in areas 1 day before treatment (day 0) and 3 days after treatment with malathion and naled.

and provided relief to citizens and visitors 87% of the time during the 3 days post spray. This figure is useful in seeking to improve the efficiency of adulticiding and also to defend its value to the public.

ACKNOWLEDGMENTS

We wish to thank Mrs. Judy Hansen, Brian Gooley, Fred Lesser, Robert Ostergaard, and Patrick Slavin, Superintendents of County Mosquito Extermination Commissions for their valuable assistance in the New Jersey Airspray Program supported by the New Jersey Mosquito Control Commission.

References Cited

Crans, W. J. 1977. The status of *Aedes sollicitans* as an epidemic vector of eastern equine encephalitis in New Jersey. Mosquito News 37:85–89.

Zar, J. H. 1974. Biostatistical analysis Prentice-Hall, Inc. N. J. 620 pp.

1978 Altman, R.
Maryland Uses Naled Against Salt March Mosquitoes
Pest Control 14-18 (Amvac Ref. #1423)

(1423)

Maryland Uses Naled Against Salt Marsh Mosquitoes

Picture 250,000 acres of salt marsh country, flat, wet, humid grassland. The Atlantic Ocean is on one side and the Chesapeake Bay on the other. Finger-like inlets carve into the long stretch of jagged coast, forming scores of bays and peninsulas.

For the people of Maryland, the salt marsh country along the Chesapeake Bay provides recreation and beauty. Last summer it provided something else, however. A spell of warm March weather and a wet spring brought swarms of mosquitoes; mosquitoes so large and numerous that many Maryland residents were literally "locked" into their homes. What began as a nuisance grew into a health hazard, and the Maryland State Department of Agriculture had to move fast to abate the problem.

"It was pretty bad, to the point that it was very uncomfortable for the people who were trying to enjoy the bay," said Department of Agriculture entomologist Cyrus Lesser. "They were more or less held prisoner in their homes."

The State Department of Agriculture decided that an aerial application of an adulticide was needed. The state picked up the tab for one $10,000 aerial application of malathion ULV; for a while it provided relief from the bloodthirsty biters. But the adulticide didn't affect the unhatched eggs or the larvae in the marshes, and within two weeks Maryland residents near Deale Island were exposed to another brood that was described as "worse than ever."

To top it all off, the State Department of Agriculture had some qualms about spraying a mosquito insecticide near the bay area because they were afraid toxicity levels in the chemical could harm fish and other non-target species.

Want long-range solution now

Entomologists in the Pest Management Section-Mosquito Control Division of the Maryland Department of Agriculture were faced with a two-sided problem.

Number one — they needed some urgent relief from the swarms of mosquitoes. "Local residents were becoming quite vocal about it," Lesser said. And to make the matter worse, the type of mosquito that was infesting the area was *Aedes sollicitans*, or the salt marsh mosquito, a vicious biter. As well as being a nuisance, it has the vector potential of carrying Eastern Equine Encephalitis (EEE) — a dangerous disease with roughly a 60 percent mortality rate in humans, who become infected.

"EEE is endemic in the wild bird population on the eastern shore of Maryland," Lesser said. "It occurs only sporadically in humans, and an outbreak of this disease was very unlikely at that time of year, so there wasn't a drastic alarm. If it does infect a human, it attacks the central nervous system."

And the number two consideration — the Department of Agriculture couldn't treat the heart of the mosquito area with a persistent or highly-toxic insecticide. Their first aerial application with the adulticide was around the edge of the marshland, where state officials believed it wouldn't harm non-target species. That, in part, explained why the mosquitoes reappeared in only two weeks. This particular species of mos-

continued on page 16

Robert Altman, PhD, Maryland Department of Agriculture, communicates with a plane, which was treating the mosquito-infested Chesapeake Bay marshes.

MOSQUITOES *from page 14*

quito is a strong flier and females are capable of moving several miles in search of a blood meal.

Lesser explained that they needed an effective insecticide they could use wherever the mosquitoes were causing an annoyance or public health problem throughout the bay country. To do that they needed an insecticide that would meet the low-toxicity requirements of the Maryland Department of Fisheries and Wildlife.

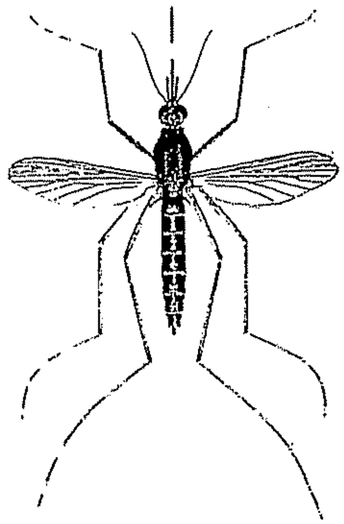
Demonstration Test Conducted

Maryland entomologists first took their problem to the University of Delaware, where extensive research with insecticides for mosquito control has been done by entomologist Dr. Frank Murphey and Bob Lake. It was then decided that a possible solution was naled (Dibrom), an insecticide produced by Chevron Chemical Company. Naled is competitive with other mosquito adulticides in effectiveness, and the Maryland entomologists felt that its toxicity level would meet the needed requirements.

Chevron took an interest in the project at that point and provided the Maryland officials with enough naled to treat spray 640 acres by air. That initial application was done as a test in cooperation with the Maryland Department of Natural Resources to determine the effect of naled on selected non-target species in Chesapeake Bay marshes.

Dr. Robert Altman, head of the Pest Management Section of the Maryland Department of Agriculture organized the test. In this demonstration, non-target specimens (some of which included the eastern oyster, mussels, fiddler crab, blue crab, grass shrimp, mallard ducks, and two kinds of small top-feeding fish) were caged, within the treated area. Ten identical non-target specimens were also caged as a check group in an area where naled wasn't being applied, so a comparison could be made later.

continued on page 18

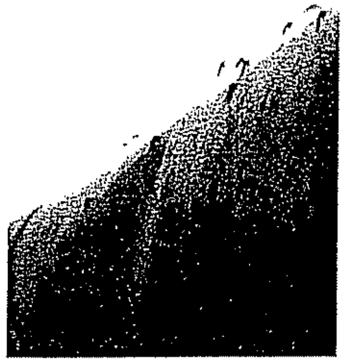


Aedes sollicitans **menaced residents of Chesapeake Bay and is a possible carrier of Eastern Equine Encephalitis. Drawing from Mosquitoes of North America, University of California Press, 1955. Drawing by Saburo Shibata.**

MOSQUITOES *from page 16*

The initial application of naled for this test was done with a single-engine airplane. The insecticide was released at a rate of only one fluid ounce per acre, being applied with the ultra low volume (ULV) method. Lesser said the Department of Agriculture contracted a local aerial applicator to do the application. He added that people at the test site could see the material falling to the ground, even though it was being applied at the low-volume rate.

Chevron representatives report that with this method, factors such as wind speed and temperature are critical to the effectiveness of the insecticide. During this test, wind conditions were considered marginal (7-10 miles per hour less would have been better), but the insecticide still made better than an 80 percent kill on mosquitoes. Cool temperatures are also desirable, such as during early morning or evening hours. As the ground heats up, wind currents pick up and warm air rises, and consequently many of the mosquitoes don't contact the insecticide on warm days.



Heavy infestation, evidenced by these mosquitoes on a tarp, kept Maryland residents locked in their homes

"We felt even before the test that naled would be environmentally acceptable due to the research done previously," Lesser said. "And, as the test proved, the mortality rate of non-target species was the same in both the test and check areas, proving that the naled had no ill-affect on these species."

The success of this demonstration prompted the Maryland State Department of Agriculture to treat an additional 43,000 acres in June. July was an unusually dry month along the eastern shore, so mosquito populations naturally dropped. But in August state officials treated an additional 1,200 acres on one date. They said at that point they might have to apply more during the early fall months because of August rains.

Despite the need to continue spraying, state entomologists in Maryland are convinced they have a solution to their kind of mosquito problem. "Right now, the future looks pretty good for mosquito control in Maryland," Lesser said. "I think people now realize that mosquito control is more than a luxury. It's a necessity for health reasons."

1977 Dukes, J. C. and R. C. Axtell
Chemical Control Of Coastal Biting Flies And Gnats
Proceedings of the New Jersey Mosquito Extermination Association 62: 232-233 (Amvac Ref. #1382)

1977
62:232-233

(1382)

Aerosol machines have proven their worth in terms of rapid knockdown of invading populations of mosquitoes which enter urban areas in California from irrigated farming, drainage and other standing water situations. To treat an entire area is possible by aircraft, but prohibitively expensive on any but an emergency situation. Thus, the ground aerosol machine serves a definite purpose in protecting urban dwellers from mosquitoes. Concerns for operators and urban dwellers exposed to toxic aerosols are another point for consideration in the use of aerosols. The low levels of application and generally dissipation of the aerosol on low wind movement precludes any significant exposure to nearby dwellers, but protection for the operators must be seriously considered in these applications. Under inversion weather conditions the aerosol held close to the ground is most effective in controlling mosquitoes, but also provides the greatest time exposure time before being dissipated. Since inversions occur usually in the early evening and continue all night, it might be considered desirable to operate in the early morning hours when the change to turbulent mixing weather after the sun rises will terminate the aerosol exposure period. For longest exposure, however, applying in the evening would be best. Considerations for local conditions will have to be made in such decisions as this.

CHEMICAL CONTROL OF COASTAL BITING FLIES AND GNATS

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ABSTRACT

Tests were conducted on three major pest species of tabanid flies (*Chrysops atlanticus*, *C. fuliginosus*, and *Tabanus nigrovittatus*) to determine the degree of control that might be expected from mosquito adulticides applied as ULV aerosols from a truck-mounted Leco ULV-HD machine. Tabanid flies (35-50 per cage) were placed 5 ft above ground at 50, 100, 150 ft perpendicular to and down wind from the path of the machine traveling at 10 mph. Each test was replicated 3 times with replicates placed 10 yards apart. Controls were treated similarly but placed upwind from

the treatment. The 5% pyrethrin (synergized with 25% piperonyl butoxide) gave the fastest knockdown and kill of the biting flies. However, many flies recovered from the immediate effects. For more effective control, 8 or more ounces per minute at 10 miles per hour is needed. Malathion (95%) gave little immediate knockdown and mortality but after three or more hours 100% mortality was sometimes achieved at 4.3 ounces per minute. Chlorpyrifos (61.5%) was slow acting and rates of 3 or more ounces per minute appear to be needed. Naled (10%) was moderately fast acting and, although results were variable, often gave 90% or better control at 12 ounces per minute. These results indicate that higher dosages are needed for effective tabanid control than are currently registered for mosquito adulticiding operations.

Insecticide-treated screens were tested for control of sand flies (*Culicoides furens*). Conventional 16 by 18 mesh window screening was cut into discs, immersed into various concentrations (water dilutions) of insecticides, and hung outdoors beneath the eaves of a dwelling for weathering. The dilutions of insecticides were prepared from a wettable powder of propoxur and from emulsifiable concentrates of the other chemicals. Test chambers were made from 2 pint-size cardboard containers sealed end to end with the treated screen separating them. One end of the test chamber was replaced with clear acetate. Gnats placed into a temporary opening in the dark end quickly migrated through the treated screen toward the light where they remained and their mortality was determined. Fiberglass screen did not retain insecticide residues as well as the aluminum screen. Gardona* and dimethoate were less effective than the other chemicals tested. Dichlorvos at both 5% and 8% gave excellent control after weathering only 1 day but was ineffective after additional weathering. Malathion and propoxur at 8% gave better than 90% mortality for at least 28 days. Propoxur gave more rapid knockdown results but the wettable powder formulation left an unsightly white residue on the screen. These data suggest that monthly applications of either malathion or propoxur at 8% to the window screens should aid in relief from *Culicoides* sand flies within a dwelling.

1977 Moseley, K., J. Mullenix, and R. T. Taylor
Organophosphorous Resistance In The Memphis, Tennessee, Culex Pipiens Complex
Mosquito News 37: 271-275 (Amvac Ref. #1383)

ORGANOPHOSPHOROUS RESISTANCE IN THE MEMPHIS, TENNESSEE, *CULEX PIPIENS* COMPLEX

KELLY MOSELEY,[1] JAKE MULLENIX[1] and ROBERT T. TAYLOR[2]

ABSTRACT. Organophosphorous resistance was confirmed in *Culex pipiens* complex mosquitoes from Memphis, Tennessee. Field and laboratory studies with fenthion, malathion, naled, and resmethrin gave comparative results. Birmingham *Culex pipiens quinquefasciatus* were tested in the laboratory against the same 4 compounds and found to be susceptible to all. The organophosphorous compounds resulted in approximately 30% kill of laboratory and field specimens from Memphis at the highest dosage level. One hundred percent kill of Birmingham *Culex p. quinquefasciatus* was recorded at the same dosage levels in the laboratory. Both *Culex* spp. were susceptible to resmethrin.

INTRODUCTION

Ineffective control of mosquitoes of the *Culex pipiens* complex with ground ultra-low-volume (ULV) malathion applications was first suspected by the Memphis and Shelby County Health Department during the 1975 season. The St. Louis encephalitis epidemic during that year made it imperative that an evaluation of the effectiveness of malathion and other compounds registered for use in ULV equipment be initiated. Field studies were carried out in Memphis during August-September 1976 while laboratory studies were being completed in Atlanta with freshly colonized mosquitoes of the *Culex pipiens* complex from Memphis, Tenn., and Birmingham, Ala.

MATERIALS AND METHODS

FIELD STUDIES. Fenthion, malathion, naled, and resmethrin were the compounds studied. In testing each compound, 25 field-collected adult female mosquitoes from within the City of Memphis were placed in each of 12 clean screen-wire cages and held in plastic bags at 72°F prior to treatment. Five percent sugar-water cotton pads were placed on each cage during holding. Control cages were handled in the same manner and transported to and from the test site. Three cages from outside the City in Shelby County were prepared for the malathion test, two for the treatment and one as control. The caged mosquitoes were placed on 6-ft stakes at stations 75, 150, and 300 ft from the point of discharge in all tests but the malathion test, where only 150- and 300-ft stations were used. Three stations with one cage each were placed at 100-ft intervals at each distance from the point of discharge. Temperature, humidity, and wind velocity were monitored at the test site. Percent kill was determined at 12 and 24 hr for the organophosphorous tests, and 12 hrs for the resmethrin tests.

Test runs were up to 1/3-mile long at vehicle speeds of from 5 to 10 mph. Approximately 30 min after exposure the cages were removed, replaced in plastic bags, and returned to the holding area. Fenthion (93%), malathion (95%), and naled (10%) were dispensed at 0.9, 3.8, and 9.27 fluid ounces per minute, respectively. These flow rates delivered 0.013, 0.0713, and 0.0152 lb actual insecticide pounds per acre, respectively. Resmethrin (10%) was dispensed at 10.52, 9.08, and 6.53 fluid ounces per min delivering, respectively, 0.007, 0.0035, and 0.0025 pounds per acre. All applications were done with a truck-mounted Leco HC ULV Fog Generator.[3]

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[2] Vector Biology & Control Div., CDC, Atlanta, Ga. 30333.

[3] Use of trade names and commercial sources are for identification only and do not constitute endorsement by the Public Health Service or by the U.S. Department of Health, Education, and Welfare.

LABORATORY STUDIES. Mosquitoes of the *Culex pipiens* complex from the city of Memphis, from outside the city in Shelby County, and from Birmingham, Ala., were colonized in the laboratories of the Vector Biology and Control Division, Bureau of Tropical Diseases, Center for Disease Control, Atlanta, Ga. Twenty male genitalia from each of the Memphis and Birmingham colonies were prepared and examined for subspecies identification using Barr's techniques (Barr 1957). The colonies were maintained on chicken blood.

A modified Hoskins-Caldwell Spray Chamber described by McCray and Schoof (1963) was used in these studies. The DeVilbiss No. 631 Atomizer used with 10 lb air pressure produced droplets in the throat of the chamber with a mass median diameter (mmd) of 12 microns. The four insecticides under study were dissolved in ethanol, 85 parts; glycerol, 15 parts, and further diluted with this ethanol-glycerol combination into concentrations of 0.05%, 0.025%, 0.01%, 0.005%, and 0.0025%.

Approximately 50 three-day-old adult female mosquitoes were placed in pint ice cream cartons which were screened on both ends. Three replicates per dosage, 3 checks, and 3 controls were prepared for each test. Carbon dioxide was used to anesthetize the mosquitoes for transfer. The checks were prepared in pint cartons as were the other mosquitoes, then anesthetized and transferred into clean holding cages and placed in the holding room. Following the controls which were treated with ethanol: glycerol only, each carton of mosquitoes was treated beginning with the low dosage and continuing to the high dosage. Each carton of mosquitoes was inserted in the throat of the chamber and exposed for 30 sec to 2 ml of the aerosol. After exposure and transfer to clean cages, the mosquitoes were given 5% honey-water cotton pads and held at 75°F for 24-hr mortality counts. The Shelby County mosquitoes were tested as 4-day-olds and 14-day-olds and only against malathion.

RESULTS

FIELD STUDIES. The results of field studies in Memphis are presented in Table 1. Of the organophosphorous compounds tested, naled gave the highest kill which was only 37% in field-collected mosquitoes. Mosquitoes from outside the city which were tested only with malathion were quite susceptible, however, with 82% kill at both stations. Resmethrin at all 3 dosage levels was 79 to 99% effective in these tests. Temperatures averaged 71.5°F, relative humidity 68.5%, and wind velocity 6.8 mph. Mortality in the checks averaged 2% with a range of 0–7%.

LABORATORY STUDIES. Subspecies identification of specimens from the Memphis colony showed that 40% of those examined were *Culex pipiens* hybrids, 30% were *C. p. pipiens*, and 30% were *C. p. quinquefasciatus*. All of the Birmingham mosquitoes were *C. p. quinquefasciatus*.

Table 1. Field studies of four compounds against mosquitoes of the *Culex pipiens* complex, Memphis, Tenn., 1976.

Compound	Fl. oz./min.	Replication	Percent female mortality (24-hour period)		
			75 ft.	150 ft.	300 ft.
fenthion	0.90	3	20	8	10
malathion (city)	3.80	4	–	21	32
malathion (Shelby County)	3.80	1	–	82	82
naled	9.27	3	21	25	37
resmethrin	6.53	3	79	98	85
resmethrin	9.08	3	99	87	84
resmethrin	10.52	3	97	98	99

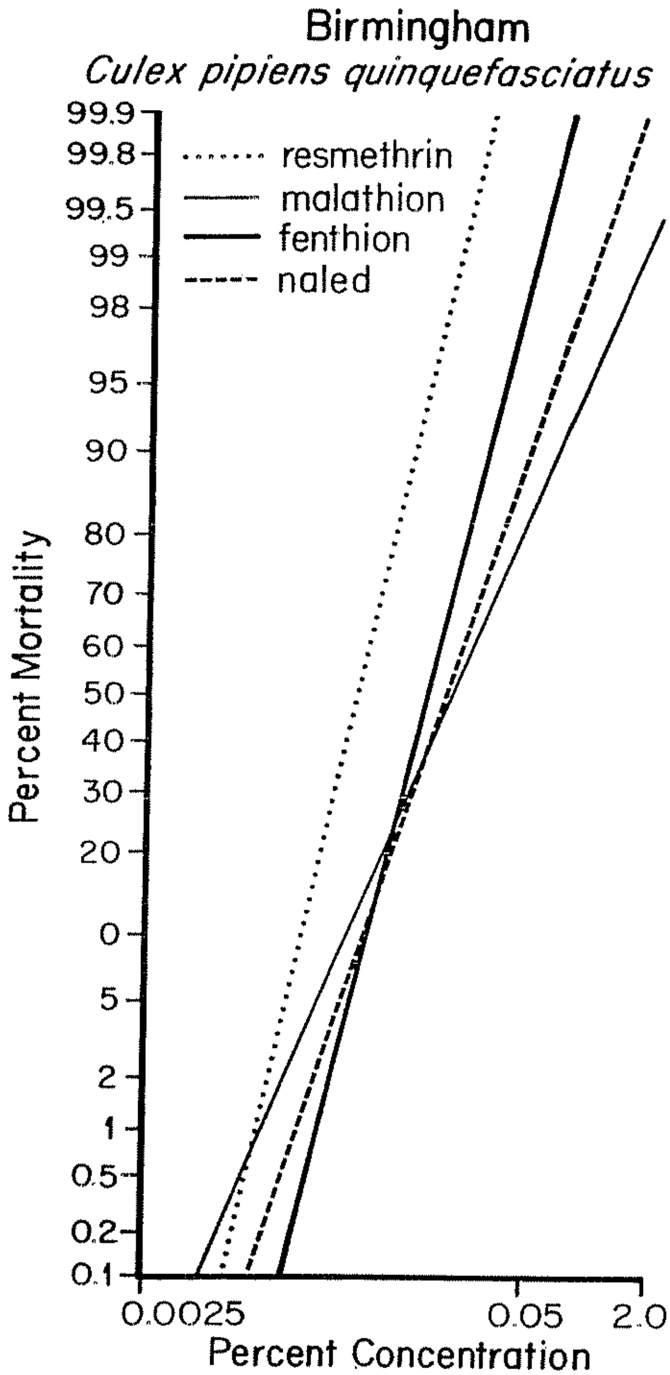

Fig. 1. Dosage-mortality regression line for four space-spray adulticides in laboratory applications against female *Culex pipiens quinquefasciatus* colonized from Birmingham, Ala.

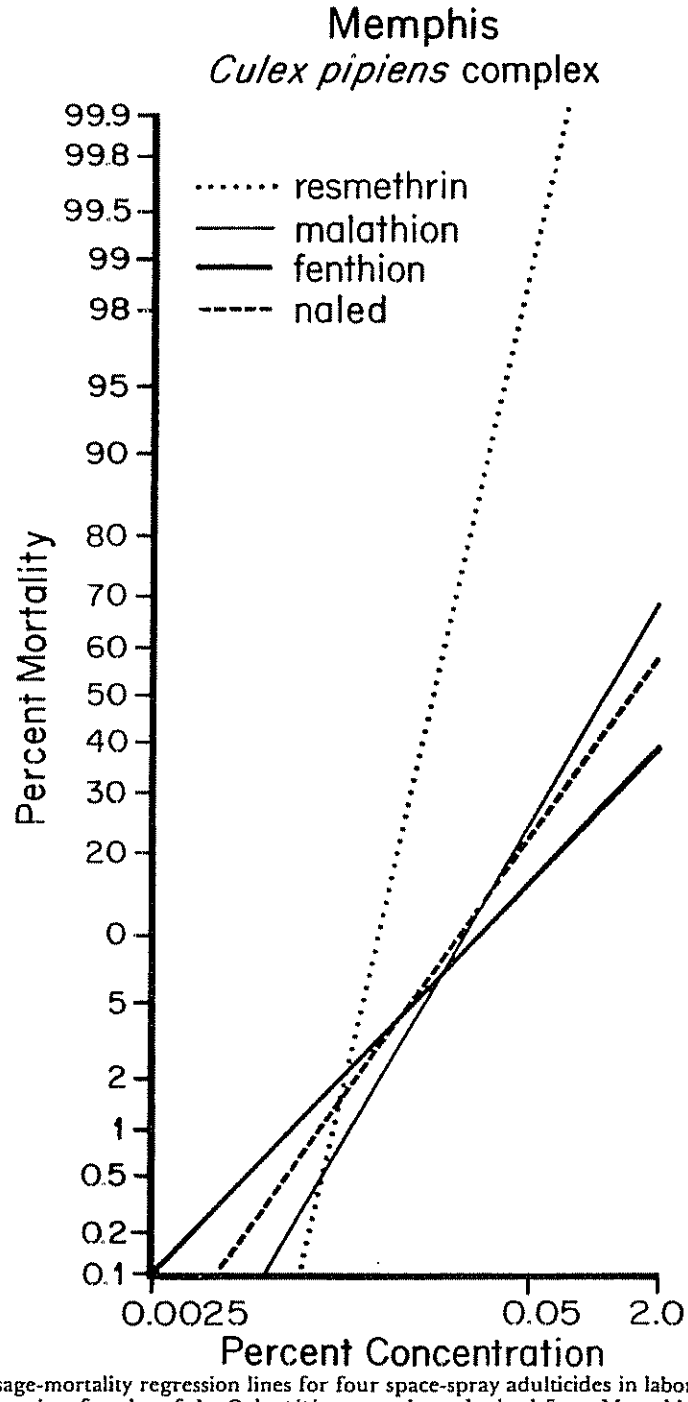

Fig. 2. Dosage-mortality regression lines for four space-spray adulticides in laboratory applications against females of the *Culex pipiens* complex colonized from Memphis, Tenn.

Aerosol test results, Figure 1, show that Birmingham *C. p. quinquefasciatus* are susceptible to all 4 of the test compounds with high mortality at lower dosages. The intrinsic toxicity of resmethrin, however, was somewhat higher than that of the other compounds. In contrast, the Memphis *C. p.* complex results presented in Figure 2 show that fenthion produced less than 20% kill at the highest dosage level of 0.05%, while naled and malathion produced only 30% kill. Regression lines have been projected to 2.0% to dramatize the level of resistance. Resmethrin was effective in all tests at the 0.025% concentration level.

Culex pipiens complex mosquitoes from outside Memphis in Shelby County were not examined for subspecies. They were, however, tested with malathion and found to be susceptible, and 96% kill at the 0.025% level was recorded with both the 4- and 14-day-olds, thus indicating that age is not a factor in susceptibility under the conditions of these tests.

DISCUSSION AND CONCLUSIONS

The use of malathion as a mosquito adulticide was initiated in Memphis-Shelby County, Tenn., during 1968 in connection with control of early spring floodwater adult mosquitoes. Initial application of adulticides was accomplished by use of 1200-B Dyna-Fog Thermal applicators. During 1970–71, Leco ULV HD nonthermal fog applicators were added. From 1969 through 1973, adult mosquito control was directed chiefly toward the control of adult floodwater species.

In 1974 and 1975, intensive adult mosquito control activities were conducted in connection with outbreaks of St. Louis encephalitis in several census tracts located in the City of Memphis.

Since the inception of the program no larviciding operations had been undertaken utilizing an organophosphorous compound.

It is evident that the *Culex pipiens* complex population in Memphis is resistant to the organophosphorous compounds tested in this study. It is surprising, however, that malathion adulticiding pressure on that population over a period of 8 summers was sufficient to select for resistance.

ACKNOWLEDGMENT

The authors wish to thank Theresa B. Blue, Mary S. Crawford, and Gregory S. Matsunaga for their assistance in the laboratory phase of these studies. Drs. George Hardy and Michael Maetz, and Messrs. Paul Pate and Phil Walkley of the Jefferson County Health Department, Birmingham, Ala., very kindly provided *Culex p. quinquefasciatus* egg rafts for the Birmingham colony used in this study.

REFERENCES

McCray, E. M., and Schoof, H. F. 1963. The use of a modified Hoskins-Caldwell spray chamber for mosquito insecticide resistance studies. Mosquito News 23(4):286–291.

Barr, A. Ralph 1957. The distribution of *Culex p. pipiens* and *C. p. quinquefasciatus* in North America. Am. J. Trop. Med. Hyg., 6(1):153–165.

APPENDIX B

Literature Reviewed

VOLUME 3 of 3

1977 Jolivet, P.H.A., Hong, H.K., Lee, C.S., and H.L. Mathis
Ground Aerosol of Ultra-Low-Volume Dibrom Against *Culex tritaeniorhynchus* in Pusan, Korea
Korean Journal of Entomology 2: 29-32 (Amvac Ref. #1427)

The Korean J. of Entomology, Vol. Ⅶ, No. 2 (1977)

Ground Aerosol of Ultra-Low-Volume Dibrom Against *Culex tritaeniorhynchus* in Pusan, Korea

P.H.A. Jolivet[1], H.K. Hong[2], C.S. Lee[2], and H.L. Mathis[3]
(WHO Vector Ecology and Control Research Unit, Seoul, Korea)

釜山地域에서 腦炎媒介蚊 *Culex tritaeniorhynchus* 의 驅除를 위한 Dibrom ULV 地上 噴霧作業에 關하여

P.H.A. Jolivet · 洪淏基 · 李鍾錫 · H.L. Mathis
(國立保健硏究院)

적 요

Culex tritaeniorhynchus 의 成虫驅除試驗을 爲하여 Dibrom 으로 地上 ULV 噴霧作業이 實施되었다. Dibrom 원액 73ml/ha 噴霧量으로 實施하였다. 噴霧作業이 實施된 一日後 *Culex tritaeniorhynchus* 成虫의 減少率은 40~50%을 나타냈고 全體的으로 4日동안의 減少率은 24~32%를 나타냈다. 이미 같은 地域에서 fenitrothion 으로 ULV 地上噴霧와 Dibrom 으로 헤리콥터를 使用한 ULV 空間 살포를 實施하여 좋은 結果를 얻은 바 있었다.

INTRODUCTION

In both 1972 and 1973 field trials were conducted in Pusan using ground applications of ultra-low-volume (ULV) fenitrothion against *Culex tritaeniorhynchus*, the local vector of Japanese Encephalitis (Mathis et al., 1974 a). The target dosage rate of these trials was 438 ml/ha. In the summer of 1973 a trial was conducted with a helicopter application of 73ml/ha of ULV Dibrom against the sametarget species in Seoul (Mathis, et al., 1974 b)

In 1974 a trial was carried out in Pusan using a ground application of ULV Dibrom and is herein reported. This study offers a comparison of effectiveness of ground applications of fenitrothion and Dibrom, and between aerial and ground applications of Dibrom.

TREATMENT

Area

The insecticide was applied over 75 ha of Sasang, a suburb of Pusan. This is exactly the same site as used the previous two years for ground applications, however, it has become considerably more industrialized. The resultant pollution of the swamp is slowly killing the *Phragmites communis* Thin., *Typha angustata* B. & C., and *Zizania latifolia* Turez. in the main breeding sites for *Culex* and *Mansonia*. The land filling of much of the area is also reducing the mosquito populations.

Application

A Trailor mounted LECO[4] cold aerosol machine, as described by Mount et al. (1970), was used for the application. Treatment was in the late evening hours, an active period for adult *C. tritaeniorhynchus*.

Wind was minimal, but coverage was good. As done previously, the roads were driven twice and the LECO outlet aimed downwind. Specifics are shown in table 1.

EVALUATION

Droplet size

Prior to treatment, droplets were collected on magnesium oxide coated slides at distances of 3 and 15m

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2) National Entomologist: National Institute of Health, Korea.
3) WHO Entomologist: Present address, WHO *Anopheles* Control Research Unit I, Kaduna, Nigeria.
4) Lowndes Engineering Co., Valdosta, Ga., U.S.A.

from the LECO discharge. The sampe droplets were measured and the volume median diameter (vmd) was calculated as recommended by WHO (1971).

Caged mosquitoes

Three replicate strips were used for bio-assay determinations; adult cages were placed from 12.5 to 150m, and the larval cages from 12.5 to 100m from the spray source. Additional adults were set, i.e. 5 cages in the village area (3 indoors and 2 outdoors) and two in the field well protected by weeds. Twenty five wild caught larvae or adults of *C. tritaeniorhynchus* were placed in each cage, and mortalities were recorded twenty four hours after treatment.

Natural mosquitoes

Five larvar sites, two cow bait collecting stations, and two light traps were used to evaluate the natural *C. tritaeniorhynchus* population. A total of forty dips were taken in the test area two days prior to treatment for a pretreatment larval index. Four, three, and two days before treatment, cow bait collections were made and light traps operated for pretreatment adult indices. This same procedure was followed daily for four days after treatment. Cow bait collections were made from 20.00 to 21.00 hours; light traps operated from 20.00 to 06.00 hours.

Parous rates

Ovaries were dissected out of females taken from cow bait collections in the test and check areas and examined for the presence or absence of tracheal skeins.

Untreated check area

A check area was selected 2.5km from the test area where evaluations were done consurrent to those in the treated area. Five larval and five adult bio-assay cages were placed in this area; one larval site, onelight trap, and one cow bait were utilized to determine natural, uncontrolled populations indices of *C. tritaeniorhynchus*.

RESULTS

Droplet size

Of 299 droplets measured from the collection 3m from the LECO discharge, the vmd was 40 um; of 476 measured droplets taken at 3 m, the vmd was 34 um. According to Mount (1970) the optimum particle size is 5-10 um, however the vmd in this test is about the same as that of the 1973/74 ground applications of fenitrothion, and it is half the diameter of the Dibrom particles applied by helicopter.

Table 1. Specifics of Dibrom Application.

Treatment data	7 September, 1974
Treatment period	19.30-22.20 hours
Hind speed	0.3 kph
Vehicle speed	8 kph
Area covered	76 ha
Total quantity sprayed	5.9 liters
Output rate	40.4 ml/min.
Concentration	85%
Dosage rate (activing.)	67 ml/ha
Temperature of Sasang	25°C
Relative humidity	86%

Larvae

Almost no larvae were killed in the bio-assay cages (table 2) The lack of larvicidal effect is substantiated by the natural population measurements of larvae (table 3). Although the natural population in the test area showed a reduction of 56%, the check area showed a like reduction indicating a normal reduction at this "tail end" of the *C. tritaeniorhynchus season.*

Table 2. Twenty four hour mortalities of caged *Culex tritaeniorhynchus* exposed to LECO ULV treatment with Dibrom.

	Location		No. of replicates	No. of mosquitoes tested	percent mortality
ADULTS	Rice field	12.5*	3	75	52
		25	3	75	29
		50	3	75	44
		100	3	75	51
		150	1	25	48
	villages	indoors	3	75	51
		outdoors	2	50	94
	heeds		2	50	52
	Composite of above		20	500	49
	Check area	indoors	3	75	1.3
		outdoors	2	50	2
LARVAR	Rice fields	12.5 m*	3	75	0
		25	3	75	0
		50	3	75	8
		100	3	75	0
		composite	12	300	2
	Check area		5	125	0

* Distance from LECO machine.

Table 3. Pre and Post Treatment Population Indices of *Culex tritaeniorhynchus*

(Parenthesis = % reduction based on pre-treatment)

Days after treatment	Larvae		ADULTS Cow baiting		Light trap	
	Treated(1)	Check(2)	Treated(3)	Check(4)	Treated(5)	Check(6)
Mean of pre-spray	15.4	379.8	267.8	380.0	3354.0	1977.7
1.	5.4 (64.9)	162.4 (57.2)	146.5 (45.3)	454.0 (0)	1183.5 (64.7)	1474 (25.4)
2.	8.9 (42.2)	229.4 (39.6)	121.0 (54.8)	226.0 (40.5)	171.5 (94.9)	268 (86.4)
3.	5.7 (63.0)	222.8 (41.3)	181.3 (52.3)	662.0 (0)	826.0 (75.4)	1080 (45.4)
4.	6.9 (55.2)	11.0 (70.8)	274.0 (0)	417.0 (0)	581.0 (82.7)	709 (64.2)
Mean of 4 post-spray days	6.7 (56.5)	181.4 (52.2)	180.7 (32.5)	439.8 (0)	690.3 (79.4)	882.8 (55.4)

(1) Mean number of 40 dips from 4 different sites
(2) Mean number of 5 dips from one site
(3) Per man hour (two cows)
(4) Per man hour (one cow)
(5) Per trap night (two traps)
(6) Per trap night (one trap)

Adults

Of 500 exposed mosquitoes 49% were killed (specifics in table 2). This, again, correlates very well with the measurements of the natural adult population. On day one, or for a composite of the four days after spraying, there was no reduction of adults collected from cows in the untreated check area, however in the treated area there was a 45% reduction on day one, and an overall four-day reduction of 32%. Due to field variables light traps required more assumptions. Day one showed a reduction of 65% in the treated area and a 25% reduction in the check area (table 3). One might consider this as a net reduction due to insecticide of about 40%. The same logic shows that the overall four-day picture for light traps is a 79% reduction in the treated area and a natural decline in the check area of 55%, a net reduction of 24%, possibly attributable to the insecticide treatment.

The overall adult bio-assays show a 49% kill; the cow bait shows a direct 45% reduction (day one); and light traps show a calculated net reduction of 40% for the first day. It seems safe to assume that the initial insecticidal effect on adult *C. tritaeniorhynchus* was a reduction somewhere between 40 and 50%, and that the overall four-day reduction was probably between 24 and 32%.

Table 4. Parous rates of *Culex tritaeniorhynchus*.

No. of days after treatment	Treated area		Check area	
	No. of mosq. disected	parous rate (%)	No. of mosq. disected	parous rate (%)
composite of 3 Pre-spray days	163	38.0	159	42.8
2	22	22.7	23	43.5
3	39	41.0	66	48.5
4	56	50.0	60	45.0
Post-spray Composite	117	41.9	149	40.3

Parous rates

Table 4 shows a considerable decrease of parous rate in the mosquitoes taken from the treated area two days after treatment as compared to both the pretreatment and check area rates. Thereafter, the treatment area rates returned to normal, probably due to immigration.

DISCUSSION

Comparison to 1972/73 ground application of ULV fenitrothion

The 1972 application showed greater than 60% reduction of adult *C. tritaeniorhynchus* six days after treatment; the 1973 reduction was about 70% five days after spraying (Mathis, et al. 1974a). This paper shows that the 1974 application of ULV Dibrom gave less than 50% control on the first day.

There are many field variables, however, all treatments were in the same area, and the same area, and the application and evaluation methods were identical or very similar. It seems clear that the ground applications of ULV fenitrothion at a target dosage rate of 438 ml/ha was superior to the ground application of ULV Dibrom at a target dosage rate of 73 ml/ha.

Comparison to 1973 helicopter applicatin of ULV Dibrom

The helicopter application gave 70% control of adult *C. tritaeniorhynchus* for at least three days (Mathis, et., 1974b). Again, a valid comparison can be made, i.e. aerial-vs ground application using the same insecticide at the same target dosage rate. The aerial application gave better control, but it must be pointed out that there was aconsiderable difference in size of test areas. The 0.75 km^2 treated by ground by ground equipment was much more susceptible to immigrating mosquitoes than the central evaluation area of the 10.6 km^2 treated from the air.

SUMMARY

A ground aplication of ULV Dibrom applied at the target rate of 73 ml/ha achieved negligible control of *Culex tritaeniorhynchus*. The initial impact on the adults of this species was between 40-50% reductien, and the overall four-day reduction was between 24-32 %. Previous ground applications in the same area using ULV fenitrothion, and a helicopter application using ULV Dibrom give superior results.

REFERENCES

Mathis, H. L. et al. (1974a) Unpublished document WHO/VBC/74.498

Matiis, H. L. et al. (1974b) Unpublised document WHO/VBC/74.501

Mount, G.A. et. al.. (1970) Mosquito News, 30, 56-59

Mount, G.A. (1970) Mosquito News, 30, 70-75

World Health Organization (1971) Wld Hlth Org. Techn. Rep. Ser., No. 465

1976 Palmisano, C. T., C. D. Steelman and P. E. Schilling
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RELATIVE EFFECTS OF INSECTICIDE USAGE IN LOUISIANA MOSQUITO CONTROL PROGRAMS ON THE SUSCEPTIBILITY OF ADULT FEMALE *CULEX PIPIENS QUINQUEFASCIATUS* POPULATIONS

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ABSTRACT. A wind tunnel device was utilized in laboratory tests to determine the susceptibility to 6 selected insecticides of natural populations of adult female *Culex pipiens quinquefasciatus* Say collected from 6 southern Louisiana parishes. Mosquitoes collected from locations having mosquito control programs were significantly less ($P<0.05$) susceptible to the organophosphate insecticides temephos, chlorpyrifos, fenthion, malathion and naled than those populations from areas having no mosquito control programs. The *C. p. quinquefasciatus* adults exposed to propoxur showed little variation in susceptibility between the populations collected from the 6 locations. Propoxur caused excellent knockdown and high mortality in 1-hour knockdown tests on mosquitoes collected from all areas sampled in this study. Naled caused excellent knockdown and high mortality to *C. p. quinquefasciatus* populations collected from areas where no organophosphate tolerance existed.

The southern house mosquito, *Culex pipiens quinquefasciatus* Say is an important vector of St. Louis encephalitis (Chamberlain et al. 1959). In 1975, outbreaks of St. Louis encephalitis occurred in various locations in North America from Ontario, Canada, diagonally across the United States to Houston, Texas. Preliminary data provided by the Viral Diseases Division, Bureau of Epidemiology, Center for Disease Control, Atlanta, Georgia, indicate that 1367 confirmed cases plus 574 cases with some serologic evidence of infection were reported from 29 states and the District of Columbia. Louisiana had 7 confirmed cases and 6 suspected cases; Mississippi had 109 confirmed cases and 80 suspected; and Texas reported 37 confirmed cases. In 1975, more than 90 deaths from St. Louis encephalitis were reported in the United States.

Culex pipiens quinquefasciatus is the most important vector of the dog heartworm, *Dirofilaria immitis* (Leidy), in Louisiana (Villavaso and Steelman 1968). An average of 63.3 *C. p. quinquefasciatus* adult females were captured per night in Louisiana with 1.45% containing the infective stage of *D. immitis* larvae.

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Steelman et al. (1967) reported that *C. p. quinquefasciatus* larval populations greater than 1500 per dip occurred in waste disposal lagoons and septic ditches throughout Louisiana. The extensive use of organophosphate insecticides by mosquito control agencies has frequently led to the development of resistance to these compounds by many mosquito species throughout the world. In Louisiana, Steelman and Devitt (1976) reported the development of organophosphate tolerance in field populations of *C. p. quinquefasciatus* larvae.

Dosage-mortality data for mosquito species relative to currently labeled insecticides are of primary concern in planning and executing mosquito control programs. These data are especially important where the target species is an important vector of disease-causing organisms.

MATERIALS AND METHODS. Mosquitoes were collected as 3rd or 4th instar larvae from septic ditches throughout the year and transported to the laboratory according to the method described by Craven and Steelman (1968). Each group of larvae was collected from three or more sites within each major area.

Natural populations of mosquitoes were collected from Cameron, Calcasieu, Jefferson, St. Tammany, East Baton Rouge, and Tangipahoa Parishes. The first four of these had organized mosquito control districts. Collections were also made in 1 parish which had a Parish Health Unit Vector Control Program and 1 parish which had no mosquito control program.

In the laboratory larvae were divided into groups of 300 and along with 1,000 ml of water collected in the field were immediately transferred to aerated 30.5 x 19 x 5 cm enamel pans. The larvae in each pan were fed 0.25 g of finely ground commercial rabbit pellets daily. Water treated with sodium thiosulfate to remove chlorine was added to the pans to replace water lost by evaporation. Pupae were transferred into 0.25 liter glass jars filled with sodium thiosulfate treated water which were then placed in cages constructed from 3.785 liter ice cream cartons. Raisins used as a carbohydrate source were placed on top of each cage for adult nourishment and a 9 cm^2 piece of water-soaked cellucotton was placed on top of the raisins to maintain humidity. A temperature of 24± 2° C and 9 hr photoperiod was maintained in the laboratory. Wind tunnel and subsequent tests described by Mount and Pierce (1973) and Mount et al. (1976) were conducted with 3- to 7-day old adult females.

Adults were anesthetized in the 3.785 liter cages within a standard chemical hood by placing a 20 cm^2 piece of cellucotton soaked with 15 ml of ether over the top of the cage for 100 sec. Twenty females were transferred into each of the test cages which consisted of 0.25 liter ice cream cartons with the bottoms and the lids covered with 18 mesh nylon screen. The test cages were placed at the end of the tunnel for exposure to the various insecticides. One ml. of insecticide solution was then pipetted into the nozzle of the insecticide dispersing mechanism and the mosquitoes exposed to the resulting aerosol spray for 10 sec. Each test was replicated 4 times with each replication consisting of 1 cage of 20 female mosquitoes for each of a series of 5–10 insecticide concentrations plus a water check. After treatment, the mosquitoes were again anesthetized and transferred into clean cages. One raisin and a moist cellucotton pad were placed on top of each holding cage. Knockdown and mortality counts were taken at 1 and 24 hr after exposure.

Emulsifiable concentrate formulations of 5 organophosphates (temephos, fenthion, naled, chlorpyrifos, and malathion) and one carbamate (propoxur) were used in the wind tunnel tests. Test concentrations of insecticides were prepared by serial dilution in deionized water.

Data obtained from wind tunnel tests performed on *C. p. quinquefasciatus* from 6 locations and exposed to 6 insecticides were statistically analyzed using a randomized block design. Dosage-mortality regression lines were established by probit analysis described by Daum (1970). An eye-fitted line was constructed on log probit graph paper in order to estimate dosage-mortality lines of tests which were computed to have a non-significant ($P<0.01$) regression coefficient.

RESULTS AND DISCUSSION. Table 1 shows the analysis of variance (ANOV) for the LC50 response of *C. p. quinquefasciatus* to temephos, propoxur, fenthion, naled, chlorpyrifos, and malathion. A highly significant ($P<0.01$) difference was detected at the LC50 responses between chemicals and between locations, indicating that *C. p. quinquefasciatus* populations collected from the same area varied in their susceptibility to the 6 insecticides and that *C. p. quinquefasciatus* populations collected from different locations varied in their susceptibility to the same insecticides.

Table 1. Analysis of variance of LC50 values of 6 insecticides used to test the susceptibility of *Culex p. quinquefasciatus* collected from 6 locations in Louisiana.

Source	df	MS
Location	5	0.1977**
Chemical	5	0.0893**
Error	25	0.0186
Total	35	

** $P<0.01$.

Tables 2–7 show the dosage-mortality responses of *C. p. quinquefasciatus* after exposure to chlorpyrifos, fenthion, propoxur, naled, malathion, temephos, respectively. Significant differences ($P<0.05$) in susceptibility to each compound existed between populations collected from different locations when confidence limits computed from probit analysis were compared.

Culex p. quinquefasciatus populations collected in Jefferson Parish appeared to be more susceptible to chlorpyrifos than any of the other populations of this species tested (Table 2). These data showed that the mosquitoes from Jefferson Parish were 27 to 52X more suspectible at the LC50 response to chlorpyrifos than the populations of *C. p. quinquefasciatus* collected from Zachary and Bakèr (both in East Baton Rouge Parish), respectively. Although no adulticide treatments of *C. p. quinquefasciatus* with chlorpyrifos has occurred in any of the areas, this compound has been used extensively as a larvicide in Jefferson and St. Tammany Parishes and in the Zachary and Baker localities of East Baton Rouge Parish for 5 to 8 years.

Populations of *C. p. quinquefasciatus* from Jefferson and Tangipahoa Parishes were the most susceptible mosquitoes to fenthion (Table 3). Susceptibility levels of the mosquitoes from Calcasieu, St. Tammany and the LSU colony were not significantly different ($P>0.05$); however, a significant difference ($P<0.05$) at the LC50 response level was shown between mosquitoes from these locations and those collected in Jefferson and Tangipahoa Parishes. At the LC50 response level the mosquitoes collected in Jefferson Parish were 30 to 43X more susceptible to fenthion than the populations collected from Zachary and Baker, respectively. The mosquitoes collected in Baker and Zachary were less than 7X as susceptible to fenthion at the LC50 response level as the *C. p. quinquefasciatus* collected from the other 5 locations.

Table 2. Susceptibility of *Culex p. quinquefasciatus* collected from 8 locations in Louisiana to chlorpyrifos.

Location	LC50 (%)	95% C.I.[b]	LC90 (%)	95% C.I.[b]	Slope
Jefferson	0.0267	0.0236–0.0300	0.0735	0.0642–0.0860	2.9124
Tangipahoa	0.0424	0.0305–0.0550	0.1254	0.0924–0.2071	2.7236
Calcasieu	0.0622	0.0329–0.0893	0.1736	0.1181–0.4044	2.8763
LSU[a]	0.0950		0.1720		3.9635
St. Tammany	0.1299	0.0988–0.1684	0.5262	0.3477–1.1797	2.1095
Cameron[a]	0.1480		0.5110		0.5475
Zachary	0.7211	0.5216–1.5321	1.5123	1.2381–7.6571	3.4821
Baker[a]	1.3900		2.7000		3.7676

[a] Eye-fitted line.
[b] Confidence limits.

Table 3. Susceptibility of *Culex p. quinquefasciatus* collected from 7 locations in Louisiana to fenthion.

Location	LC50 (%)	95% C.I.[a]	LC90 (%)	95% C.I.[a]	Slope
Jefferson	0.0176	0.0124–0.0239	0.0681	0.0479–0.1132	2.1831
Tangipahoa	0.0307	0.0204–0.0413	0.0886	0.0633–0.1600	2.7822
Calcasieu	0.0775	0.0627–0.0928	0.1629	0.1309–0.2330	3.9751
LSU	0.0916	0.0813–0.1036	0.2811	0.2291–0.3698	2.6306
St. Tammany	0.0904	0.0598–0.1271	0.7260	0.4726–1.5696	1.4439
Zachary	0.5354	0.2670–2.0330	2.4297	1.0154–569.73	1.9510
Baker	0.7710	0.7185–0.8325	1.4297	1.2507–1.7350	4.7785

[a] Confidence limits.

The only record of fenthion use for mosquito control was in Jefferson Parish 5 years prior to the time of this study. Apparently little if any selective pressure on the adult populations occurred as a result of this limited usage in Jefferson Parish.

The susceptibility of *C. p. quinquefasciatus* to the carbamate propoxur is shown in Table 4. Mosquitoes exposed to propoxur showed little variation in susceptibility between 6 collection localities in Louisiana. However, mosquitoes collected from Tangipahoa Parish were significantly ($P < 0.05$) more susceptible than the LSU laboratory colony but the difference in the LC50's was only about 2X. Mosquitoes collected from the various localities appeared to be relatively susceptible to propoxur. At the present time, propoxur is not presently labeled for mosquito control therefore natural populations of *C. p. quinquefasciatus* have not been exposed to the compound and this accounted for less variation between the locations.

Susceptibility of adult *C. p. quinquefasciatus* to naled is shown in Table 5. Less than 2X difference occurred between the LC50 response level of *C. p. quinquefasciatus* collected from Tangipahoa, Calcasieu, and St. Tammany Parishes and the LSU laboratory colony. At the LC50 response level, the LSU colony, St. Tammany, and Cameron Parish mosquitoes differed significantly ($P < 0.05$) from those collected in Calcasieu and Tangipahoa Parishes. The LC50 response levels obtained from mosquitoes collected in Jefferson Parish differed significantly ($P < 0.05$) from those obtained from Tangipahoa, Calcasieu, and St. Tammany and the LSU colony. Naled has been the adulticide used by the Jefferson Parish MCD during the past 5 years. Selective pressure on the adults of *C. p. quinquefasciatus* by naled was apparent and was

Table 4. Susceptibility of *Culex p. quinquefasciatus* collected from 6 locations in Louisiana to propoxur.

Location	LC50 (%)	95% C.L.[a]	LC90 (%)	95% C.L.[a]	Slope
Tangipahoa	0.0837	0.0728–0.0950	0.2314	0.1932–0.2963	2.9011
Zachary	0.1056	0.0080–0.1811	0.2449	0.1510–45.5031	3.5070
St. Tammany	0.1157	0.0932–0.1386	0.3012	0.2376–0.4392	3.0843
Calcasieu	0.1404	0.1051–0.1972	0.3328	0.2257–1.0050	3.4200
Jefferson	0.1604	0.1489–0.1724	0.4000	0.3546–0.4655	3.2297
L.S.U.	0.1782	0.1327–0.2781	0.4852	0.3006–2.2026	2.9465

[a] Confidence limits.

Table 5. Susceptibility of *Culex p. quinquefasciatus* collected from 8 locations in Louisiana to naled.

Location	LC50 (%)	95% C.L.[c]	LC90 (%)	95% C.L.[c]	Slope
Tangipahoa	0.0521	0.0187–0.0762	0.1235	0.0834–0.5537	3.4189
Calcasieu	0.0605	0.0431–0.0810	0.1967	0.1346–0.4097	2.6491
St. Tammany	0.1100	0.0824–0.1545	0.5966	0.3466–1.7171	1.7457
L.S.U.	0.1110	0.0858–0.1442	0.2760	0.1964–0.5846	3.2403
Cameron	0.1830	0.0819–1.3241	1.3894	0.4266–18404.02	1.4556
Jefferson	0.3166	0.2237–1.6465	0.7540	0.4119–127.310	3.4004
Baker[a]	0.6820		1.6900		3.3278
Zachary[b]	0.7267	0.5074–	1.7370	0.9316–	3.3867

[a] Eye-fitted line.
[b] Upper confidence limit not computed.
[c] Confidence limits.

reflected in their comparative degree of susceptibility to this compound. Naled has been utilized as an adulticide to some degree in St. Tammany Parish with ground ULV equipment over the last 5 years and extensively used in aircraft applications in Cameron Parish since 1972. Thus, it appears that the use of naled as an adulticide has lowered the susceptibility level of *C. p. quinquefasciatus* to this compound in these parishes.

Susceptibility of *C. p. quinquefasciatus* adult females to malathion is shown in Table 6. Malathion has been used as an adulticide in all of the areas from which mosquitoes were collected except Tangipahoa Parish. Only limited amounts of malathion have been utilized by the Jefferson Parish MCD. This is apparent in the LC50 response levels of the mosquitoes collected from this parish to malathion (identical LC50 response values in the LSU laboratory colony and less than 2X difference in susceptibility from the Tangipahoa populations). Malathion has been used as an adulticide extensively in the Calcasieu, St. Tammany, Cameron, Zachary, and Baker locations in ULV ground and/or aerial applications. Thus, the difference in susceptibility (LC50) ranges from 3X between Tangipahoa and Calcasieu to 9X between Tangipahoa and Baker.

Temephos has been used as a larvicide to control *C. p. quinquefasciatus* in Jefferson Parish and in Zachary. No record of its use as an adulticide was obtained in any of the areas from which *C. p. quinquefasciatus* was collected. The susceptibility of *C. p. quinquefasciatus* to temephos is shown in Table 7. Because no insecticide applications have been made for mosquito control in Tangipahoa Parish, mosquitoes collected in this parish were used as an indicator of the effectiveness of temephos as an adulticide. The LC50 response showed that a 4X difference existed between the mosquitoes collected in

Table 6. Susceptibility of *Culex p. quinquefasciatus* collected from 8 locations in Louisiana to malathion.

Location	LC50 (%)	95% C.L.[b]	LC90 (%)	95% C.L.[b]	Slope
Tangipahoa[a]	0.1410		0.2750		4.1176
Jefferson	0.2599	0.1297–0.2461	0.3524	0.2662–0.7072	4.7245
LSU	0.2599	0.2341–0.2904	0.7015	0.5878–0.8815	2.9720
Calcasieu	0.4340	0.3753–0.5300	0.8854	0.6690–1.7565	4.1385
St. Tammany	0.5243	0.4345–0.6915	1.4819	0.9985–3.4919	2.8400
Cameron	0.5259	0.3703–1.7887	1.3840	0.7586–164.020	3.0497
Zachary	0.7644	0.5668–1.5038	2.1031	1.1905–25.6215	2.9157
Baker[a]	1.3000		2.7800		6.0187

[a] Eye-fitted line.
[b] Confidence limits.

Table 7. Susceptibility of *Culex p. quinquefasciatus* collected from 6 locations in Louisiana to temephos.

Location	LC50 (%)	95% C.L.[b]	LC90 (%)	95% C.L.[b]	Slope
Tangipahoa	0.1620	0.1310–0.2089	0.3227	0.2390–0.7172	4.2837
Calcasieu	0.2557	0.2362–0.2777	0.6263	0.5416–0.7564	3.2943
Jefferson[a]	0.3790		0.6580		5.1673
St. Tammany	0.4834	0.3589–0.7860	1.0353	0.6850–5.1517	3.8745
LSU	0.5102	0.3441–0.9882	1.7329	0.9252–20.7582	2.4135
Zachary	0.6889	0.5739–0.9111	1.5013	1.0644–4.0334	3.7879

[a] Eye fitted line.
[b] Confidence limits.

Table 8. One hour mortality of *Culex p. quinquefasciatus* treated with propoxur.

Location	LC50 (%)	95% C.L.[b]	LC90 (%)	95% C.L.[b]	Slope
Zachary[a]	0.0820		0.1540		4.2604
Tangipahoa	0.0914	0.0803–0.1028	0.2304	0.1937–0.2944	3.1920
St. Tammany	0.0996	0.0742–0.1242	0.2220	0.1725–0.3451	3.6814
Jefferson	0.1429	0.1208–0.1653	0.3284	0.2694–0.4478	3.5467
Calcasieu	0.1516	0.1144–0.2189	0.3218	0.2218–0.9666	3.9216
L.S.U.	0.1518	0.1219–0.1934	0.3796	0.2719–0.7786	3.2203

[a] Eye fitted line.
[b] Confidence limits.

Tangipahoa as compared to those collected from Zachary. Since a portion of the mosquitoes used to start the LSU colony were collected in Zachary in 1968 before it was known that the area had been treated with temephos, this probably explains the lack of susceptibility of the LSU colony to temephos and other insecticides tested.

The results of 1-hr knockdown and mortality tests conducted with propoxur are shown in Table 8. Propoxur showed excellent knockdown qualities on *C. p. quinquefasciatus* collected from all 5 areas. Mosquitoes collected from Zachary which had the highest degree of tolerance to the organophosphate insecticides were highly susceptible to propoxur in the 1-hr knockdown tests. These data indicate that in an emergency situation (i.e., an epidemic of St. Louis encephalitis) propoxur could be used effectively to control the vector *C. p. quinquefasciatus* even in areas where organophosphate tolerance exists.

Table 9 shows the 1-hr mortality response of *C. p. quinquefasciatus* to naled. This chemical caused excellent knockdown and high mortality to the mosquito populations collected from Calcasieu, Tangipahoa and St. Tammany Parishes where no tolerance existed and could be used effectively to control the mosquito vector of St. Louis encephalitis in such areas.

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Literature Cited

Chamberlain, R. W., W. D. Sudia, and J. D. Gillett. 1959. St. Louis encephalitis virus in mosquitoes. Amer. J. Hyg. 70:221–36.

Craven, B. R. and C. D. Steelman. 1968. Relative susceptibility of *Psorophora confinnis* (Lynch-Arribálzaga) larvae in the rice producing area of southern Louisiana to selected insecticides. Mosquito News 28:596–7.

Daum, R. J. 1970. A revision of two computer programs for probit analysis. Bull. Entomol. Soc. Amer. 16:10–5.

Mount, G. A. and N. W. Pierce. 1973. Toxicity of selected adulticides to six species of mosquitoes. Mosquito News 33:368–70.

Mount, G. A., N. W. Pierce and K. F. Baldwin. 1976. A new wind-tunnel system for testing insecticidal aerosols against mosquitoes and flies. Mosquito News 36:127–31.

Table 9. One hour mortality of *Culex p. quinquefasciatus* treated with naled.

Location	LC50 (%)	95% C.L.[b]	LC90 (%)	95% C.L.[b]	Slope
Calcasieu	0.0844	0.0618–0.1083	0.1765	0.1328–0.3179	3.9975
Tangipahoa	0.0868	0.0606–0.1244	0.1711	0.1207–0.6049	4.3478
St. Tammany[a]	0.2664	0.1555–	0.8637	0.3044–	2.5090
Zachary	3.2592	1.4075–69.5407	37.120	6.6904–22567.9	1.2130

[a] Upper confidence limit not computed.
[b] Confidence limits.

Steelman, C. D and D. S. Devitt. 1976. Development of organophosphate tolerance in field populations of *Culex pipiens quinquefasciatus* Say in Louisiana. Mosquito News 36:361–363.
Steelman, C. D., J. M. Gassie and B. R. Craven. 1967. Laboratory and field studies on mosquito control in waste disposal lagoons in Louisiana. Mosquito News 27:57–9.
Villavaso, E. J. and C. D. Steelman. 1968. Laboratory and field studies of the southern house mosquito *Culex pipiens quinquefasciatus* Say infected with the dog heartworm, *Dirofilaria immitis* (Leidy) in Louisiana. J. Med. Entomol. 7:471–6.

MAINTENANCE AND TRANSPORTATION OF FEMALE MOSQUITOES COLLECTED IN THE FIELD[1]

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ABSTRACT. Maintenance and transportation of large numbers of female mosquitoes collected during an interval of several days may be performed easily and simply without significant mortality. Small cages used to collect were carried in large transport boxes of styrofoam. The mosquitoes, 10 to 15 females in each cage, were permitted to feed daily on blood and a 10% solution of honey. The transport boxes were kept at 21° C by use of ice in plastic bags. Important to high survival and egg production for the species of *Aedes* collected in northern Michigan was the blood-feeding in the field within a few hours of capture and the maintenance of proper humidity in the transport boxes.

Maintenance and transportation of large numbers of female mosquitoes collected during an interval of several days can be accomplished easily and simply without significant mortality. Dr. William R. Horsfall began developing this method in 1962 at the University of Illinois. Since that time numerous changes have been introduced by him and by the author. The many modifications and adaptations culminated in the following procedure used in 1975 and 1976 for some 15 species of *Aedes* collected in northern Michigan.

In 1976 about 2500 female mosquitoes were collected over a 4-day period from several areas in Michigan north of 45° latitude. These areas which had both high densities of adults and variety of species were either proximal to larval habitats or near margins of barriers to movement such as large lakes. At such sites, 10 to 15 female mosquitoes, attracted to human bait, were collected in each cage.

Cages used for collecting, transport and maintenance of mosquitoes were the *Illinois oviposition cage*, long used in this laboratory. This cage consists of 2 walls and ends of transparent Lucite® (3 mm thick) and a top of Lumite®[3] screen (mesh: 32x32 natural) and a bottom of nylon tulle (available at local fabric shops). Dimensions of each cage are 150x25x25 mm. One end has a hole 10 mm in diameter which is fitted with a cork stopper when in use.

After collecting was completed and cages labelled for later reference, they were arranged in layers above a false bottom in transport boxes made of styrofoam (size: about 200x350x250 mm). Stoppered ends of the cages were placed

[1] The opinions and use of product names contained herein are the private views of the author and are not to be construed as official or reflecting the views or endorsements of the Department of the Army and the Department of Defense.

[2] Captain, U. S. Army Medical Service Corps.

[3] Available from Chicopee Mfg. Co., Cornelia, Georgia 30531.

1976 Steelman, C. D., and D. S. Devitt
Development Of Organophosphate Tolerance In Field Populations Of Culex Pipiens Quinquefasciatus Say In Louisiana
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DEVELOPMENT OF ORGANOPHOSPHATE TOLERANCE IN FIELD POPULATIONS OF *CULEX PIPIENS QUINQUEFASCIATUS* SAY IN LOUISIANA [1]

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ABSTRACT. In a 5-year study, *Culex pipiens quinquefasciatus* Say larvae from 2 Louisiana Mosquito Control Districts (MCD) developed varying degrees of tolerance to chlorpyrifos, malathion and naled. Larvae collected in the Jefferson Parish Mosquito Control District exhibited an approximate 2x decrease in susceptibility to the 3 compounds in 1975 when compared to base lines established in 1970. Larvae collected from septic ditches in the St. Tammany Parish Mosquito Control District were approximately 25x less susceptible to naled in 1975 when compared to data obtained in 1970 (LC_{90} data). Susceptibility to malathion and chlorpyrifos decreased 28x and 5x, respectively, during the 5-year period. There was no evidence of increased tolerance to these chemicals in larval populations collected in the Orleans Parish MCD.

The importance of the southern house mosquito, *Culex pipiens quinquefasciatus* Say, as a vector of the St. Louis strain of encephalitis (Chamberlain et al. 1959) and the dog heartworm, *Dirofilaria immitis* (Leidy) (Villavaso and Steelman 1970) necessitated the development of larvicide programs by Louisiana mosquito control districts. Effective and economical control of *C. p. quinquefasciatus* has been achieved by the application of various organophosphate insecticides to the larval habitat.

The value of establishing dosage-mortality data on mosquito species that are currently being controlled by larvicidal treatments has been established (Boike and Rathburn 1968, 1969, 1972 and 1975; Mount et al. 1971 and 1974; and Seawright and Mount 1975). These reports indicated that certain populations of *Aedes taeniorhynchus* (Wiedemann) had developed resistance to malathion in Florida along most of the east coast, the lower half of the west coast, and in the Florida Keys.

In 1970, The Louisiana Mosquito Control Association Board of Directors established a grant-in-aid with the Department of Entomology at Louisiana State University to determine the susceptibility of natural populations of mosquito larvae to various insecticides. Mosquito larvae from various Louisiana mosquito control districts (MCD) have been tested annually since 1970 to determine possible development of resistance that might occur as a result of insecticide application programs in the abatement districts.

METHODS AND MATERIALS. Mosquito larvae were collected in Jefferson, Orleans, St. Bernard and St. Tammany Parish Mosquito Control Districts (MCD), and transported to the laboratory in essentially the same manner as described by Craven and Steelman (1968). All larvae were collected for susceptibility tests prior to insecticide treatment. Mortality of *C. p. quinquefasciatus* larvae to the selected test insecticides was determined by the procedure described by the World Health Organization (1963) except that emulsifiable concentrate formulations of the insecticides were used. The desired concentrations were obtained by serial dilutions of the emulsifiable concentrates with deionized water.

Since chlorpyrifos is a frequently used larvicide to control *C. p. quinquefasciatus* breeding in septic ditches in Louisiana and either malathion or naled is used as an adulticide, these three insecticides were selected for the dosage-mortality tests. Dosage-mortality data were determined at least 6 times per year for the Jefferson and St.

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[2] Professor and Research Assistant.

Tammany Parish MCD's and the average LC_{50} and LC_{90} for the year calculated. Dosage-mortality data were determined in 1971 for St. Bernard MCD and in 1971, 1972, and 1975 in the Orleans Parish MCD.

RESULTS AND DISCUSSION. The lethal concentrations (in ppm) for *C. p. quinquefasciatus* larvae collected from the MCD's and tested against chlorpyrifos, malathion and naled are shown in Table 1. These data indicate that little if any variation had occurred in the susceptibility of *C. p. quinquefasciatus* larvae collected in Orleans MCD over the 5-year period. However, it should be noted that only limited data have been available from the Orleans Parish MCD. No comparative data were obtained for the St. Bernard Parish MCD.

A slight change in the susceptibility of the larvae collected in Jefferson Parish to chlorpyrifos, malathion and naled was observed in the dosage-mortality tests over the 5-year period. The LC_{50} and LC_{90} in 1975 of chlorpyrifos were about 2x times higher than the values recorded in 1970. Similarly, a 2x increase had occurred in the LC_{50} of naled and malathion during the 5-year period.

Larvae from the St. Tammany MCD showed a 10x decrease in susceptibility to malathion between 1972 and 1973 in both the LC_{50} and LC_{90} values. This decrease in susceptibility to malathion continued through 1974 and in 1975 there was a greater than 100x decrease in susceptibility as shown by the LC_{50} value and greater than 250x increase in the LC_{90} value. The larvae were approximately 20x (LC_{50}) and 50x (LC_{90}) less susceptible to naled in 1975 as compared to the data obtained in 1970. A decrease in susceptibility of *C. p. quinquefasciatus* larvae to chlorpyrifos was detected in 1974. These data indicate that a 15x decrease in susceptibility occurred between 1974 and 1975 in the LC_{90} value and approximately 4x in the LC_{50} value.

Mosquito control activities were initiated

Table 1. Susceptibility of *Culex pipiens quinquefasciatus* Say larvae from Jefferson, Orleans, St. Bernard and St. Tammany Parish Mosquito Control Districts, Louisiana, to chlorpyrifos, malathion and naled, 1970–75.

Year	Lethal Concentration (ppm) LC_{50}/LC_{90} Chlorpyrifos	Malathion	Naled
	Jefferson MCD		
1970	.00024/.00090	.0760/0.710	.015/0.740
1971	.00020/.00050	.0600/0.110	.010/0.710
1972	.00010/.00060	.0220/0.105	–
1973	.00005/.00030	.0420/0.150	–
1974	.00050/.00300	.1630/0.671	.050/0.211
1975	.00037/.00170	.1400/0.650	.036/0.135
	Orleans MCD		
1971	.00013/.00032	.0430/0.123	.021/0.074
1972	.00006/.00031	.0050/0.121	.024/0.135
1975	.00004/.00020	.0190/0.020	.020/0.180
	St. Bernard MCD		
1971	.0001/.00026	.0380/0.190	.011/0.056
	St. Tammany MCD		
1970	.00030/.00040	.0220/0.081	.009/0.026
1971	.00007/.00034	.0016/0.014	–
1972	.00014/.00050	.0040/0.014	–
1973	.00008/.00020	.0450/0.140	–
1974	.00037/.00340	.3980/1.624	.176/1.396
1975	.00150/.01700	.6100/3.825	.225/1.610

in 1965 by the Jefferson Parish MCD and in 1968 by the St. Tammany MCD. Chlorpyrifos has been utilized by both of these mosquito control districts as a larvicide treatment for the control of *C. p. quinquefasciatus* breeding in septic ditches. Either malathion or naled applied by ULV ground equipment has been used as an adulticide by these 2 mosquito control districts. In addition to the adult control obtained by the ULV ground application units, a certain amount of larval mortality could have occurred as a result of larger aerosol particles falling into the open septic ditches as the adulticide equipment moved along the adjacent roadways. Coombes et al. (1973) reported that ULV application of technical (95%) malathion with ground equipment at a rate of 35 ml/hectare caused 94% mortality to *Psorophora columbiae* (Dyar and Knab) larvae 15m downwind from the path of an ULV generator. Therefore, it is logical that some populations of *C. p. quinquefasciatus* larvae could have been pressured with these 3 organophosphate insecticides (chlorpyrifos, malathion and naled).

Data from this 5-year study indicate that the application of chlorpyrifos as a larvicide and malathion and naled as adulticides have resulted in the development of tolerance to these three organophosphate insecticides in 2 Louisiana Mosquito Control Districts. These insecticides applied according to the labeled rates are currently providing effective control of *C. p. quinquefasciatus* populations in the Louisiana MCD's.

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Literature Cited

Boike, A. H., Jr. and C. B. Rathburn, Jr. 1968. Tests of the susceptibility of Florida mosquitoes to insecticides, 1967. Mosquito News 28:313–6.

Boike, A. H., Jr. and C. B. Rathburn, Jr. 1969. Laboratory tests of the susceptibility of mosquito larvae to insecticides in Florida, 1968. Mosquito News 29:392–5.

Boike, A. H., Jr. and C. B. Rathburn, Jr. 1972. The susceptibility of mosquito larvae to insecticides in Florida, 1969–1971. Mosquito News 32:328–31.

Boike, A. H., Jr. and C. B. Rathburn, Jr. 1975. Laboratory susceptibility tests of some Florida strains of *Aedes taeniorhynchus* (Wied.) and *Culex nigripalpus* Theob. to malathion and naled, 1972–1974. Mosquito News 35:137–40.

Chamberlain, R. W., W. D. Sudia and J. D. Gillett. 1959. St. Louis encephalitis virus in mosquitoes. Amer. J. Hyg. 70:221–36.

Coombes, L. E., J. T. Lee and M. V. Meisch. 1973. Effectiveness of ground ULV aerosols against larvae of *Psorophora confinnis* (Lynch-Arribálzaga). Mosquito News 33:203–5.

Craven, B. R. and C. D. Steelman. 1968. Relative susceptibility of *Psorophora confinnis* (Lynch-Arribálzaga) larvae in the rice producing area of southern Louisiana to selected insecticides. Mosquito News 28:596–7.

Mount, G. A., D. A. Dame and C. S. Lofgren. 1971. Susceptibility of a Florida strain of *Aedes taeniorhynchus* (Wiedemann) to insecticides. Mosquito News 31:438–40.

Mount, G. A., J. A. Seawright and N. W. Pierce. 1974. Selection response and cross susceptibility of a malathion-resistant strain of *Aedes taeniorhynchus* (Wiedemann) to other adulticides. Mosquito News 34:276–7.

Seawright, J. A. and G. A. Mount. 1975. Inheritance of malathion resistance in *Aedes taeniorhynchus* (Wiedemann). Mosquito News 35:365–71.

Villavaso, E. J. and C. D. Steelman. 1970. Laboratory and field studies of the southern house mosquito, *Culex pipiens quinquefasciatus* Say, infected with the dog heartworm, *Dirofilaria immitis* (Leidy) in Louisiana. J. Med. Entomol. 7:471–6.

World Health Organization. 1963. Instructions for determining the susceptibility or resistance of mosquito larvae to insecticides. WHO Rep. Ser. No. 265. pp. 55–61.

1975 Boike, A. H., and C. B. Rathburn, Jr.
Laboratory Susceptibility Tests Of Some Florida Strains Of Aedes Taeniorhynchus (Wied.) And Culex Nigripalpus Theob. To Malathion And Naled, 1972-1974
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ARTICLES

LABORATORY SUSCEPTIBILITY TESTS OF SOME FLORIDA STRAINS OF *AEDES TAENIORHYNCHUS* (WIED.) AND *CULEX NIGRIPALPUS* THEOB. TO MALATHION AND NALED, 1972–1974

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ABSTRACT. First generation larvae from field collected adults of *Aedes taeniorhynchus* (Wied.) from eight areas of Florida were found to be from 2–30 times more resistant to malathion at the LC_{90} level than larvae from the susceptible colony maintained at the West Florida Arthropod Research Laboratory. F_1 adults from some areas were up to 31 times less susceptible than those of the laboratory colony. The study areas were selected on the basis of previous tests that indicated a decrease in susceptibility to malathion. No resistance to naled (<2 times) was found in either the larval or adult stages. F_1 larvae and adults of *Culex nigripalpus* Theob. collected from five counties were shown to be as susceptible to malathion as those of the susceptible laboratory colony of this species. Larvae of this species from two counties showed no resistance (<2 times) to naled compared to the laboratory colony, while F_1 adults from two counties appeared to be 2½–3 times less susceptible.

Concurrent reports of resistance to malathion in 1966 by Gahan et al., and in 1967 by Rathburn and Boike revealed that populations of *A. taeniorhynchus* on some of the offshore islands of southwest Florida, in some areas of Pinellas and Hillsborough Counties, and in some locations on the East Coast were becoming increasingly less susceptible to malathion. During 1969–71, populations of *A. taeniorhynchus* from Sanibel Island exhibited malathion resistance (Boike and Rathburn, 1972), while Mount et al. (1971) reported on a malathion resistant strain of *A. taeniorhynchus* from Allenhurst in Brevard County on the East Coast. This is a report of testing Florida mosquito populations for insecticide susceptibility during 1972–74 with emphasis on areas of suspected and previously reported malathion resistance.

MATERIALS AND METHODS. Samples of wild adult mosquitoes from different areas in the state were sent to the laboratory in styrofoam cooler chests. The methods of collecting, shipping, rearing, and larval testing were the same as described by Rathburn and Boike (1967). Adult mosquitoes tested were 2–8 days old and were fed a 5% sugar solution on a cotton pad prior to and after testing. Tests were conducted in a wind tunnel similar to that described by Rathburn (1969), with the exception that the heater and condensation tube were not used. One-half milliliter of the insecticide solution, diluted to predetermined concentrations in acetone, was sprayed at 15 psi into the wind tunnel. A replication consisted of 1 cage of 25 female mosquitoes for each of a series of 4 insecticide dilutions plus an acetone check. Fewer mosquitoes were sometimes used if sufficient numbers were not available. The test cages used and other methods of the wind tunnel operation were essentially the same as described by Rathburn and Boike (1972).

RESULTS AND DISCUSSION. Results of tests of malathion and naled against larvae of both species are shown in Table 1 and against adults in Table 2. In the discussion of results, the statements of resistance levels are based upon the susceptibility level of the test mosquitoes as compared with the susceptibility level of the laboratory colony. It is felt that an

Table 1. Susceptibility of F_1 generation *Aedes taeniorhynchus* and *Culex nigripalpus* larvae from various areas of Florida to malathion and naled, 1972–74.

County	Area	Year	Reps	Lethal concentration in ppm. LC50	LC90
		Aedes taeniorhynchus—malathion			
Lab colony	Panama City	1972	40	0.018	0.034
Lab colony	Panama City	1973	18	0.018	0.035
Bay	P. C. Beach	1972	4	0.024	....
Brevard	Shiloh	1972	11	0.135	0.650
Monroe	Marathon	1973	10	0.210	0.910
Monroe	Little Duck Key	1973	4	0.300	1.040
Lee	Sanibel Is.	1973	16	0.086	0.370
Sarasota	Longboat Key	1973	20	0.036	0.220
Hillsborough	MacDill AFB	1973	8	0.380	0.970
Hillsborough	Ruskin	1973	4	0.021	0.074
Martin	Jensen Bch.	1973	2	0.048	0.380
Dade	Miami	1974	14	0.132	0.504
		Culex nigripalpus—malathion			
Lab colony	Panama City	1972	28	0.027	0.046
Lab colony	Panama City	1973	28	0.029	0.045
Bay	P. C. Beach	1972	8	0.048	0.064
Bay	State Park	1972	4	0.026	0.048
Pinellas	L. Maggiore	1973	16	0.040	0.062
Manatee	Bradenton	1973	12	0.038	0.071
Martin	Jensen Bch.	1973	8	0.048	0.079
Martin	Salerno	1973	16	0.045	0.075
Palm Beach	Boynton Bch.	1973	17	0.055	0.077
		Aedes taeniorhynchus—naled			
Lab colony	Panama City	1972	28	0.064	0.118
Lab colony	Panama City	1973	14	0.063	0.134
Monroe	Marathon	1973	4	0.085	0.240
Sarasota	Longboat Key	1973	4	0.074	0.180
Hillsborough	MacDill AFB	1973	2	0.098	0.148
Dade	Miami	1974	7	0.060	0.130
		Culex nigripalpus—naled			
Lab colony	Panama City	1972	22	0.042	0.056
Lab colony	Panama City	1973	12	0.040	0.060
Manatee	Bradenton	1973	12	0.046	0.064
Martin	Jensen Bch.	1973	5	0.075	0.101
Martin	Salerno	1973	12	0.053	0.084

increase in the LC_{50} and LC_{90} of approximately 2 times or less as compared to the laboratory colony does not indicate a significant degree of resistance and may be due to a natural tolerance of some field strains to these insecticides.

MALATHION vs *Aedes taeniorhynchus*. In these tests, larvae from Marathon and Little Duck Key in Monroe County were 11.7 and 16.7 times respectively more resistant at the LC_{50} level than the laboratory colony, and 26.0 and 29.7 times respectively at the LC_{90} level. In extreme north Brevard County a population of *A. taeniorhynchus* was 7.5 times more resistant at the LC_{50} level and 18.6 times at the LC_{90} level. This substantiates reports of Rathburn and Boike (1967), Boike and Rathburn (1969, 1972) and Mount, et al. (1971) of a high degree of tolerance to malathion in populations of *A. taeniorhynchus* in that part of Brevard County. Larvae from MacDill AFB in Hillsborough County were 21.1 times more resistant at the LC_{50} level and 27.7 times at the LC_{90} level. These values indicate that a high level of resistance has continued in *A. taeniorhynchus* in this area since it was first found in 1965 (Rathburn and Boike, 1967).

Larvae from Sanibel Island in Lee County were 4.8 and 10.6 times more resistant at the LC_{50} and LC_{90} levels than the laboratory colony while F_1 adults were approximately 10 and 18 times resistant at these levels. A fairly high level of resistance was found in a population of *A. taeniorhynchus* from Dade County; the LC_{50} and LC_{90} values being 7.3 and 14.4 times the laboratory colony. Adults from this same area were 23 times less susceptible to malathion than the laboratory colony at the LC_{50} level. Larvae from Longboat Key in Sarasota County were 2.0 and 6.3 times more resistant to malathion at the LC_{50} and LC_{90} levels; however, adults from this area showed approximately 9-fold tolerance at the LC_{50} level and about 30 times at the LC_{90}. A lower level of resistance was found in larvae from Jensen Beach in Martin County where the LC_{50} and LC_{90} values were 2.7 and 10.9 times that of the laboratory colony. Two of the areas sampled showed no resistance, Ruskin, located across Tampa Bay from MacDill AFB in Hillsborough County and Panama City Beach in Bay County. Similar results were reported from Ruskin in 1965 (Rathburn and Boike, 1967) and from Panama City Beach in 1967 and 1968 (Boike and Rathburn, 1968, 1969).

Malathion vs *Culex nigripalpus*. LC_{50} and LC_{90} values for larvae from seven areas in five counties were all less than two times that of the laboratory colony, indicating no resistance to malathion. F_1 adults from Salerno, Lake Maggiore and Bradenton were approximately two times less susceptible at both the LC_{50} and LC_{90} levels.

Naled vs *Aedes taeniorhynchus*. Larvae from Marathon, Longboat Key, MacDill

Table 2. Susceptibility of F_1 generation *Aedes taeniorhynchus* and *Culex nigripalpus* adults from various areas in Florida to malathion and naled, 1972–74.

County	Area	Year	Reps	Milligrams a.i. per Milliliter LC_{50}	LC_{90}
		Aedes taeniorhynchus—malathion			
Lab colony	Panama City	1973	10	0.013	0.33
Sarasota	Longboat Key	1973	8	1.15	10.30
Lee	Sanibel Is.	1973	11	1.19	6.00
Dade	Miami	1974	5	3.20	....
		Culex nigripalpus—malathion			
Lab colony	Panama City	1973	20	0.64	2.80
Martin	Salerno	1973	5	1.36	3.90
Palm Beach	Boynton Bch.	1973	12	1.03	4.50
Pinellas	L. Maggiore	1973	9	1.26	4.50
Manatee	Bradenton	1973	10	1.41	5.80
		Aedes taeniorhynchus—naled			
Lab colony	Panama City	1972	10	0.100	0.256
Lab colony	Panama City	1973	10	0.083	0.255
Sarasota	Longboat Key	1973	4	0.155	0.222
Lee	Sanibel Is.	1973	4	0.110	0.235
		Culex nigripalpus—naled			
Lab colony	Panama City	1972	10	0.076	0.196
Lab colony	Panama City	1973	14	0.063	0.131
Martin	Salerno	1973	4	0.114	0.278
Martin	Jensen Bch.	1973	2	0.190	0.400
Palm Beach	Boynton Bch.	1973	2	0.177	0.321

AFB, and Miami showed no resistance to naled. Both LC_{50} and LC_{90} values were less than twice that of the laboratory colony. Similarly, F_1 adults from Longboat Key and Sanibel Island showed no resistance.

NALED vs *Culex nigripalpus*. Larvae from Jensen Beach in Martin County were approximately twice as tolerant to naled as the laboratory colony while F_1 adults were 3 times. Larvae from Bradenton and Salerno and F_1 adults from Salerno were not resistant, and adults from Boynton Beach and Jensen Beach were only 2½–3 times less susceptible than the laboratory colony.

In general, the above tests indicate malathion resistant populations of *A. taeniorhynchus* were confined mainly to coastal areas of Florida and the Keys, and no resistance to naled was found. Populations of *C. nigripalpus* from these same areas were generally susceptible to both malathion and naled.

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References Cited

Boike, A. H., Jr. and C. B. Rathburn, Jr. 1968. Tests of the susceptibility of Florida mosquitoes to insecticides, 1967. Mosq. News 28(3):313–316.

Boike, A. H., Jr. and C. B. Rathburn, Jr. 1969. Laboratory tests of the susceptibility of mosquito larvae to insecticides in Florida, 1968. Mosq. News 29(3):392–395.

Boike, A. H., Jr. and C. B. Rathburn, Jr. 1972. The susceptibility of mosquito larvae to insecticides in Florida, 1969–1971. Mosq. News 32(3):328–331.

Gahan, J. B., C. N. Smith and B. M. Glancy. 1966. Resistance in Florida and countermeasures involving chemicals. Mosq. News 26(3):330–337.

Mount, G. A., D. A. Dame and C. S. Lofgren. 1971. Susceptibility of a Florida strain of *Aedes taeniorhynchus* (Wiedemann) to insecticides. Mosq. News 31(3):438–440.

Rathburn, C. B., Jr. and A. H. Boike, Jr. 1967. Studies of insecticide resistance in Florida mosquitoes. Mosq. News 27(3):377–382.

Rathburn, C. B., Jr. 1969. A laboratory thermal aerosol generator for the testing of insecticidal aerosols. Mosq. News 29(1):1–6.

Rathburn, C. B., Jr. and A. H. Boike, Jr. 1972. Laboratory thermal aerosol tests of new insecticides for the control of adult mosquitoes. Mosq. News 32(2):179–183.

1975 Boike, A. H., Jr., and C. B. Rathburn, Jr.
Laboratory Non-Thermal Aerosol Tests Of Insecticides For The Control Of Adult Mosquitoes
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CONCLUSION. The new sampling method described will produce a droplet spectrum on a slide which is essentially the same as that produced by the conventional method. However, the new method 1) eliminates several potential sampling errors, 2) avoids the unpleasantness of standing in the concentrated insecticide cloud, and 3) produces more droplets on the slide which are nearly round in shape and thus more accurately measured.

The Leco produces an unusually high output velocity. Further experimentation is needed to see if this method of sampling can be adapted to measure the droplet output of other ULV machines. Moving the pendulum closer to the nozzle and impeding or accelerating its swing through the aerosol cloud in some easily repeatable fashion might be necessary to achieve results comparable to ours run with the Leco. Or it may turn out that other ULV's simply do not produce enough velocity to impinge small droplets on a passive target, and that with these, the swing method will remain the best inexpensive sampling technique.

References Cited

Anderson, C. H. and Schulte, W. 1971. Teflon® as a surface for deposition of aerosol droplets. Mosq. News 31:499–504.

Anon. 1974. Malathion ULV concentrate insecticide, U.S.D.A. Reg. No. 241–110–AA, Label No. PE3567. American Cyanamid Co., Princeton N. J. 21 pp.

Mount, G. A. and Pierce, N. W. 1972. Droplet size of ultra low volume ground aerosols as determined by three collection methods. Mosq. News 32:586–589.

LABORATORY NON-THERMAL AEROSOL TESTS OF INSECTICIDES FOR THE CONTROL OF ADULT MOSQUITOES

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ABSTRACT. Non-thermal aerosol sprays of 13 insecticides were compared with malathion as the standard against laboratory reared females of *Aedes taeniorhynchus* (Wied.) and *Culex nigripalpus* Theob. in a laboratory wind tunnel. Baygon and the natural and synthetic pyrethrins were more toxic to *Culex* and the organophosphates were more effective against *Aedes*.

The West Florida Arthropod Research Laboratory conducts preliminary laboratory wind tunnel tests of promising new insecticides for possible use as mosquito adulticides. This report contains the results of non-thermal aerosol tests of 13 insecticides against 2 species of mosquitoes.

MATERIALS AND METHODS. Laboratory reared adults of *Aedes taeniorhynchus* (Wied.) and *Culex nigripalpus* Theob. were placed in circular screened cages and exposed to predetermined concentrations of various insecticides as previously described by Boike and Rathburn (1975). The insecticides evaluated were Baygon 1-MOS, S-bioallethrin, SBP-1513 (3-phenoxybenzyl (±)-cis, trans-2, 2-dimethyl 1-3-(2,2-dichlorovinyl) cyclopropane carboxylate), pyrethrins, naled, chlorpyrifos, Dowco 214 (o,o-dimethyl o-3,5,6-trichloro-2-pyridyl phosphorothioate), phenthoate, pirimiphos methyl, d-trans allethrin, resmethrin, BAS-2350-I (3,5 diethyl-phenyl-N-methyl-carbamate) and dimethrin. Malathion was used as the standard.

RESULTS AND DISCUSSION. Results are shown in Table 1. The LC_{50} and LC_{90} in milligrams of active ingredient per mil

Table 1. Toxicity of insecticides applied as non-thermal aerosols in the laboratory to caged adult *Aedes taeniorhynchus* (Wied.) and *Culex nigripalpus* Theob.

	Milligrams a.i. per milliliter						Reciprocal LC_{90} ratio to malathion		LC_{90} ratio of *Culex* to *Aedes*
	Aedes			*Culex*					
Insecticide	Reps	LC_{50}	LC_{90}	Reps	LC_{50}	LC_{90}	*Aedes*	*Culex*	
Baygon 1-MOS	12	0.071	0.212	12	0.062	0.178	1.76	10.62	0.84
S-bioallethrin [1]	10	0.075	0.215	8	0.058	0.155	1.74	12.19	0.72
SBP-1513	8	0.063	0.230	10	0.021	0.068	1.63	27.79	0.30
pyrethrins [1]	11	0.088	0.250	12	0.029	0.092	1.50	20.54	0.37
naled	34	0.095	0.251	36	0.069	0.159	1.49	11.89	0.63
chlorpyrifos	12	0.140	0.288	12	0.219	0.465	1.30	4.06	1.61
Dowco 214	8	0.152	0.320	12	0.330	1.020	1.17	1.85	3.19
phenthoate	10	0.103	0.325	11	0.190	0.725	1.15	2.61	2.23
pirimiphos methyl	10	0.155	0.335	11	0.207	0.455	1.12	4.15	1.36
malathion	52	0.148	0.374	59	0.620	1.890	1.00	1.00	5.05
d-trans allethrin [2]	11	0.280	0.870	11	0.110	0.310	0.43	6.10	0.36
resmethrin	10	0.370	1.300	8	0.043	0.142	0.29	13.31	0.11
BAS-2350-I	10	1.200	3.700	10	0.830	2.300	0.10	0.82	0.62
dimethrin	10	1.100	3.700	12	2.100	6.300	0.10	0.30	1.70
dimethrin [3]	10	1.100	4.500	13	1.700	6.200	0.08	0.30	1.38

[1] Synergized with piperonyl butoxide (1:5).
[2] Synergized with tropital (1:5).
[3] Synergized with piperonyl butoxide (1:1).

liliter were obtained from dosage-mortality curves. The insecticides are arranged in descending order of their toxicity to *A. taeniorhynchus* when compared with malathion. Baygon 1-MOS, S-bioallethrin, SBP-1513, synergized pyrethrin, naled, and chloryprifos were 1.76 to 1.30 times more toxic to *A. taeniorhynchus* in that order than was malathion. The relative toxicity of naled to malathion is the same as that obtained by Mount and Pierce (1973); however, the relative toxicity of pyrethrins is considerably less than the 6-fold difference they obtained. Data in Table 1 also show that Dowco 214, phenthoate and pirimphos methyl were only slightly more toxic than the standard. Mount et al. (1970) also reported similar results for Dowco 214. Synergized d-trans allethrin, unsynergized resmethrin, BAS-2350-I and dimethrin (alone and synergized) were all found to be less toxic to *A. taeniorhynchus* than malathion. The relatively poor performance of unsynergized resmethrin against *A. taeniorhynchus* both in the laboratory and in the field, has been substantiated by Rathburn and Boike (1972, 1975) and Mount and Pierce (1973). Dimethrin also was reported by Hadaway et al. (1970) to give poor results against *Anopheles stephensi* Liston and *Aedes aegypti* (L.).

Against *C. nigripalpus*, SBP-1513 and synergized pyrethrin were 28 and 21 times more toxic respectively than malathion. The data obtained with pyrethrin compare favorably with that of Mount and Pierce (1973) who found pyrethrin synergized by piperonyl butoxide to be about 25 times as toxic as malathion. Resmethrin, S-bioallethrin, naled, and Baygon 1-MOS were approximately 11–13 times more toxic, while d-trans allethrin, pirimiphos methyl, chlorpyrifos, and phenthoate were 2–6 times more toxic than malathion to *C. nigripalpus*. The carbamate BAS-2350-I and dimethrin (alone and synergized) were less effective than the standard.

The pyrethroids (SBP-1513, d-trans allethirn, and resmethrin) and the pyrethrin were found to be considerably more toxic to *C. nigripalpus* than to *A. taeniorhynchus*, while Dowco 214, phenthoate, and malathion were more toxic to *A. taeniorhynchus* than *C. nigripalpus*.

The relative toxicity of naled to *A. taeniorhynchus* and *C. nigripalpus* compares favorably to the difference obtained by Mount and Pierce (1973); however, they showed pyrethrins to be equally effective against both species. The results of these tests indicate that pyrethrins are 2–3 times more effective against *C. nigripalpus* than *A. taeniorhynchus*. This difference was also substantiated in field tests (Rathburn and Boike, 1975).

References Cited

Boike, A. H., Jr. and C. B. Rathburn, Jr. 1975. Laboratory susceptibility tests of some Florida strains of *Aedes taeniorhynchus* (Wied.) and *Culex nigripalpus* Theob. to malathion and naled, 1972–1974. Mosq. News 35(2):137–140.

Hadaway, A. B., F. Barlow, J. E. H. Grose, C. R. Turner and L. S. Flower. 1970. Evaluation of compounds for insecticidal activity on adult mosquitoes. WHO Bull. 42(3):387–398.

Mount, G. A., K. F. Baldwin and C. S. Lofgren. 1970. Effectiveness of seven promising mosquito adulticides. Mosq. News 30(2):213–214.

Mount, G. A. and N. W. Pierce. 1973. Toxicity of selected adulticides to six species of mosquitoes. Mosq. News 33(3):368–370.

Rathburn, C. B., Jr. and A. H. Boike, Jr. 1972. Laboratory thermal aerosol tests of new insecticides for the control of adult mosquitoes. Mosq. News 32(3):179–183.

Rathburn, C. B., Jr. and A. H. Boike, Jr. 1975. Ultra low volume tests of several insecticides applied by ground equipment for the control of adult mosquitoes. Mosq. News 35(1):26–29.

ULTRALOW VOLUME GROUND AEROSOLS OF PROPOXUR (BAYGON® MOS) FOR CONTROL OF ADULT MOSQUITOES [1]

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ABSTRACT. Comparative tests demonstrated that ultralow volume (ULV) aerosols of propoxur (Baygon® MOS) were 2.4 and 3.2× more effective than aerosols of technical malathion against *Aedes taeniorhynchus* (Wiedemann) and *Anopheles quadrimaculatus* Say, respectively. The Baygon MOS formulation provided more efficient use of propoxur than a previous Baygon ULV formulation used as an ULV aerosol.

The first wind-tunnel aerosol tests with propoxur at our laboratory showed it to be ca. 3× more toxic than malathion to adult female *Aedes taeniorhynchus* (Wiedemann) (Gahan and Davis 1964). Since that time a number of investigators have demonstrated the efficacy of high volume aerosols of propoxur against *Aedes, Culex,* and *Anopheles* mosquitoes (Gahan *et al.* 1965; Lofgren *et al.* 1966, 1967; Mount *et al.* 1966; Mount and Lofgren 1967; Shipp and Hazeltine 1967; Taylor and Schoof 1968). The first ultralow volume (ULV) aerosol tests with propoxur (2 lb AI/gal ULV formulation) indicated that it was about equal to malathion against caged adult *Ae. taeniorhynchus* (Mount and Pierce 1971). This comparison suggested that some changes in formulation and/or aerosolization were needed to utilize more efficiently propoxur as a ULV aerosol. Subsequently, a new formulation of propoxur (Baygon® Mosquito Oil Spray (MOS) —1 lb AI/gal) was developed

[1] This paper reflects the results of research only. Mention of a pesticide or a commercial or proprietary product in this paper does not constitute a recommendation or an endorsement of this product by the U.S. Department of Agriculture.

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149

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ULTRA LOW VOLUME TESTS OF SEVERAL INSECTICIDES APPLIED BY GROUND EQUIPMENT FOR THE CONTROL OF ADULT MOSQUITOES

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ABSTRACT. Ultra low volume field tests of several insecticides applied by ground equipment were conducted using caged adult *Aedes taeniorhynchus* and *Culex nigripalpus*. Species susceptibility was an important factor in establishing the effective dosage of each insecticide. Chlorpyrifos, fenthion, actellic, Dowco 214, malathion and malathion-naled gave better kill of *A. taeniorhynchus* than *C. nigripalpus*, while pyrethrum-piperonyl butoxide and resmethrin gave better kill of *C. nigripalpus* than *A. taeniorhynchus*.

Presently there are 6 insecticides that have label approval for application as ultra low volume (ULV) sprays by ground equipment in Florida. These are malathion, pyrethrins, resmethrin, fenthion, naled and chlorpyrifos (Dursban). The authors have previously reported on the ULV application of malathion (Rathburn and Boike, 1972a) and resmethrin (Rathburn and Boike, 1972b) for the control of *Aedes taeniorhynchus* (Wiedemann) and *Culex nigripalpus* Theobald. This research was conducted to establish effective dosages for the insecticides presently labeled for ULV use and for other insecticides which have shown promise in laboratory spray tests against the above two mosquito species in Florida.

METHODS. All tests were conducted in the early evening hours after sunset. Temperatures ranged from 66 to 86° F and averaged 78.8° F. Wind velocities ranged from 1 to 10 mph and averaged 4.6 mph. The test plot was a fairly open beach residential area with a few houses and a few large pine trees but with little ground vegetation.

Four cages of mosquitoes, two of *A. taeniorhynchus* and two of *C. nigripalpus* each containing 25 females, were attached to a metal pole. One cage of each species was hung at 6 ft. and another at 2 ft. above the ground. The poles were placed at 165 and 330 ft. down wind and perpendicular to the line of travel of the first swath of the aerosol generator. A second and third swath were applied at 1 and 2 blocks (300 and 600 ft.) up wind of the 1st swath. Each test or replicate consisted of the cages of mosquitoes from 3 sets of 2 poles (165 and 330 ft.) placed a block (600 ft.) apart, or a total of 12 cages of each species. The cages were 6 in. in diameter and 1 in. deep with 14 x 18 mesh screen on both circular surfaces, and were hung vertically on the poles with the screened surfaces facing into the wind.

All mosquitoes used in the test were from laboratory colonies and were between 2 and 8 days old. After exposure the mosquitoes were transferred to clean holding cages and held with access to a 5% sugar solution on cotton pads for 12 to 15 hours at which time mortality counts were made.

All tests except those with 1% naled were conducted with a Leco HD ULV cold aerosol generator mounted on a flat bed truck. The aerosol was discharged at an upward angle of 45° and at a vehicle speed of 5 or 10 mph. An insecticide tank pressure of 4 psi was used in all tests except those with malathion and malathion-naled. These tests were conducted with an earlier model Leco HD ULV with which a formulation pressure of 3 psi was recommended. The flow rate was adjusted by means of a needle valve in the flowmeter. Various flowmeter tube and ball float combinations were used to obtain the desired discharge rates over the range of temperatures which would be experienced. The tests with 1% naled were conducted with a Buffalo Turbine Model M cold aerosol generator utilizing 5 Sonicore nozzles at 80 psi air pressure and 40 psi liquid pressure. It was necessary to use this equipment since the desired discharge rate could not be obtained with the Leco HD ULV unit. Spraying time was recorded by a stop watch and the insecticide was measured before and after each test. Actual spray times averaged 16.5 minutes and varied from 11 to 25 minutes, depending on the length of run necessary to cover the test area. Tests in which the actual discharge varied more than 10% were discarded.

Results. The average corrected percent kill of the 2 species of mosquitoes at various discharge rates of the different insecticides is shown in Table 1. All percentage formulations shown except for pyrethrins-piperonyl butoxide are given as volume to volume. The pyrethrins-piperonyl butoxide formulation is given as weight to weight as shown on the label. The pounds active ingredient per gallon are shown in parentheses for each insecticide used as an undiluted ULV spray. Discharges are reported in gallons per hour instead of fl. oz./min. because the amounts discharged in actual control operations can more readily be obtained since spraying time is recorded in hours. The actual kill obtained in each test was corrected for check mortality which averaged 1.3% for *A. taeniorhynchus* and 0.4% for *C. nigripalpus*.

Chlorpyrifos is labeled for use at up to 1⅓ fl. oz./min. (0.62 gph) at a vehicle speed of 10 mph. Although excellent kill was obtained with *A. taeniorhynchus* at this dosage, it appears that at least 0.75 gph will be required to control *C. nigripalpus*.

Fenthion is labeled for use at up to 1 fl. oz./min. (0.5 gph) at a vehicle speed of 10 mph. At this dosage excellent kill of both *A. taeniorhynchus* and *C. nigripalpus* was obtained.

Naled is labeled for use at 6 to 12 fl. oz./min. of 10% by volume solution of Dibrom 14 in heavy aromatic naphtha (HAN) or soybean oil at 10 mph. However, due to severe respiratory irritation at this concentration, this formulation is not recommended by the Florida Division of Health, Bureau of Entomology. A 1% by volume solution of Dibrom in No. 2 diesel oil with 1% by volume Ortho Additive was shown not to cause respiratory irritation; therefore, this formulation was tested at 20 gph with the Buffalo Turbine Model M. As shown in Table 1, this formulation of naled gave excellent kill of both *A. taeniorhynchus* and *C. nigripalpus*.

A solution of 5% pyrethrins and 25% piperonyl butoxide by weight in Klearol is labeled for use at 2 to 2.25 fl. oz./min. at a vehicle speed of 5 mph or 0.002 to

Table 1. Ultra low volume tests of several insecticides applied by ground equipment for the control of adult mosquitoes.

Insecticide	Formulation percent or (lb A.I./gal)	Discharge gph	Vehicle speed mph	No. of tests[1]	*A. taeniorhynchus* Avg	*A. taeniorhynchus* Range	*C. nigripalpus* Avg	*C. nigripalpus* Range
Chlorpyrifos	(6.0)	1.00	10	5	100	99–100	94	89–98
		0.75	10	2	100	all 100	98	97–98
		0.62	10	5(7)	99	97–100	70	44–96
		0.50	10	4	91	83–96	55	38–77
Fenthion	(9.67)	0.50	10	4(5)	100	all 100	98	93–100
Naled	1.0	20.00	10	4	95	89–99	95	89–100
Pyrethrins-Piperonyl Butoxide	5.0–25.0	4.00	10	2	97	96–98	100	all 100
		2.00	10	3	81	69–91	96	93–97
Actellic	(5.0)	1.00	5	2	99	all 99	99	98–100
		0.75	5	1	97	....	62	....
		0.50	5	4	83	56–98	58	32–93
Dowco 214	(6.0)	1.00	5	3	100	99–100	63	38–80
		0.50	5	3	93	79–100	65	all 65
Malathion	25.0	1.00	5	5	95	90–100	57	40–76
Malathion-Naled	25.0–2.5	1.00	5	2	95	91–98	72	69–75
	25.0–5.0	1.00	5	2	96	91–100	64	43–85
Resmethrin	10.0	2.00	5	3(2)	4	2–8	83	72–93

(Average corrected percent kill)

[1] Figures in parentheses are the number of tests for *C. nigripalpus*.

0.0025 lb./acre pyrethrins. For *A. taeniorhynchus* in Florida the label states that rates up to 0.008 lb./acre of pyrethrins may be used. The results show that the 5% pyrethrins-25% piperonyl butoxide formulation by weight in Klearol at 2.0 gph gave excellent kill of *C. nigripalpus*, but 4.0 gph was required to give the same degree of kill of *A. taeniorhynchus*.

Two compounds, Actellic (pirimiphos-methyl) and Dowco 214 (0,0-diethyl 0-(3, 5, 6-trichloro-2-pyridyl) phosphorothioate) which at present do not have label approval for use as ULV sprays, also were tested because they had previously shown promise in laboratory spray tests (Rathburn and Boike, 1972c). As shown in Table 1, excellent control of both mosquito species was obtained with Actellic at 1 gph at a vehicle speed of 5 mph, whereas 0.5 gph was not effective. One test at 0.75 gph resulted in good kill of *A. taeniorhynchus* but poor kill of *C. nigripalpus*. Dowco 214 gave satisfactory kill of *A. taeniorhynchus* at 0.5 gph at a vehicle speed of 5 mph but even at 1.0 gph was not effective against *C. nigripalpus*.

Malathion at 0.5 gph at a vehicle speed of 5 mph has been shown to give excellent kill of *A. taeniorhynchus* (Rathburn and Boike, 1972a) and even lower dosages may be satisfactory in open areas. Because higher discharge rates might result in better coverage and higher kill under varying conditions of terrain and vegetation, a mixture of 25% by volume of malathion 95 in peanut oil was tested at 1 gph. Even at this reduced dosage excellent kill of *A. taeniorhynchus* was obtained. The kill of *C. nigripalpus*, however, was poorer than that obtained with 0.5 gph technical malathion. Since naled is extremely effective against *C. nigripalpus*, small percentages of this toxicant were formulated with the 25% malathion in peanut oil. Although a slight increase in kill of *C. nigri-*

palpus was noted, these amounts of naled did not increase the kill to an effective level.

Resmethrin, which is labeled for use at 0.007 lb./a. (equivalent to 0.42 gph @ 5 mph for swath of 330 ft.), also had been tested previously (Rathburn and Boike, 1972b) and was found to be effective against *C. nigripalpus* but not against *A. taeniorhynchus* at 0.5 gph at a vehicle speed of 5 mph. Higher volumes of this insecticide were tested in an effort to increase the degree of coverage and possibly increase the kill. As shown in Table 1, unsatisfactory results were obtained with a 10% by volume dilution of resmethrin (40% technical concentrate) in peanut oil at 2 gph. The results were similar to those previously obtained with the equivalent dosage of 0.2 to 0.25 gph of the undiluted 40 percent concentrate.

DISCUSSION. Mount and Pierce (1971) using field tests of caged *Aedes taeniorhynchus* calculated an LD_{90} in fl. oz. per min. at 10 mph of 1.9 for Dowco 214, 2.2 for Dursban (chlorpyrifos) 10.3 for SBP-1382 (resmethrin), 0.7 for fenthion and 2.0 for malathion. Since the actual discharge rates and vehicle speeds were not stated and ranged from 1 to 9.5 fl. oz. per min. and from 5 to 20 mph respectively, precise comparisons with the data shown in Table 1 are questionable, but generally results are similar. Many other similar studies are also reported in the literature, but because different testing procedures, different equipment, different insecticides, and/or different mosquito species were used results cannot be compared to those shown here.

Although labeled dosages of fenthion appear to be effective against both *A. taeniorhynchus* and *C. nigripalpus*, this is not the case with chlorpyrifos which gives considerably less kill against *C. nigripalpus*. This points out the fact that all insecticides are not equally effective against all mosquito species at the same dosage. Only 2 species of mosquitoes were used in these tests, but they represent 2 different genera, and experience has shown that these species generally show a great difference in susceptibility to many insecticides. For instance, about twice the dosage of malathion is required to kill *C. nigripalpus* as *A. taeniorhynchus*, but with pyrethrins this difference is reversed, *A. taeniorhynchus* requiring about twice the dosage as *C. nigripalpus*; and with resmethrin, a synthetic pyrethrin, the dosage which gave 83% kill of *C. nigripalpus* gave only 4% kill of *A. taeniorhynchus*. Therefore, we cannot state that a particular dosage is effective for all mosquitoes; we must stipulate what species that dosage will control.

Literature Cited

Mount, G. A. and N. W. Pierce. 1971. Eleven promising insecticides evaluated as ultra low volume cold aerosols against *Aedes taeniorhynchus* (Wiedemann). Mosq. News 31(1): 77-79.

Rathburn, C. B., Jr. and A. H. Boike, Jr. 1972a. Ultra low volume tests of malathion applied by ground equipment for the control of adult mosquitoes. Mosq. News 32(2):183-187.

Rathburn, C. B., Jr. and A. H. Boike, Jr. 1972b. Ultra low volume tests of SBP-1382 applied by ground equipment for the control of adult mosquitoes. Mosq. News 32(3):334-337.

Rathburn, C. B., Jr. and A. H. Boike, Jr. 1972c. Laboratory thermal aerosol tests of new insecticides for the control of adult mosquitoes. Mosq. News 32(2):179-183.

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MALATHION AND NALED AS MOSQUITO ADULTICIDES IN ALASKA [1]

J. RICHARD GORHAM [2]

ABSTRACT Wild-caught *Aedes* mosquitoes and water striders *(Gerris buenoi)* were exposed in cages to low-volume fogs of malathion and naled. The cages were arrayed at two levels—on the ground and 6 feet above ground—from 100 feet to 500 feet from point of discharge. Mortality was consistently high at 100 feet for both insecticides when the cages were placed 6 feet above ground, but beyond that point mortality decreased in relation to increasing distance from point of discharge and in relation to the height and density of ground cover between each cage and the point of discharge. Malathion nonthermal fog and naled thermal fog penetrated dense ground cover much more readily and with greater insecticidal effect than naled nonthermal fog. In those cases where the fog readily reached the cages, naled produced a much higher percentage of knockdown (1-hour postspray) of both mosquitoes and water striders. Water striders were more susceptible to naled (40–61% mortality) than to malathion (13–21%). Malathion and naled as nonthermal fogs were both effective against adult mosquitoes, but malathion would be preferable where the target areas included dense underbrush and aquatic habitats.

Introduction. Adulticiding as a technique of mosquito suppression was extensively tested in Alaska about 25 years ago (Jackowski and Schultz 1948, Blanton *et al.* 1950, Hedeen and Keegan 1952, Wilson 1951). Three organochlorine adulticides (DDT, dieldrin and lindane) were tested, but only DDT came into operational use. Those early tests demonstrated that the duration of effective protection from mosquito attack was related to either frequency of treatment (in the case of ground application) or size of the treated area (in the case of aerial application).

A ground-based system, consisting of generators to dispense DDT in an aerosol form (Wilson 1950), was developed as one approach to the major mosquito problem of Alaska: How to protect small enclaves of people surrounded by vast regions highly productive of mosquitoes. This system provided effective protection from mosquitoes (also from blackflies, Berg 1951) so long as it was in operation and for a short period thereafter. Frequent applications of DDT were required to maintain an acceptable level of protection, and the equipment required careful attention to keep it in operating condition.

Ground-based methods aimed at adult mosquito suppression were largely abandoned in favor of aerial techniques. Reinvasion of treated areas still occurred, but the aerial techniques permitted treatment of much larger target areas. Treatment of a 4 mi^2 area with DDT provided protection for about 48 hours; 24–30 mi^2, 5–7 days; 100 mi^2, 3 days; and 100 mi^2, 14 days (Blanton *et al.* 1949, Wilson 1951). Such treatments kill a large part of the mosquitoes in the target area, but the duration of relief from further attack seems to depend on the population dynamics of the mosquitoes peripheral to the treated area.

From 1950 until 1965, Fairbanks and the major military installations were sprayed with DDT at least once each summer by military aircraft. Bush pilots did some contract spraying with small aircraft in Anchorage during this period. With the exception of one experimental application in 1967 (Mount *et al.* 1969), DDT was last used as a mosquito adulticide in Alaska in 1965. Malathion was used thereafter for that purpose in all

[1] Paper number 9 in the series, "Studies of the Biology and Control of Arthropods of Health Significance in Alaska." This project was partially supported by the Alaskan Air Command. Use of trade names is for identification purposes only and does not constitute endorsement by the Public Health Service.

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localities (except Ft. Greeley) where adult mosquito suppression was attempted. At Ft. Greeley naled was used routinely in a ULV system from 1967 to 1972.

From 1966 to 1969 the Special Aerial Spray Flight of Langley Air Force Base, Virginia, made one trip each summer to Alaska to apply adulticidal malathion to those military reservations requiring treatment. Since 1969 aerial applications of malathion have been done only by bush pilots working under private contracts to spray certain residential districts of Anchorage. Except for these occasional operations by bush pilots, all adult mosquito suppression in Alaska, since 1970, has been done with ground equipment.

Tests were conducted in 1967 to compare the effectiveness of malathion and DDT as adulticides applied from the ground as nonthermal fogs, and to demonstrate the effectiveness of malathion applied with an aerial ULV system (Mount *et al.* 1969). Analysis of soil samples collected before and after this series of tests indicated that malathion and one of its degradation products, malaoxon, persisted in the soil for various lengths of time ranging up to one year (Holty 1970).

TEST POPULATIONS. Fifteen species of mosquitoes, all females, were included in the test populations, but most of these species comprised less than 1 percent of the total (main species: *Aedes intrudens*, 49%; *Ae. fitchii*, 14%; *Ae. communis*, 10%; *Ae. punctor*, 9%). All mosquitoes and water striders used in these tests were collected within the limits of Eielson Air Force Base.

The water striders (*Gerris buenoi*), all taken from one pond, were chosen for use in these tests because they were abundant and readily available and because they are usually associated with unpolluted aquatic environments. Their presence at the air-water interface makes them probable, if inadvertent, targets of air-borne insecticides.

The water striders proved to be very tractable experimental subjects. Once captured, they assumed a quiescent disposition which made them very easy to count and transfer to cages. They were kept in an insulated chest on water from their pond until time for transfer to cages. If the high rate of survival of the controls was any indication, then the loss of contact with water upon transfer to the cages was not notably detrimental.

TEST PROCEDURES. The basic test procedure, described elsewhere (Gorham 1972), called for an array of cages (see Rathburn *et al.* 1969 for cage description) at intervals of 100, 200, and 300 feet from the point of insecticidal discharge. The tests were done in June 1970 and June, July and August 1971, some in an open area of close-cropped lawn, others in areas of natural vegetation. Variations of the basic procedure are described under the appropriate sections below. No testing was attempted when wind speeds exceeded 10 mph. Extremes of temperature and relative humidity, during the entire series of tests, were 56–81 F (average, 67 F) and 34–53% (average, 42%). Routine operational formulations and procedures were used for both insecticides: malathion in No. 2 fuel oil, 40 gallons per hour, 6% at 5 miles per hour or 12% at 10 miles per hour; naled in No. 2 fuel oil, 40 gallons per hour, 0.7% at 5 miles per hour. Runs past the experimental target areas were merely detours from the usual fogging pattern. Abbott's formula was applied where control mortalities exceeded 5%.

TESTS WITH NONTHERMAL FOGS AT 100 TO 300 FEET. Malathion and naled produced very high and essentially equal mortalities among the mosquitoes; the water striders appeared to be much more susceptible to naled than to malathion (Table 1).

TESTS WITH NONTHERMAL FOGS AT 100 TO 500 FEET. These tests were conducted in two natural areas where the predominant plants were horsetails and willows. The willows, standing about 5 feet tall, formed a dense cover over much of the target area. At 6 feet above ground, the caged mosquitoes were in the direct line

TABLE 1. Mortality caused by nonthermal fogs.

Insect[a]	Insecticide	Feet from point of discharge 100	200	300	Controls
Mosquitoes	Malathion	96:23[b]	80:21	75:19	10:20
	Naled	99:15	86:13	66:10	6:15
Water striders	Malathion	21:11	14:9	13:7	6:10
	Naled	46:9	40:7	61:6	4:3

[a] Wild-caught specimens in cages suspended six feet above ground. Average number of specimens per replicate: mosquitoes, 26; water striders, 22.
[b] Percent mortality (24 hours after treatment): Number of replicates.

of drift, but the dense undergrowth obstructed much of the intervening space between the point of discharge and the cages (Table 2). Both adulticides were effective to the 200-foot level; malathion was effective, with 83% mortality, to the 500-foot level.

CAGES ON GROUND AND SIX FEET ABOVE GROUND. The same brush-covered locations were used for these tests as for those just described. The attenuated effect of naled, which was apparent in the above-ground tests and which may presumably be attributed to the dense undercover, was even more pronounced in the ground-level tests (Table 2). Although the performance of malathion was superior under these conditions, its effectiveness dropped sharply beyond the 200-foot level.

TESTS WITH NALED THERMAL FOG. The poor penetration of the underbrush by the nonthermal naled fog prompted further testing with a thermal fog. This was generated by a portable fogger (Dyna-Fog 150B, FSN 3740-682-5286). One gallon of 0.7% naled was dispersed over the test area. The thermal fog penetrated the brush barrier much more effectively than the nonthermal fog (Table 3).

SURVIVAL OF MOSQUITOES IN TREATED AREAS. These areas of dense willow underbrush normally support a large population of resident mosquitoes. I noted that mosquitoes were present in such areas shortly after treatment with nonthermal fogs even though the caged mosquitoes had sustained high mortalities. I was not able to thoroughly explore the question of survival in treated areas, but the very limited results available (Table 4) suggest that malathion had greater impact on the resident mosquitoes than naled. This conclusion is strengthened by the results of the ground-level tests on caged mosquitoes (Table 2). Reinvasion of the treated area by unaffected mosquitoes certainly occurs, but this could not account for 100% survival following naled treatments and 41% survival after malathion treatments. Survival levels approximating those of the

TABLE 2. Effects of nonthermal fogs on mosquitoes.[a]

Cage location	Insecticide	Feet from point of discharge 100	200	300	400	500	Controls
Six feet above ground	Malathion	100:6[b]	89:6	95:6	93:6	83:6	17:6
	Naled	100:2	100:2	44:2	53:2	15:2	5:2
On ground	Malathion	100:2	100:2	48:2	19:2	24:2	0:2
	Naled	65:2	18:2	4:2	2:2	0:2	0:2

[a] 24 hours after treatment. Wild-caught specimens. Average number per replicate, 30.
[b] Percent mortality: Number of replicates.

TABLE 3. Effects of naled thermal fog on mosquitoes.[a]

Cage location	Effect	Feet from point of discharge		
		100	200	Controls
Cages six feet above ground	Knockdown[b]	100:6[d]	99:4	..
	Mortality[c]	100:6	100:4	4:1
Cages on ground	Knockdown	89:5	23:4	..
	Mortality	100:4	97:4	16:1

[a] Wild-caught specimens. Average of 31 mosquitoes per replicate.
[b] One hour after treatment.
[c] 24 hours after treatment.
[d] Percent (mortality or knockdown): Number of replicates.

controls would be expected in both instances if reinvasion were taken as the explanation of these results.

KNOCKDOWN EFFECTS. As nonthermal aerosols, both adulticides produced readily-observable deleterious effects on mosquitoes at 1-hour post-treatment (Table 5). Naled produced effects of much greater magnitude than malathion, but those effects were markedly diminished when the target cages were at ground level and somewhat protected by a dense layer of shrubby vegetation. This moderation of the knockdown effect also occurred in the naled thermal fog tests (Table 3).

The waterstriders appeared to be much more susceptible to the immediate effects of naled than of malathion. However, no knockdown at 1-hour post-treatment was not necessarily followed by complete survival at 24 hours; neither did a low knockdown rate predispose a low mortality rate. Except for the ground-level tests with naled reported in Table 5, Tables 1 and 5 are essentially comparable, that is, the knockdown reported in Table 5 may be compared with the mortality reported in Table 1. For example, even though water strider knockdown by malathion was zero, mortality eventually amounted to 13 and 14% at 24 hours.

DISCUSSION. Adult mosquito suppression in Alaska was first achieved by ground-based techniques (Wilson 1951). This approach was quickly dropped in favor of aerial techniques, which dominated the scene for about 20 years. Now with the current renewed emphasis on ground-based techniques, the evolution of adulticidal techniques has come full circle. Ground-based adulticiding techniques have proved

TABLE 4. Survival of mosquitoes in treated areas.

Nonthermal fogs	Number of replicates	Percent survival in	
		Control area[a]	Treated area[b]
Malathion	2	81	41
Naled	2	97	100

[a] Wild-caught specimens collected before treatment.
[b] Wild-caught specimens collected in the middle of the target area approximately one hour after treatment.

TABLE 5. Knockdown effects of nonthermal fogs.[a]

Insect	Insecticide	Feet from point of discharge		
		100	200	300
Mosquitoes[e]	Malathion[b]	64:26[d]	40:25	33:23
	Naled[b]	92:17	83:13	64:10
	Naled[c]	25:4	0:2	0:2
Water striders[f]	Malathion[b]	1:11	0:9	0:7
	Naled[b]	29:9	18:7	14:6

[a] One hour after fogging. Dead mosquitoes, as well as those debilitated and dying, were counted.
[b] Cages suspended six feet above ground.
[c] Cages located at ground level and surrounded by dense underbrush about five feet tall.
[d] Percent knockdown: Number of replicates.
[e] Average number per replicate, 27.
[f] Average number per replicate, 21.

to be generally more compatible with Alaskan conditions than aerial techniques, but there are doubtless circumstances where aerial methods would be more advantageous.

Both malathion and naled nonthermal fogs are effective mosquito adulticides, and both have been used successfully in routine mosquito suppression programs in Alaska. Malathion or its toxic derivatives may persist in some Alaskan soils for prolonged periods, in contrast to its demonstrated lability in other parts of the world, but there is no evidence that this small residual is environmentally dangerous. The behavior of naled in Alaskan soils has not been investigated.

Both adulticides performed well in an open area where the path of insecticidal drift was unobstructed. In areas of dense, shrubby undergrowth, both malathion nonthermol fog and naled thermal fog produced satisfactory levels of mortality in caged mosquitoes (malathion thermal fog was not tested). In those instances where aquatic habitats would be included in the target area, the results of these tests suggest that, of the two adulticides tested, malathion should be the insecticide of choice.

ACKNOWLEDGMENTS. Operational support for these tests was coordinated and facilitated by Mr. Robert Probert of Eielson Air Force Base. *Gerris buenoi* was identified by Mr. Jon L. Herring, Insect Identification and Beneficial Insect Introduction Institute, U.S. Department of Agriculture, Beltsville, Maryland.

Literature Cited

Berg, C. O. 1951. A preliminary survey of the biting Diptera of the lower Yukon Valley. Science in Alaska 1951:303–308.

Blanton, F. S., C. N. Husman, B. V. Travis and C. S. Wilson. 1949. Control of Alaskan mosquito adults by aerial sprays. J. of Econ. Entomol. 42(1):106–109.

Blanton, F. S., B. V. Travis, N. Smith, C. N. Husman. 1950. Control of adult mosquitoes in Alaska with aerial sprays. J. of Econ. Entomol. 43(3):347–350.

Gorham, J. R. 1972. Studies of the biology and control of arthropods of health significance in Alaska. 2. Control studies at Eielson Air Force Base—1970. Arctic Health Research Center, Fairbanks, Alaska.

Hedeen, R. A. and H. L. Keegan. 1952. The use of lindane and dieldrin as mosquito adulticides in Alaska. Mosq. News 12(4):242–243.

Holty, J. G. 1970. Residual pesticide in soil after aerial spray with malathion at Eielson AFB and Murphy Dome AFB. Arctic Health Research Center, Fairbanks, Alaska.

Jachowski, L. A., Jr., and C. Schultz. 1948. Notes on the biology and control of mosquitoes at Umiat, Alaska. Mosq. News 8(4):155–165.

Mount, G. A., J. G. McWilliams and C. T. Adams. 1969. Control of adult moquitoes in Alaska with malathion. Mosq. News 29(1): 84–86.

Rathburn, C. B., Jr., A. J. Rogers, A. H. Boike, Jr., and R. M. Lee. 1969. Evaluation of the ultra-low volume aerial spray technique by use of caged adult mosquitoes. Mosq. News 29(3):376–381.

Wilson, C. S. 1950. Aerosol spray units for control of biting insects. Mosq. News 10(2): 51–54.

Wilson, C. S. 1951. Control of Alaskan biting insects. *In* Public health problems in Alaska. Public Health Reports 66(29):911–944.

NOTICE

The Bishop Museum in Hawaii should be added to the list of cooperators in the National Mosquito Identification Service. They will identify mosquitoes from the Pacific Basin and Southwest Pacific, including New Guinea. Requests should be sent to Dr. Wallace A. Steffan, Bernice P. Bishop Museum, Box 6037, Honolulu, Hawaii 96818.

1974 Mount, G. A. and N. W. Pierce
Ultralow Volume Ground Aerosols Of Naled For Control Of Aedes Taeniorhynchus (Wiedemann)
In The Florida Keys
Mosquito News 34: 268-269 (Amvac Ref. #1376)

ULTRALOW VOLUME GROUND AEROSOLS OF NALED FOR CONTROL OF *AEDES TAENIORHYNCHUS* (WIEDEMANN) IN THE FLORIDA KEYS[1]

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Insects Affecting Man Research Laboratory, Agr. Res. Serv., USDA, Gainesville, Florida 32604

ABSTRACT. Field tests were conducted to determine the feasibility of using ultralow volume ground aerosols of naled for control of adult *Aedes taeniorhynchus* (Wiedemann). Good reductions (81–94%) were obtained in three tests with a dose of 0.02 pound per acre. Also, in five of seven tests doses of 0.015 and 0.01 pound per acre gave 73–94% reductions. Applications made in the early morning gave more satisfactory control than applications made at night because of rapid reinfestation of mosquitoes during the night following treatment.

The use of adulticides has been the method of choice for controlling mosquitoes in the Florida Keys (Monroe County) because larvicides and permanent control have not been feasible on a large scale basis. However, the compounds have usually been applied with aircraft, a method that is expensive and that probably causes resistance to develop more rapidly than ground methods because of extended coverage which greatly increases the selection for resistance. Thus, we conducted field tests to determine the practicability of using ultralow volume (ULV) ground aerosols as a control method for *Aedes taeniorhynchus* (Wiedemann) which is the prevailing species of pestiferous mosquitoes in the Florida Keys.

Test Procedures. Three residential sections on Sugarloaf Key (about 17 miles north of Key West) were selected as test areas. These areas ranged in size from approximately 120 to 350 acres and contained road networks that allowed adequate coverage with the ground aerosol method.

Naled, formulated as 10% Dibrom® 14 in heavy aromatic naphtha (HAN), was selected as the adulticide to be tested because of its rapid knockdown characteristic which allowed evaluation soon after application. Also, naled was used in these tests because of observed resistance to malathion in the native population of *A. taeniorhynchus* (12.5 fold; unpublished data). Naled was applied at doses of 0.01, 0.015, and 0.02 pound per acre of active ingredient with a Leco® Model HD ULV aerosol generator operated at an air pressure of 1.5 psi. A pressure of 1.5 psi was determined to be optimum for 10% Dibrom 14 in HAN in previous tests by Mount and Pierce (1972). The instrument panel of the aerosol generator was mounted in the cab of the truck (½ ton) on which the generator was carried so that the air pressure and the rate of flow could easily be monitored during applications. Previous calibrations with 10% Dibrom 14 in HAN at our laboratory indicated that flowmeter corrections were unnecessary to maintain a constant liquid flow within a 75 to 95° F temperature range. Aerosol applications were made either at night (8–9:30 pm) or during the morning (7–10:00 am).

The effectiveness of the aerosols was determined by making pre- and posttreatment landing counts just before and 30–45 minutes after each application at 8–10 counting stations within each plot. The average pretreatment count of mosquitoes at each station was 10.6 (total count of two observers), indicating a moderate infestation of *A. taeniorhynchus*.

Results and Discussion. The data (Table 1) indicated reductions of 81 to 94% of adult *A. taeniorhynchus* with the 0.02 pound per acre dose of naled. These results agree closely with the LD_{90} of 0.019 pound per acre for caged mosquitoes of

[1] This paper reflects the results of research only. Mention of a pesticide or a commercial or proprietary product in this paper does not constitute a recommendation or an endorsement by the USDA.

TABLE 1. Effectiveness of ULV ground aerosols of naled (10% Dibrom 14 in HAN) against native infestations of *Aedes taeniorhynchus* in the Florida Keys.

Dose (lb/acre)	Flow rate (fl oz/min)	Truck speed (MPH)	No. of tests	Percentage reduction after 30–45 min [a]	
				Average	Range
0.01	6	10	4	72	42–94
0.015	12	15	3	73	52–89
0.02	12	10	3	86	81–94

[a] Adjusted by Abbott's formula for fluctuations in the untreated populations, which ranged from a 20% reduction to a 14% increase.

the same species exposed in screen wire cages (Mount and Pierce 1972) and with the high degree of control of native infestations of *Psorophora confinnis* (Lynch Arribálzaga) in Arkansas with doses of 0.02 pound per acre of naled (Mount *et al.* 1972). The doses of 0.01 and 0.015 pound per acre also produced reductions of 73 to 94% in five of seven tests; the other two tests gave reductions of 42 and 52%. Thus, the average reductions were 72 and 73% for doses of 0.01 and 0.015, respectively.

However, the posttreatment landing counts at either 12 or 24 hours, depending on the time of application usually showed a high rate of mosquito reinfestation. Therefore, repetitive applications are necessary to maintain satisfactory control in small residential areas that are subject to heavy reinfestation of migratory mosquitoes such as *A. taeniorhynchus*. Nevertheless, we observed that applications made in the early morning produced more satisfactory control than applications made at night. *Aedes taeniorhynchus* feeds during daylight in shaded areas around homes and is particularly active on cool, overcast days. Also, the species does not normally migrate during the day. Thus, our early morning treatments which gave lower densities during the day when residents were in the yards, provided satisfactory protection from biting. The two successful nighttime treatments (94 and 89% reductions at 0.02 and 0.015 pound per acre, respectively) provided little decrease in mosquito density (only 26% reduction) in the test plots the next day because of rapid reinfestation.

ACKNOWLEDGMENT. We gratefully acknowledge the advice and cooperation of the Monroe County Mosquito Control District.

Literature Cited

Mount, G. A. and Pierce, N. W. 1972. Adult mosquito kill and droplet size of ultralow volume ground aerosols of insecticides. Mosq. News 32(3):354–357.

Mount, G. A., Meisch, M. V., Lee, J. T., Pierce, N. W. and Baldwin, K. F. 1972. Ultralow volume ground aerosols of insecticides for control of rice field mosquitoes in Arkansas. Mosq. News 32(3):444–446.

1974 Mount, G. A., J. A. Seawright, and N. W. Pierce
Selection Response And Cross Susceptibility Of A Malathion-Resistant Strain Of Aedes Taehiorhynchus (Wiedmann) To Other Adulticides
Mosquito News 34: 276-277 (Amvac Ref. #1377)

SELECTION RESPONSE AND CROSS SUSCEPTIBILITY OF A MALATHION-RESISTANT STRAIN OF *AEDES TAENIORHYNCHUS* (WIEDEMANN) TO OTHER ADULTICIDES [1]

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ABSTRACT. Selection experiments with a heterogenous strain of *Aedes taeniorhynchus* (Wiedemann) (susceptible laboratory female x resistant native male) indicated that this species of mosquito has the potential to develop a high degree of resistance to malathion. However, resistance (33-fold) to malathion apparently did not cause cross resistance to other mosquito adulticides.

The widespread acceptance of the ground ultralow volume method of mosquito adulticiding has brought about renewed usage of malathion against *Aedes taeniorhynchus* (Wiedemann). We were therefore concerned about the greater degree of resistance to malathion that might develop in *A. taeniorhynchus* and also about the possible development of cross resistance to other adulticides. We indicated previously that research with a colonized strain that is resistant to malathion could yield valuable information on the resistance potential in this species (Mount *et al.*, 1971).

The objectives of the present paper are (1) to report the results of 10 generations of selection of a heterogenous strain (susceptible female x native male) of *A. taeniorhynchus* with malathion and (2) to report the susceptibilities of the selected strain to adulticides other than malathion.

TEST PROCEDURES. Native *A. taeniorhynchus* larvae were collected from Little Talbot Island State Park (Duval County) in December 1971 and brought to the Gainesville laboratory. Then we reared the field-collected larvae to adults and exposed them to contact sprays of malathion in our wind tunnel (Mount *et al.*, 1970). Since the native adult females proved to have a 10-fold resistance to malathion, we established a strain for our selection experiments by crossing the virgin females from our laboratory (malathion-susceptible strain) with the virgin native males. The heterogenous strain was then selected (beginning in the second generation) by exposing virgin females and males (<24 hr old) to contact sprays of malathion in the wind tunnel. This procedure allowed the selection of both sexes, which is not possible when inseminated females are used. The concentrations of malathion that were used for selection usually produced >50% mortality of each generation. (We also exposed adults from each generation to contact sprays of malathion in the wind tunnel to determine the levels of resistance.)

The cross susceptibility tests with nine other adulticides were also conducted with the selected malathion-resistant strain by exposing the adult females from the F_4, F_6, and F_{13} generations to contact sprays of the adulticides in the wind tunnel. Adult females from the malathion-susceptible laboratory strain were included in these tests for comparison.

RESULTS AND DISCUSSION. Table 1 shows that the F_1 and F_2 generations of heterogenous females (unselected) showed a slight increase in resistance to malathion (17- and 13-fold, respectively). However, the F_3 generation (progeny of the 1st selected generation) showed a marked increase (45- and 24-fold, respectively, for females and males). Thereafter, during the next 9 selected generations, the level of resistance to malathion ranged from 30- to 87-

[1] This paper reflects the results of research only. Mention of a pesticide or a commercial or proprietary product in this paper does not constitute a recommendation or an endorsement of this product by the USDA.

TABLE 1. Increase in resistance of a heterogenous strain (susceptible female x native resistant male) of *Aedes taeniorhynchus* selected with contact sprays of malathion.

Generation	LC_{90} reciprocal ratio to susceptible strain[a] Female	Male	Selection concentration[b] (%)
F_1	17	12	(unselected)
F_2	13	3	0.05
F_3	45	24	0.1
F_4	49	42	1
F_5	44	24	1
F_6	30	13	1.5
F_7	58	62	1.5
F_8	87	86	2
F_9	73	66	1.1
F_{10}	43	28	2
F_{11}	87	[c]	2.5
F_{12}	73	65	...

[a] LC_{90}'s for susceptible females and males were 0.037 and 0.031%, respectively; LC_{90}'s are based on two replications of a complete range of discriminating concentrations.
[b] Effect of each selection is indicated for subsequent generation.
[c] Not determined because of shortage of specimens.

fold in females and from 13- to 86-fold in males. Native populations of *A. taeniorhynchus* thus have the potential to develop a high degree of resistance to malathion. Table 2 indicates that a high degree of resistance to malathion in *A. taeniorhynchus* apparently does not cause cross resistance to other adulticides. The LC_{90}'s for the 9 other chemicals, 6 organophosphates, 1 carbamate, and 2 pyrethroids, showed no substantial differences in susceptibility in the malathion-resistant and susceptible strains.

TABLE 2. Effectiveness of contact sprays of nine adulticides against females from malathion-resistant and susceptible strains of *Aedes taeniorhynchus*.

Adulticide	24 hr LC_{90} for indicated strain Resistant[a]	Susceptible
Naled	0.021	0.026
Fenthion	0.009	0.013
Chlorpyrifos	0.017	0.024
Chlorpyrifos-methyl	0.043	0.022
Montecatini L-561 (ethyl mercaptophenyl acetate *S*-ester with *O,O*-dimethyl phosphorodithioate)	0.033	0.023
Plant Protection PP-511 (*O*-[2 diethyl amino)-6-methyl-4-pyrimidinyl] *O,O*-dimethyl phosphorothioate)	0.024	0.029
Propoxur	0.018	0.014
Resmethrin[b]	0.0025	0.0036
Pyrethrins[b]	0.007	0.006
Malathion	1.2[c]	0.036

[a] Strain selected with malathion in the laboratory (F_4, F_5, and F_{12} tested); LC_{90}'s are based on four replications of a complete range of discriminating concentrations.
[b] Synergized at a ratio of 1 part adulticide to 5 parts piperonyl butoxide.
[c] 33-fold resistance.

Literature Cited

Mount, G. A., Baldwin, K. F. and Lofgren, C. S. 1970. Effectiveness of seven promising mosquito adulticides. Mosq. News 30(2):213–214.

Mount, G. A., Dame, D. A. and Lofgren, C. S. 1971. Susceptibility of a Florida strain of *Aedes taeniorhynchus* (Wiedemann) to insecticides. Mosq. News 31(3):438–440.

1974 Stains, G. S
Emergency Mosquito Adulticiding Operations Conducted In The Palo Verde Valley, Eastern Riverside County, California
Proceedings of the California Mosquito Control Association, Inc. 98 (Amvac Ref. #1378)

1974 Proceedings of the California Mosquito Control Association, Inc. (1378)

Table 1.—Results of various chemicals applied by ground ULV to Caged female *Culex pipiens*.

	LD90		
Chemical	Flow Rate oz/min	lb. A/A 300 ft swath	Cost/acre (cents)
Cythion	3.7	0.046	$.034
Cythion + HAN (1:1)	7.5	0.047[1]	-
Cythion + HAN + Lethane 384 (1:1:1)	13.1	0.054[1]	-
Pyrocide	11.1	0.005[2]	$.321

[1] A/A of malathion
[2] A/A of pyrethrins

The caged mosquitoes located in the open parkway had mortalities equal to those observed in the open field test of Area 1 with an average mortality of 93%. Mortality in the test cages in the open in this zone averaged 87% and those in the shrubs averaged 57%.

The cages at the end of the block (400 ft) averaged 86% mortality in the open parkway and 71% in the open front yard.

These results demonstrate the effectiveness of Cythion ULV applications for mosquito control in urban situations, and chemicals accepted for the control of mosquitoes, when properly applied by the ULV method, should give excellent control of flying mosquitoes and fair to good control of resting mosquitoes.

References Cited

Mount, G. A. and N. W. Pierce. 1972. Adult mosquito kill and droplet size of ultra low volume ground aerosols of insecticides. Mosq. News 32(3):354-357.

Thompson, G. A. 1973. Some errors inherent in ULV operations. Mosq. News 33(3):364-367.

EMERGENCY MOSQUITO ADULTICIDING OPERATIONS CONDUCTED IN THE PALO VERDE VALLEY, EASTERN RIVERSIDE COUNTY, CALIFORNIA

George S. Stains

Coachella Valley Mosquito Abatement District

Route 1, Box 22 E, Thermal, California 92274

ABSTRACT

Pooled light trap collections of *Culex tarsalis* mosquitoes from the Palo Verde Valley, Eastern Riverside County, California were found to be over 50 percent postive for encephalitis virus. Because of the possible threat of mosquito-borne disease the State Department of Health, Vector Control Section, recommended immediate control measures be instituted to reduce the adult mosquito population. The Coachella Valley Mosquito Abatement District was asked by Riverside County for assistance in conducting the control program. Adulticiding operations over a 42 square mile area surrounding the City of Blythe were begun on 1 September, utilizing two non-thermal aerosol generators (Micro-Gen type) on loan from the U.S. Navy. The insecticide dispensed from these generators was naled (Dibrom) diluted 1 to 5 with cottonseed oil. Pre- and post-treatment light trap counts were tabulated. Pre-treatment counts averaged 246 per trap night. When control operations were terminated on 20 September or 19 days later, the count was reduced to an average of three mosquitoes per trap night.

1973 Ludlam, K. W., R. A. Berry, and S. R. Joseph
The Effect Of Ground ULV Applications On Natural Populations As Evaluated By Landing Rate Counts
Proceedings of the New Jersey Mosquito Extermination Association 60: 93-96 (Amvac Ref. #1373)

1973
60 : 93-96

(1373)

budgets for all commissions in the state and have each commission spend sufficient time and thought each year to produce a budget that will benefit the taxpayers of the entire state, one that will meet with the close scrutiny that will be given it by the Department of Environmental Protection and measure up in every way.

PRESIDENT SAWKA: The next paper to be presented is "The Effect of Ground ULV Applications," by R. A. Berry, University of Maryland, College Park.

THE EFFECT OF GROUND ULV APPLICATIONS ON NATURAL MOSQUITO POPULATIONS AS EVALUATED BY LANDING RATE COUNTS

K. W. LUDLAM, R. A. BERRY and S. R. JOSEPH

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College Park, Maryland 20742

Introduction

During the summer of 1972, several evaluations of ground ultra-low volume applications were conducted by Maryland mosquito control workers. The results presented in this report were based solely on numbers of mosquitoes landing on collectors before and after treatment with the various insecticides.

Materials and Methods

All applications were made with a Leco model HD cold aerosol fog generator. Insecticides used in the tests were Cythion® (95% malathion), Dibrom® (10% v/v in Heavy Aromatic Naptha), and Pyrethrum (5% plus synergist). Pyrethrum and Cythion were dispensed at 4 or 4.3 fl. oz./minute at 10 mph, while Dibrom was applied at a rate of 8 fl. oz./minute at 10 mph. A total of 20 tests were conducted in 7 areas or communities. Test areas varied widely in composition, ranging from woodlands or open fields to densely populated communities. Seventeen species of mosquitoes were encountered during the tests (Table 1).

Landing rate stations were selected by collectors within 200 feet from the point of insecticides discharge. Numbers of stations per test ranged from 3 to 10, and numbers of collectors varied from 1 to 5. Counts were made at the same station by the same individual before and after treatment. Generally, all mosquitoes which landed on the legs of

Maryland Department of Agriculture Contribution No. 2.

TABLE 1. — *Mosquito species taken in landing rate collections before or after ULV applications.*

Aedes sollicitans	*Psorophora ciliata*
Aedes atlanticus	*Psorophora confinnis*
Aedes canadensis	*Psorophora cyanescens*
Aedes taeniorhynchus	*Anopheles crucians/bradleyi*
Aedes cantator	*Anopheles punctipennis*
Aedes vexans	*Anopheles quadrimaculatus*
Aedes triseriatus	*Culex salinarius*
Aedes trivittatus	*Coquillettidia perturbans*
Psorophora ferox	

collectors were counted for either 5 or 10 minutes at each station. Counts conducted at night were made with the aid of a flashlight.

Day ULV treatments were made between the hours of 8:00 a.m. and 2:45 p.m., while night applications were made between 6:00 p.m. and 11:00 p.m.

Results

Evaluations of night ULV treatments by night landing rates using 24-hour pre-counts showed a reduction 1, 24 and 48 hours after Cythion treatment of 47%, 12% and 38% respectively (Table 2). Reductions in counts 1, 24, 48 and 72 hours after Dibrom treatment were 44%, 80%, 82% and 72% respectively.

TABLE 2. — *Evaluation of night ULV treatments by night landing rate counts. Pre-treatment counts taken at 24 hours.*

	% Reduction Post Treatment[1]			
Insecticide	1 hr.	24 hrs.	48 hrs.	72 hrs.
Cythion	47	12	38	-
Dibrom	44	80	82	72

[1]Average of 1-7 tests.

Daytime ULV applications as evaluated by night landing rates using 12-hour pre-counts showed a 6% decrease, a 10% increase and a 26% decrease 12, 36 and 60 hours respectively after Cythion treatment, and a 49% decrease 12 hours after Dibrom treatment (Table 3).

TABLE 3. — *Evaluation of day ULV treatments by night landing rate counts. Pre-treatment counts taken at 12 hours.*

Insecticides	% Reduction Post Treatment[1] 12 hrs.	36 hrs.	60 hrs.
Cythion	6	+10	26
Dibrom	49	-	-

[1]Average of 1-3 tests.

Day landing rate count evaluations of day ULV treatments using 1-hour pre-counts showed a reduction 2, 3 and 4 hours after Cythion treatment of 28%, 44% and 66% respectively, while counts 1 hour after Pyrethrum treatment showed a 73% reduction (Table 4).

TABLE 4. — *Evaluation of day ULV treatment by day landing rate counts. Pre-treatment counts taken at 1 hour.*

Insecticide	% Reduction Post Treatment[1] 1 hr.	2 hrs.	3 hrs.	4 hrs.
Cythion	-	28	44	66
Pyrethrum	73	-	-	-

[1]Average of 1-3 tests.

Discussion and Conclusion

Despite attempts to maintain consistency, a great deal of variation was observed in landing counts between different individuals. Results of individual counts conducted during one daytime test ranged from 175% increase to a 100% decrease. Wherever possible, several collectors were used for each test, and results of tests were combined to achieve an average reduction. Differences in meteorological conditions such as wind, precipitation, and relative humidity could effect pre-and post-treatment counts. Except in cases where light intensity and the resultant host seeking activity are changing rapidly, pre-and post-treatment counts are probably best made as close to treatment as possible in order not to introduce the variable of changes in populations, meterological conditions, and tendencies of migratory species to move into or out of the target area.

Acknowledgment

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PRESIDENT SAWKA: Paper number 20 will be presented by E. J. Hansens, the State University of New Jersey.

INTEGRATED CONTROL OF BLOOD-SUCKING DIPTERA IN SEASHORE AREAS*

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Abstract

Control of salt marsh mosquitoes in New Jersey began 60 years ago by managing water levels and providing access for minnows to breeding areas. Drainage, tide gates, and similar water management techniques were developed. Under adverse climatic conditions large mosquito populations may require use of insecticides against aquatic stages or adults. Minimum dosages have resulted in little damage to predators and in little evidence of resistance to insecticides. High levels of resistance have been encountered in other states where insecticides have been used in larger quantities.

Mosquito control agencies have given little attention to other biting flies. The populations of some species of *Culicoides, Tabanus,* and *Chrysops* may have been increased through mosquito control. Scientific data is essential to develop water management and other techniques for control of immature stages of other biting flies. Then an integrated program can be developed for control of the whole complex even including *Stomoxys calcitrans*.

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1973 Mount, G. A., and N. W. Pierce
Toxicity Of Selected Adulticides To Six Species Of Mosquitoes
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TOXICITY OF SELECTED ADULTICIDES TO SIX SPECIES OF MOSQUITOES [1]

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ABSTRACT. Six adulticides were evaluated as contact aerosols in a wind tunnel against adult females of *Aedes taeniorhynchus* (Wiedemann), *Aedes aegypti* L., *Culex pipiens quinquefasciatus* Say, *Culex nigripalpus* Theobald, *Anopheles quadrimaculatus* Say, and *Anopheles albimanus* Wiedemann. In general, resmethrin, pyrethrins, and tetramethrin, when synergized with piperonyl butoxide, were considerably more toxic to the mosquitoes than fenthion, naled, and malathion. The pyrethroid compounds, particularly resmethrin, were outstanding against the two species of *Anopheles*. The finding that unsynergized pyrethroids were about 6 times less toxic to *A. taeniorhynchus* than synergized pyrethroids was of particular interest. Fenthion and naled were consistently more effective than malathion, which was markedly less toxic to the species of *Culex* than to the species of *Aedes* and *Anopheles*.

At our laboratory, we routinely evaluate candidate mosquito adulticides against *Aedes taeniorhynchus* (Wiedemann) as contact aerosols in laboratory wind-tunnel tests. However, variations in the susceptibility of species to chemicals and the increasing interest in mosquito adulticides in many areas of the world encouraged us to obtain comparable data on the toxicity of six adulticides to five additional species of mosquitoes. We then compared the susceptibilities of these species to those of our standard test strain of *A. taeniorhynchus*.

Methods and Materials. The species of mosquitoes tested in addition to the standard species were *Aedes aegypti* L., *Culex pipiens quinquefasciatus* Say, *Culex nigripalpus* Theobald, *Anopheles quadrimaculatus* Say, and *Anopheles albimanus* Wiedemann. All except *C. nigripalpus* were from our laboratory colonies. *Culex nigripalpus* was obtained as eggs from a colony maintained by W. W. Smith, Entomology Department, University of Florida, Gainesville, Florida.

The adulticides evaluated were three pyrethroids, resmethrin, pyrethrins, and tetramethrin, and three organophosphates, fenthion, naled, and malathion. The pyrethroid compounds were tested both unsynergized and synergized with piperonyl butoxide at a ratio of one part adulticide to five parts synergist.

All compounds were tested as contact aerosols in a wind tunnel, a cylindrical tube 4 inches in diameter through which a column of air is drawn at a rate of 4 miles per hour by a suction fan. In each exposure, 25 mosquitoes were confined in a tubular galvanized metal cage with screened ends that was placed in the center of the tube. Then 0.25 milliliter of a solution of the adulticide in deodorized kerosene was atomized at a pressure of one pound per square inch into the mouth of the tunnel, and the mosquitoes were exposed momentarily to the aerosol droplets as they were drawn through the cage. Duplicate cages were used in each test, and one to four tests were made with each concentration of each insecticide. After treatment, the mosquitoes were anesthetized with carbon dioxide, transferred to cardboard holding cages, and furnished with a 10 percent sugar-water solution. Knockdown and mortality counts were taken 1 and 24 hours after exposure, respectively. Mosquitoes handled in the same manner but not exposed to the chemicals showed less than 10 percent kill except for species of *Anopheles* which had an average check kill of 15 percent. The data were corrected by Abbott's formula.

Results and Discussion. The 24-hour LC_{90}'s for each adulticide against each

[1] This paper reflects the results of research only. Mention of a pesticide or a commercial or proprietary product in this paper does not constitute a recommendation or an endorsement of this product by the USDA.

TABLE 1.—Effectiveness of contact aerosols of six adulticides to females of six species of mosquitoes.

Adulticide	ENT No.	24 hour LC_{90} (%) for indicated species					
		Aedes taeniorhynchus	*Aedes aegypti*	*Culex p. quinquefasciatus*	*Culex nigripalpus*	*Anopheles quadrimaculatus*	*Anopheles albimanus*
Resmethrin [a]	27474	0.0046 (6.3)	0.0016 (1.6)	0.008 (1.9)	0.0034 (1.3)	0.0013 (1.9)	0.0005 (2.2)
Pyrethrins [a]	3107	.006 (6.2)	.003 (2)	.009 (3)	.006 (2.7)	.003 (4)	.0017 (1.4)
Tetramethrin [a]	27339	.007 (5.8)	.007 (1.5)	.014 (2.3)	.029 (.9)	.002 (1.3)	.0013 (2.4)
Fenthion	25540	.012	.008	.016	.024	.015	.01
Naled	24988	.024	.012	.02	.01	.02	.015
Malathion	17034	.035	.026	.07	.15	.04	.04

[a] Synergized at a ratio of 1 part adulticide to 5 parts piperonyl butoxide (ENT-14250); numbers in parentheses indicate reciprocal ratio of unsynergized adulticide.

species of mosquito are presented in Table 1. In general, the compounds are listed in order of decreasing effectiveness, but there are several notable exceptions which will be discussed with respect to the species of mosquito.

Against *A. taeniorhynchus*, the synergized pyrethroids were about 2 to 7 times more toxic than the organophosphates; however, the toxicity of the unsynergized pyrethroids was only about equal to that of malathion and was less than that of fenthion and naled. Also, in our previous field tests (Mount and Pierce, 1971, and Mount and Pierce, 1972) resmethrin (Penick SBP-1382) and tetramethrin were about as toxic as malathion, but pyrethrins synergized with piperonyl butoxide was 7.5 times more toxic than malathion. Rathburn and Boike (1972) also reported that resmethrin was 3 times less effective than malathion against *A. taeniorhynchus* exposed to thermal aerosols in the laboratory. Our results indicated that for maximum efficiency against *A. taeniorhynchus*, pyrethroid compounds must be synergized.

A. aegypti was more susceptible than *A. taeniorhynchus* to all of the adulticides except synergized tetramethrin (LC_{90}'s equal for the two species). Synergized and unsynergized resmethrin and synergized pyrethrins were the outstanding adulticides against *A. aegypti*.

C. p. quinquefasciatus was about as susceptible as *A. taeniorhynchus* to naled and fenthion but about 1.5 to 2.0 times less susceptible to malathion and the synergized pyrethroids. Although synergized resmethrin and pyrethrins were the most toxic of all the adulticides to *C. p. quinquefasciatus*, this species was the least susceptible of all the species of mosquitoes to these two adulticides.

Synergized and unsynergized resmethrin, synergized pyrethrins, and naled were the most effective adulticides against *C. nigripalpus*. This species was 0.5 as susceptible to fenthion and only 0.25 as susceptible to synergized tetramethrin and malathion as adults of *A. taeniorhynchus*. Our results and those of Rathburn and Boike (1972) showed that unsynergized resmethrin was 33 times more effective than malathion against *C. nigripalpus*. Also, our laboratory data and that of Rathburn and Boike both indicate that *C. nigripalpus* is 4 to 6 times less susceptible than *A. taeniorhynchus* to malathion.

Both species of *Anopheles* were highly susceptible to all the synergized pyrethroids, but synergized resmethrin was the most toxic and was 31 and 80 times more effective than malathion against *A. quadrimaculatus* and *A. albimanus*, respectively. The organophosphates had about the same degree of toxicity to both *Anopheles* species as to *A. taeniorhynchus*.

Thus, as a group, the synergized pyrethroids were considerably more toxic than the organophosphates to the six species of mosquitoes. Without exception, synergized resmethrin was more effective than synergized pyrethrins, which was the second most effective adulticide. The other pyrethroid, tetramethrin (synergized), was slightly more toxic than synergized pyrethrins to the two species of *Anopheles*. Synergized tetramethrin was consistently more effective than any of the organophosphates except against *C. nigripalpus*.

Among the organophosphates, fenthion was the most effective adulticide and was 1.25 to 2 times more toxic than naled to all species except *C. nigripalpus*. Naled was the most consistent of the adulticides since there was only a two-fold range between the most and the least susceptible species of mosquito. Malathion was uniform in its performance against the species of *Aedes* and *Anopheles*, but it was 2 to 4 times less effective against the species of *Culex*.

The three pyrethroids and naled produced relatively quick knockdown (within one hour) of all the species of mosquitoes at concentrations that were either considerably lower or about the same as the concentrations required for 24-hour kill. Malathion yielded only moderate knockdown and fenthion produced little, if any, knockdown within one hour.

Literature Cited

Mount, G. A. and Pierce, N. W. 1971. Eleven promising insecticides evaluated as ultralow volume cold aerosols against *Aedes taeniorhynchus* (Wiedemann). Mosq. News 31(1): 77–80.

Mount, G. A. and Pierce, N. W. 1972. Adult mosquito kill and droplet size of ultralow volume ground aerosols of insecticides. Mosq. News 32(3):354–358.

Rathburn, C. B., Jr. and Boike, A. H., Jr. 1972. Laboratory thermal aerosol tests of new insecticides for the control of adult mosquitoes. Mosq. News 32(2):179–183.

1972 Boike, Jr. A. H., and C. B. Rathburn, Jr.
The Susceptibility Of Mosquito Larvae To Insecticides In Florida, 1969-1971
Mosquito News 32: 328-331 (Amvac Ref. #1366)

TABLE 4.—The droplet size of MALATHION LV Concentrate insecticide produced with the Beecomist 10μ, 20μ and 40μ spray heads, using needle valve settings 3, 4 and 5.

Needle valve setting	10μ sleeve			20μ sleeve			40μ sleeve		
	MMD (μ)	Average diameter (μ)	Maximum diameter (μ)	MMD (μ)	Average diameter (μ)	Maximum diameter (μ)	MMD (μ)	Average diameter (μ)	Maximum diameter (μ)
3	17	20	66	61	47	97	28	30	88
4	14	17	60	28	31	97	29	30	91
5	14	17	54	27	28	94	26	27	94

In determining the droplet sizes, needle valve settings 3, 4 and 5 were tested because (1) high flow rates were obtained (Table 2), and (2) the number of droplets per cm^2 (in^2) was greater at these settings (Table 3).

The smallest droplet measured using the 10μ sleeve was 6μ, while the smallest droplets with the 20μ and 40μ sleeves measured 11μ.

CONCLUSION. Aside from refining the mechanical operations, the next step is to relate these data to residual efficacy.

The Beecomist ULV hand applicator is being developed primarily as a tool for applying LVC residual insecticides in malaria eradication and control programs. The data presented here are preliminary, but they do indicate that the potential uses of this unit are many, and that it could be adapted for other insect vector control programs.

Literature Cited

Anderson, C. H. and Schulte, 1971. Teflon as a surface for deposition of aerosol droplets. Mosq. News 31(4):499–504.

Buzicky, A. W. 1967. How we modified a back pack sprayer for ULV insecticide applications. Pest Control 35(6):42–46.

Lofgren, C. S. 1970. Ultra low volume applications of concentrated insecticides in medical and veterinary entomology. Ann. Rev. of Entomology Vol. 15:321–342.

THE SUSCEPTIBILITY OF MOSQUITO LARVAE TO INSECTICIDES IN FLORIDA, 1969–1971

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Since 1964 mosquito larvae from different areas of Florida have been tested for their susceptibility to various insecticides in order to determine any possible resistance build-up. Previous papers dealt mainly with two-year comparative results, while this paper covers the period 1969–1971.

METHODS. The methods for mosquito collection, shipments, and larval testing were essentially the same as described by Rathburn and Boike (1967) and Boike and Rathburn (1969). Since water temperature and kind of testing vessel were found to be important factors affecting test results (Rathburn and Boike, 1969), tests were performed using 400 ml. polypropylene beakers and, except where noted, suspended in a water bath at 80° F. All insecticides were diluted in acetone with the exception of malathion for 1969 which was diluted in 95 percent ethyl alcohol. In order to have a standard diluent for all insecticides, malathion dilutions in alcohol were compared with acetone dilutions in paired tests using larvae from laboratory colonies of *Aedes taeniorhynchus* (Wiedemann) and *Culex nigripalpus* Theob.

Results and Discussion. The lethal concentrations (in p.p.m.) for several mosquito species from several areas tested against malathion, naled, fenthion, and Abate are shown in Table 1. From the areas sampled there appears to be little variation in susceptibility of the different

Table 1.—Susceptibility of mosquito larvae from various areas of Florida to several insecticides, 1969–1971.

					Lethal concentration in ppm.	
Mosquito species	County	Area	Year	Reps.	LC_{50}	LC_{90}
		malathion				
Aedes taeniorhynchus	Lab. colony	Panama City	1969[a]	10	0.020	0.034
	Lab. colony	Panama City	1970	3	0.028	0.042
	Brevard	Merritt Is.	1970	8	0.140	(1.350)
	Lee	Sanibel Is.	1969[a, b]	8	0.067	(0.400)
	Lee	Sanibel Is.	1971	28	0.039	0.195
	Lee	Pine Is.	1969[a, b]	4	0.054	(0.126)
Aedes sollicitans	Hillsborough	Big Bend	1969[a]	4	0.030	0.051
	Lee	Little Pine Is.	1969[a, b]	4	0.035	0.055
Culex nigripalpus	Lab. colony	Panama City	1969[a]	26	0.031	0.041
	Lab. colony	Panama City	1970	16	0.038	0.052
	Brevard	Mims	1969[a]	8	0.046	0.063
	Pinellas	Lake Maggiore	1971	8	0.051	0.077
Culex restuans	Bay	Lynn Haven	1969[a]	4	0.030	0.048
Culex salinarius	Bay	State Park	1969[a]	8	0.042	0.063
	Bay	Tyndall AFB	1970[a]	16	0.062	0.093
	Bay	Tyndall AFB	1971	16	0.060	0.088
	Pinellas	Lake Maggiore	1971	7	0.047	0.074
		naled				
Aedes taeniorhynchus	Lab. colony	Panama City	1970	8	0.077	0.154
Aedes sollicitans	Hillsborough	Big Bend	1969	10	0.096	0.128
Culex nigripalpus	Lab. colony	Panama City	1969	16	0.069	0.087
	Lab. colony	Panama City	1970	8	0.050	0.084
	Brevard	Mims	1969	8	0.079	0.110
	Pinellas	Lake Maggiore	1971	8	0.072	0.090
Culex salinarius	Bay	Tyndall AFB	1971	8	0.075	0.097
	Pinellas	Lake Maggiore	1971	11	0.070	0.109
		fenthion				
Aedes taeniorhynchus	Lab. colony	Panama City	1970	8	0.00084	0.00125
Culex nigripalpus	Lab. colony	Panama City	1970	24	0.00330	0.00440
Culex salinarius	Bay	State Park	1969[b]	7	0.00240	0.00330
	Bay	Woodlawn	1969[b]	7	0.00235	0.00310
		Abate				
Culex salinarius	Bay	Woodlawn	1969[b]	4	0.00058	0.00091

[a] Diluent is alcohol.
[b] Not tested in water bath.
[c] Figures in parentheses are extrapolated values.

species to the various insecticides. An exception is the LC_{50} of malathion obtained with *A. taeniorhynchus* from Merritt Island in Brevard County which is five times higher than with the laboratory colony. Larvae of *Culex nigripalpus* and *Culex salinarius* from Lake Maggiore in Pinellas County, however, showed little variation in susceptibility to malathion or naled compared to figures obtained during previous years, (Rathburn and Boike, 1967 and Boike and Rathburn, 1969). In 1966 the LC_{50} and LC_{90} values for *C. nigripalpus* from Lake Maggiore tested against malathion were 0.038 and 0.058 respectively while in 1971 the values were 0.051 and 0.077, indicating little change over a 5-year period. Similarly, when larvae of *C. nigripalpus* from Lake Maggiore were tested against naled in 1966, the LC_{50} and LC_{90} figures were 0.068 and 0.090 respectively as compared to 0.072 and 0.090 obtained in 1971.

In comparing the difference between alcohol and acetone as diluents for malathion (Table 2) no difference could be detected for *A. taeniorhynchus*. When comparisons were made with *C. nigripalpus*, acetone gave slightly higher LC_{50} and LC_{90} figures than alcohol. However, for practical purposes no significant differences could be found.

Since first sampled in 1965, *Aedes taeniorhynchus* from Brevard and Lee Counties have shown variable degrees of susceptibility to malathion when compared to the laboratory colony, as shown in Table 3. The data from Lee County for 1969 and 1971 further substantiate a trend stated by Boike and Rathburn (1969) that the decrease in usage of malathion in that area was reflected in lower LC_{50} and LC_{90} values. Although no figures were available on the amount of malathion dispersed during 1969–1971, the LC_{50} and LC_{90} values for *A. taeniorhynchus* from Sanibel and Captiva Islands of 0.039 and 0.195 for 1971 are considerably lower than those of 1965.

In Brevard County no increase in susceptibility of *A. taeniorhynchus* from Merritt Island was noted from 1965 to 1970. However, little difference could be detected in 1969 when *C. nigripalpus* from Mims was tested against malathion and naled as compared to the susceptible laboratory colony. Recently Mount, *et al.* (1971) reported a strain of *A. taeniorhynchus* from Allenhurst as having an LC_{50} of 0.88 ppm of malathion. The LC_{50} shown for Allenhurst in Table 3 is considerably lower than that reported by Mount from this area; however, the LC_{50} for malathion in Table 3 was obtained with *A. sollicitans* which may account for the apparent difference. A similar difference is also evident between the data obtained from Merritt Island in 1968 where 50 percent of the larvae tested were *A. sollicitans* and in 1965 and 1970 where the larvae tested were all *A. taeniorhynchus*. Although no tests were performed recently against *A. taeniorhynchus* from the northern part of Brevard County, it is highly probable that local populations may still show resistance to malathion.

SUMMARY. Larvae of *C. nigripalpus* and *C. salinarius* from Brevard, Bay and Pinellas Counties collected during 1969–1971 showed little variation in suscepti-

TABLE 2.—Comparison of acetone and alcohol used as diluent in susceptibility tests of *Aedes taeniorhynchus* and *Culex nigripalpus* larvae to malathion (1969).

Mosquito species	Diluent	Reps	Lethal concentration in ppm. LC_{50}	LC_{90}
Culex nigripalpus	alcohol	20	0.034	0.045
	acetone	20	0.043	0.063
Aedes taeniorhynchus	alcohol	7	0.015	0.030
	acetone	7	0.016	0.029

Table 3.—Susceptibility of *Aedes taeniorhynchus* larvae to malathion in Brevard and Lee County, Florida.

County	Area	Year	Lethal concentration in ppm LC50	Lethal concentration in ppm LC90
Brevard	Mims	1965	0.100	0.780
	Allenhurst	1966	0.042 [a]	0.086
	Titusville Beach	1966	0.075	0.124
	South Brevard Co.	1966	0.080	1.500
	Merritt Island	1965	0.180	0.460
	Merritt Island	1968	0.076 [b]	0.250
	Merritt Island	1970	0.140	(1.350)
	Sanibel-Capt. Island	1965	0.457	3.400
	Sanibel-Capt. Island	1966	0.220	2.600
	Sanibel-Capt. Island	1967	0.086	0.280
	Sanibel-Capt. Island	1969	0.067	(0.400)
	Sanibel-Capt. Island	1971	0.039	0.195
	Bonita Beach	1965	0.275	1.500
	Bonita Beach	1966	0.105	1.050
	Bonita Beach	1968	0.072	0.280
...Colony	Panama City	1965	0.029	0.062
		1966	0.025	0.050
		1967	0.030	0.047
		1968	0.021	0.037
		1969	0.020	0.034
		1970	0.028	0.042

[a] *Aedes sollicitans*.
[b] Mixed population—approx. 50% *A. taeniorhynchus*, 50% *A. sollicitans*.
[c] Figures in parentheses are extrapolated values

...ity to malathion, naled or fenthion when compared to the laboratory colony and data of previous years. Larvae of *A. taeniorhynchus* from Merritt Island in Brevard County collected in 1970 still showed a 5-fold decrease in susceptibility to malathion when compared to the laboratory colony, while those collected from Sanibel and Captiva Islands in Lee County showed a 10-fold increase in susceptibility since 1965. The Panama City laboratory colony of *A. taeniorhynchus* showed little variation in susceptibility to malathion from 1965 to 1970.

References Cited

Boike, A. H., Jr. and Rathburn, C. B., Jr. 1969. Laboratory tests of the susceptibility of mosquito larvae to insecticides in Florida, 1968. Mosq. News 29(3):392–395.

Mount, G. A., Dame, D. A., and Lofgren, C. S. 1971. Susceptibility of a Florida strain of *Aedes taeniorhynchus* (Wiedemann) to insecticides. Mosq. News 31(3):438–440.

Rathburn, C. B., Jr. and Boike, A. H., Jr. 1967. Studies of insecticide resistance in Florida mosquitoes. Mosq. News 27(3):377–382.

Rathburn, C. B., Jr. and Boike, A. H., Jr. 1969. A study of factors affecting the susceptibility of mosquito larvae to insecticides in laboratory resistance tests. Mosq. News 29(3):395–401.

1972 Gillies, P. A., E. M. Fussell, and D. J. Womeldorf
Mortality Of Cages Organophosphorous-Resistant Culex Tarsalis Coquillette Using Various Adulticides Applied As Nonthermal Aerosols (Amvac Ref. #1367)

1972 (1367)

MORTALITY OF CAGED ORGANOPHOSPHORUS–RESISTANT *CULEX TARSALIS* COQUILLETT USING VARIOUS ADULTICIDES APPLIED AS NONTHERMAL AEROSOLS

Patricia A. Gillies[1], Edward M. Fussell[2] and Don J. Womeldorf[3]

INTRODUCTION.–The first organophosphorus insecticide resistance in California *Culex tarsalis* Coquillett was documented in 1956 when Gjullin and Isaak (1957) reported larval resistance to malathion. Since that time, resistance to malathion has become widespread, affecting most controlled areas within the State (Womeldorf et al., 1971). Some scattered instances of resistance to other larvicides were reported, but rarely included more than one chemical in addition to malathion (Womeldorf et al., 1968). Then in 1969, populations cross resistant to other organophosphorus compounds were detected in the southern San Joaquin Valley (Gillies and Womeldorf, 1969; Georghiou et al., 1969). The problem spread and currently involves San Joaquin Valley mosquito control agencies from Stanislaus County in the north to Kern County in the south, as well as one agency in southern California.

C. tarsalis is not only a pest mosquito but is a direct threat to the public health as the primary vector of both St. Louis and western equine encephalitis in California. This species is also a vector of Venezuelan equine encephalomyelitis, although presence of the virus has not yet been detected in California. Should widespread control become necessary in the event of an epidemic, the organophosphorus larvicides would be useless, at legal dosages, in areas afflicted with resistance.

Control is further threatened in that high tolerance in adults has been shown in the laboratory to be related to organophosphorus resistance in larvae (Georghiou et al., 1969; Schaefer and Wilder, 1970), but the effects on control in the field are not yet clear. Attempts to evaluate organophosphorus materials in the field are complicated by the facts that the adults are capable of moving considerable distances, quickly reinfesting treated areas and that field population density is difficult to measure.

The present study was initiated to try to relate mortality in caged populations of organophosphorus resistant *C. tarsalis* with mortality in caged populations of other species about which information on operational resistance is available. Adult mosquitoes, representing various populations, were exposed simultaneously to adulticides dispensed from a nonthermal aerosol generator. The resultant mortality was then compared.

METHODS AND MATERIALS.–Tests were conducted cooperatively between personnel of the California Department of Public Health and the Navy Disease Vector Ecology and Control Center. The test site was a flat, unobstructed stubble field at Skaggs Island, a military reservation in Sonoma County, California. The test materials were applied from a truck-mounted nonthermal aerosol generator. The generator, specifically designed to dispense low volume, high concentrate insecticides, produces a fog dependent upon air movement for dispersal. Capabilities of the generator, including droplet size and distribution pattern, have been discussed by Stains et al. (1969).

Mosquitoes used in the tests were field-collected *Aedes nigromaculis* (Ludlow), *A. melanimon* Dyar and *C. tarsalis* and a laboratory strain of *C. pipiens* L. The field populations were collected as larvae or pupae and were reared to the adult stage in the laboratory. Before taking the mosquitoes to the field, approximately 20 unsexed adults from each test population were transferred to cylindrical cages (2-5/8 x 7 inches) of 16 x 18-inch mesh wire screen. Fruit jar rings with screen inserts closed the ends of the tubes. Sugar water saturated cotton pads were available to the caged mosquitoes prior to testing. For the test, stakes were set out at intervals for a total distance of 5,000 feet downwind from the point of application and the caged adults were suspended from the stakes approximately three feet above ground level. Controls representing each test population were treated in the same manner but were placed upwind where they would not be exposed to the applied insecticide. Any pre-treatment mortality was recorded at the time the cages were placed on stakes. The caged adults were picked up about 30 minutes after each application. The cages were then wrapped individually and placed in plastic bags. Humidity was provided by damp toweling interspersed among the cages. Final post-treatment mortality was assessed at 24 hours.

Insecticides evaluated in the test series were malathion, fenthion, Dursban®, Dowco 214 (methyl Dursban), naled, and propoxur. Commercial formulations were used undiluted or diluted with cottonseed oil as necessary to achieve the desired concentrations.

RESULTS AND DISCUSSION.–The generator output is impossible to determine in terms of rate per acre as the small droplets are carried by the wind as a moving aerosol cloud, and the number of acres covered is dependent upon meteorological conditions during the dispersal. Apparently very little material is lost as ground deposition. Stains et al. (1969), using naled and a fluorescent particle tracer technique, found less than one percent of the aerosol cloud was deposited on the ground and foliage in the first mile. The generator output is best described as the number of ounces dispersed per minute. Both ounces per minute and a nominal dosage rate, designated as pounds per acre, are listed for each test (Table 1). The nominal dosage rate is for comparative purposes only and is based on a forward speed of five mph and the assumption that the entire aerosol cloud was effective within a 5,000 foot swath.

Larvae representing each of the adult populations were tested to determine their susceptibility to the organophosphorus compounds. The results are shown in Table 2. The adults were not tested in the laboratory. Both the Kings and

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Table 1.–Application details for adult tests shown in Figures 1-7.

Insecticide	Figure Number	Generator output (oz/min)	Nominal dosage rate (lb/acre)[a]	Wind (mph)	Temperature (degrees F)
Malathion	1	37.8	.012	12-15	75
Fenthion	2	32.0	.0099	10	70
Dursban®	3	36.8	.0115	8-10	70
Dowco® 214 (Methyl Dursban)	4	42.0	.013	8	70
Naled	5	33.0	.010	11	70
Propoxur	6	32.0	.007	8-10	75
Propoxur	7	32.0	.007	7.5	70

[a]Based on the assumption that the entire aerosol cloud was effective within a 5,000-foot swath.

Table 2.–Susceptibility levels (ppm) determined for the larval stage of the test adults.

	Malathion		Parathion		Methyl parathion		Fenthion		Dursban®	
	LC_{50}	LC_{90}	LC_{50}	LC_{90}	LC_{50}	LC_{90}	LC_{50}	LC_{90}	LC_{50}	LC_{90}
Culex pipiens Laboratory colony	.035	.061	.0026	.0040	.0018	.0027	.0026	.0041	.0014	.0019
C. tarsalis Kings MAD							.0057	.032		
C. tarsalis Tulare MAD	.37	2.75	.030	.19	.011	.084	.016	.035	.012	.034
Aedes nigromaculis Turlock MAD			.11	.67	.035	.25	.026	.13	.013	.054
A. melanimon Sutter-Yuba MAD					.0033	.0048	.0015	.0039	.0015	.0050

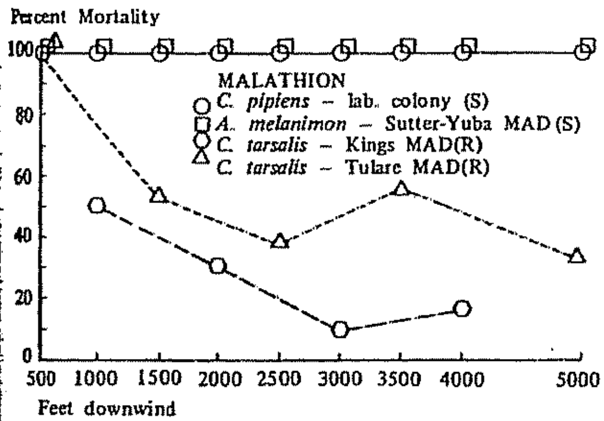

Fig. 1.–Mortality of caged adult mosquitoes at 24 hours after application of malathion from a nonthermal aerosol generator.

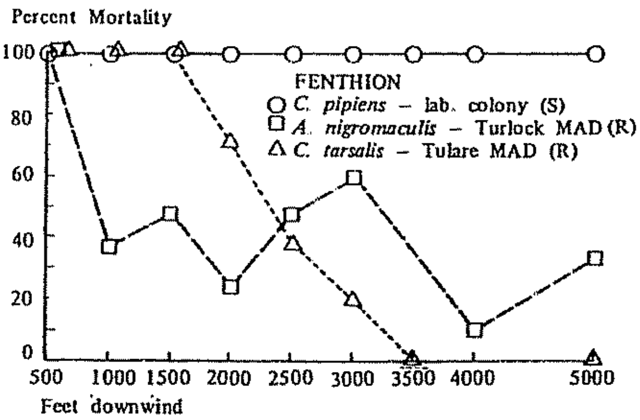

Fig. 2.–Mortality of caged adult mosquitoes at 24 hours after application of fenthion from a nonthermal aerosol generator.

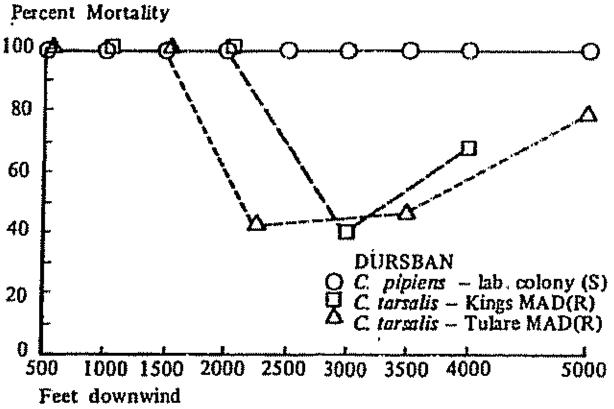

Fig. 3.–Mortality of caged adult mosquitoes at 24 hours after application of Dursban from a nonthermal aerosol generator.

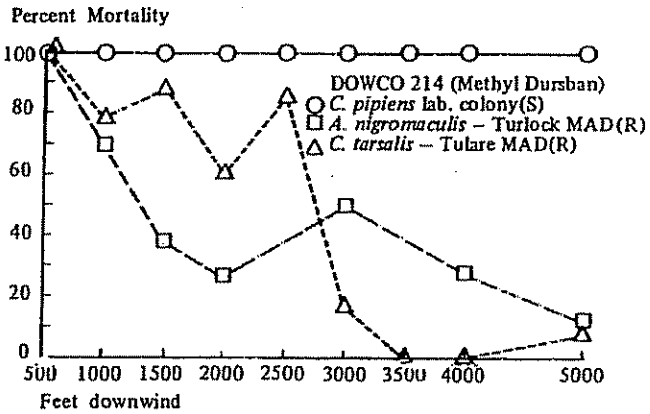

Fig. 4.–Mortality of caged adult mosquitoes at 24 hours after application of Dowco 214 from a nonthermal aerosol generator.

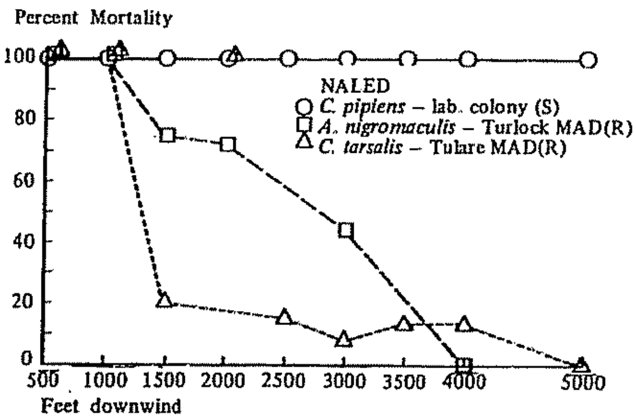

Fig. 5.–Mortality of caged adult mosquitoes at 24 hours after application of naled from a nonthermal aerosol generator.

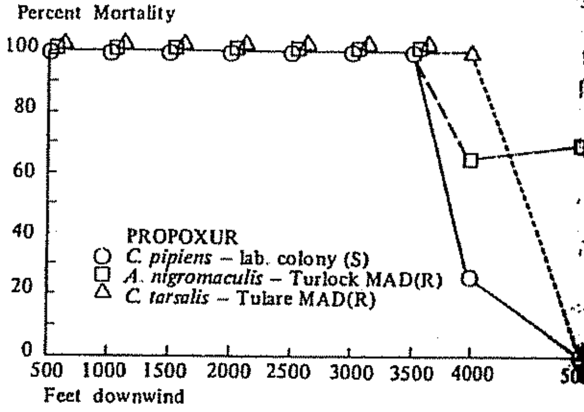

Fig. 6.–Mortality of caged adult mosquitoes at 24 hours after application of propoxur from a nonthermal aerosol generator.

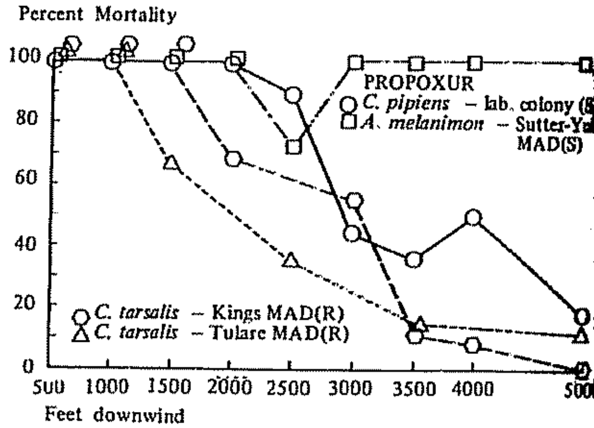

Fig. 7.–Mortality of caged adult mosquitoes at 24 hours after application of propoxur from a nonthermal aerosol generator.

Tulare Mosquito Abatement District populations of *C. tarsalis* are known to be operationally resistant to the organophosphorus larvicides. Georghiou, et al. (1969) and Wilder and Schaefer (1969) demonstrated adult resistance in populations with comparable levels of larval resistance. The *A. nigromaculis* from the Turlock Mosquito Abatement District have a history of larval and adult resistance which has been verified both in the laboratory and in the field. Adulticiding with propoxur is the only currently successful control method. The *A. melanimon* from Sutter-Yuba Mosquito Abatement District and the laboratory strain of *C. pipiens* are susceptible both as larvae and as adults.

Propoxur (Figs. 6 and 7) appeared to be the most promising of the test materials for the control of the resistant *C. tarsalis*. Comparable mortality was achieved against both the resistant species and the susceptible *C. pipiens*. Since it is known that propoxur is the only available adulticide effective for control of highly resistant populations of *A. nigromaculis*, and 100 percent mortality of both the *C. tarsalis* and the *A. nigromaculis* was achieved of the 3,500-foot station, it could be assumed that this material would be as effective against *C. tarsalis* as it is against *A. nigromaculis* (Fig. 6). Womeldorf, et al. (1971) found the larval failure threshold of organophosphorus resistant *A. nigromaculis* to match that for resistant *C. tarsalis*.

Unfortunately, *A. nigromaculis* adults were not available for the second propoxur test (Fig. 7), but again propoxur appeared to be only slightly more toxic to the susceptible *C. pipiens* than to the resistant *C. tarsalis*. In this test, 100 percent mortality of *A. melanimon* was achieved at the 5,000-foot station, perhaps indicating greater susceptibility of this species to propoxur. At the 2,500-foot station, only 73 percent mortality was achieved. The reason for this discrepancy is not known.

One hundred percent mortality of the resistant populations did not extend past the 2,000-foot station for any of the other materials tested, although complete mortality of the susceptible species occurred out to the 5,000-foot station.

References Cited

Georghiou, G. P., P. A. Gillies, and D. J. Womeldorf. 1969. *Culex tarsalis* Coquillett: detection of resistance to parathion, methyl parathion, fenthion, Dursban® and ABATE® in a malathion resistant population. Calif. Vector Views 16(12): 115-118.

Gillies, P. A. and D. J. Womeldorf. 1969. Resistance of California mosquitoes to insecticides – 1969. Proc. Utah Mosq. Abatement Assoc. 22:25-26.

Gjullin, C. M. and L. W. Isaak. 1957. Present status of mosquito resistance to insecticides in the San Joaquin Valley in California. Mosq. News 17:67-70.

Schaefer, C. H. and W. H. Wilder. 1970. A new carbamate insecticide, RE-11775, with promising activity against organophosphorus resistant mosquitoes. J. Econ. Entomol. 63(2):480-483.

Stains, G. S., E. M. Fussell, J. P. Keathley, J. A. Murray and L. M. Vaughan. 1969. Caged insect kills of up to two miles utilizing a new low-volume aerosol generator. Mosq. News 19(4):535-544.

Wilder, W. H. and C. H. Schaefer. 1969. Organophosphorus resistance levels in adults and larvae of the pasture mosquito, *Aedes nigromaculis* (Ludlow), in the San Joaquin Valley. Proc. Calif. Mosq. Control Assoc. 37:64-67.

Womeldorf, D. J., P. A. Gillies and K. E. White. 1968. Present status of insecticide resistance in California mosquito larvae. Proc. Calif. Mosq. Control Assoc. 36:81-84.

Womeldorf, D. J., P. A. Gillies and K. E. White. 1971. Insecticide susceptibility of mosquitoes in California: status of resistance and interpretation through 1970. Proc. Calif. Mosq. Control Assoc. 39:56-62.

PUBLIC HEALTH PROTECTION CHEMICAL RESISTANCE IN LARVAL *CULEX PIPIENS QUINQUEFACIATUS* SAY AND *CULEX PEUS* (DYAR) IN THE SOUTHEAST MOSQUITO ABATEMENT DISTRICT

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The development of resistances in many species of mosquitoes to "Public Health Protection Chemicals" (abbreviated PHP chemicals) has become a growing problem throughout the State of California, and the Southeast Mosquito Abatement District (SEMAD) has been no exception.

Resistance to organochlorine compounds was observed in the SEMAD during the late 1950's. At that time, the District was using DDT and toxaphene in its larviciding program. When the organochlorine compounds began failing in 1958, the District integrated the organophosphate chemical, malathion, into its larviciding program. This material lasted approximately three years as failures were observed in the early 1960's. Fortunately, this was the "golden age" of pesticide chemical development; consequently, new mosquito larvicides were continually being developed and when one chemical started to fail at the dosage rates for controlling mosquitoes a new material was substituted.

There were many materials to choose from when malathion failed, but most of these were not suitable for an urban mosquito control program due to their high mammalian toxicity.

The material of choice to replace malathion was fenthion. This material, although more toxic than malathion to warm-blooded animals, was easier on fish and could be used at much lower dosage rates than malathion.

As it became apparent that mosquitoes had the ability to become rapidly resistant to many of the PHP chemical larvicides, the SEMAD initiated its own resistance surveillance program in cooperation with the Bureau of Vector Control of the California State Department of Public Health. This program was started in 1963 after malathion was observed to be no longer effective in controlling mosquito larvae at economical dosage rates.

Fenthion was incorporated into the SEMAD's integrated control program in 1962 showing great promise of controlling all the major mosquito species at low dosage levels. Continuous monitoring of the susceptibility levels of our problem species *Culex pipiens quinquefasciatus* Say and *Culex peus* (Dyar) indicated a slow increase in tolerance levels in certain populations throughout the District. In 1967, we experienced our first control failure in *Culex peus* to fenthion. From this time on fenthion resistance became rather general throughout the District in *C. peus*. Although *C. peus* is not known to be a persistent biter of man, its

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1972 Gilotra, S., W. Schulte, C. Anderson, G. Carmichael, G. Stokes, and S. Richie. Determination Of Susceptibility Levels Of Mosquitoes To Non-Persistent Insecticides By Microinjections
Mosquito News 32: 358-362 (Amvac Ref. #1368)

DETERMINATION OF SUSCEPTIBILITY LEVELS OF MOSQUITOES TO NON-PERSISTENT INSECTICIDES BY MICROINJECTIONS [1]

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ABSTRACT. A new approach for determining susceptibility levels of adult mosquitoes to insecticides by subcuticle injections has been offered. Several field populations belonging to the genera *Culex, Aedes, Anopheles,* and *Uranotaenia* were tested against commonly used insecticides. Advantages and limitations of the new method are discussed.

INTRODUCTION AND OBJECTIVES. During the 1971 Venezuelan equine encephalitis epidemic in U.S. about 12 million acres had to be sprayed for mosquito control to contain the epidemic in a limited area. Emergency situations like this arise from time to time, and resorting to massive spraying becomes absolutely essential. In addition to this, mosquito control districts spray routinely to insure comfortable living and to minimize the threat of arthropod-borne diseases. It is not uncommon for a large district to cover one million acres in a year, and considering that there are 350 organized mosquito control districts active in the U.S. (Shelton 1971), it would not be unfair to assume that well over 100 million acres are sprayed for mosquito control alone in this country every year. It is, therefore, important that mosquito control workers not only use those insecticides which are non-persistent and proven to be safe, but these must be used in minimum amounts so that we do not add to the environment, intentionally or inadvertently, any more "bad" or "good" insecticides (a "good" insecticide may become "less good" by further knowledge) than are absolutely essential. However, fundamental information on minimum lethal dose (Min. L. D.) is not easily available, especially for the non-persistent insecticides that are used in mosquito control in this country. One reason for this lack of vital information is that a satisfactory laboratory test to determine the susceptibility of adult mosquitoes to these types of insecticides has not been heretofore available. The commonly used WHO test is not satisfactory for biodegradable insecticides. Therefore, the objectives of the present study were:

(1) Determination of the absolute minimum lethal dosage of commonly used insecticides that will kill the different species of mosquitoes.

(2) Development of a simple laboratory test to determine the susceptibility of field and laboratory-reared mosquitoes to non-persistent insecticides.

METHODS AND MATERIALS. In the laboratory, insecticides can be applied by three ways: topical application, infusion, or injection. It seems that the last of these (injection method) is more accurate. Table 1 compares the results obtained with the three methods using house flies as test species. Variation, as measured by the standard error (SE), was generally more in the topically-applied group than in the injected group. However, when the infused group was compared with the injected

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TABLE 1.—Variability of topical (top), injection (inj), and infusion (inf), results for female houseflies.

Comparison of Standard Errors*

Insecticide	top/inj	inf/inj
SD-11319	2	...
AD-11373	10	10
SD-11097	0.5	1
Monocrotophos	2	1

* From the data of Sun and Johnson (1971).

group variation was about the same, or more, in the infused group. Furthermore, most insecticides, if not all, act after they have been absorbed through the cuticle. Therefore, after careful considerations it was decided to inject the test insecticides under the cuticle (Fig. 1). The insecticide dilutions were made in acetone which in turn was further diluted in a balanced salt solution for the purpose of injecting mosquitoes. Each mosquito was inoculated with 1 μl (0.001 ml) of appropriate dilution and the mortality was recorded after 24 hours of injection, as has been described elsewhere (Gilotra *et al.*, 1972).

Several species covering the genera *Aedes*, *Culex*, *Anopheles*, and *Uranotaenia*, and two insecticides, namely malathion and dibrom-14 were used. These insecticides have good safety records, and their oral toxicity (LD_{50}) in laboratory-bred white rats is 2800 and 430 mg per kilogram weight of animal, respectively (Neumeyer *et al.*, 1969).

RESULTS. In order that results be comparable, for each test (except *Uranotaenia* mosquitoes) the mosquitoes were divided into two groups; one group was exposed to the test insecticide I (i.e., malathion), and the other to the test insecticide II (dibrom). Table 2 shows the response of *Aedes* mosquitoes to malathion. In general, these mosquitoes are susceptible. Even at a low dosage of 3 ngms (nanograms) per mosquito, more than 50 percent of *A. sollicitans* were killed. The LD_{90} for *A. sollicitans* and *A. taeniorhynchus* was about 9 ngms. However, *A. aegypti* was a bit more tolerant. The LD_{90} was about 29 ngms. Table 3 shows the response of mosquitoes from the same pool to dibrom. All *Aedes* species were highly susceptible. The LD_{90} was 4 ngms. or less.

In the next series of tests the responses of *C. quinquefasciatus* (several different populations) and *C. salinarius* (three populations) were explored. These mosquitoes are major problems in the State of Louisiana. The so-called laboratory susceptible strain BR-L of *C. quinquefasciatus* was moderately tolerant to malathion (Table 4); the LD_{90} being about 29 ngms. The other three strains of *C. quinquefasciatus* (SB-F, PL-F and JF-F) and three strains of *C. salinarius* (NO-F, SB-F, SB-F-I) which were field-collected, were at least two to four times more tolerant than the BR-L strain of *C. quinquefasciatus*. When the same populations were exposed to dibrom (Table 5) they were all highly susceptible. The LD_{90} varied from 4 to 8 ngms.

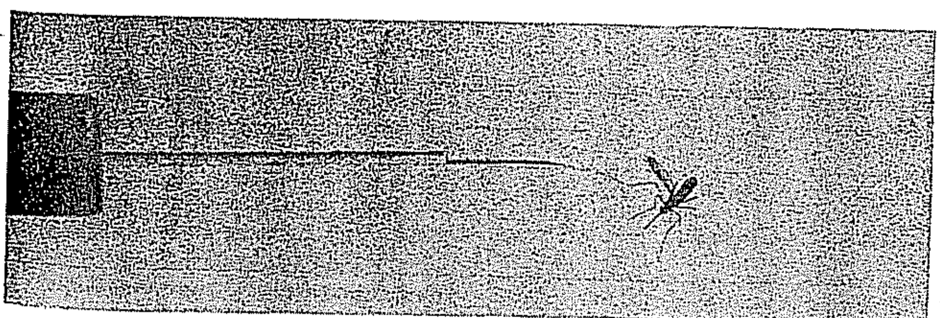

FIG. 1.—Microinjection of an insecticide formulation into a mosquito.

TABLE 2.—Percent kill of 2- to 5-day old *Aedes* mosquitoes after application of technical grade malathion by SC (subcuticle) route.

Species	Strain	Nanograms per mosquito						
		0	1	3	6	9	12	29
sollicitans	PL–F†	0 (10)*	6 (16)	60 (15)	88 (25)	96 (24)	100 (22)	NT
aegypti	NO–F	...	0 (6)	0 (5)	0 (10)	43 (7)	69 (16)	100 (10)
taeniorhynchus	PL–F	...	NT	NT	NT	82 (17)	100 (10)	NT

* Number in parentheses represents the number of mosquitoes tested.
† F indicates that test mosquitoes were reared from field collected larvae and pupae.
NT Not tested at that dosage.

Two populations of *An. crucians* were also tested, and they were moderately susceptible to malathion (LD_{90} was 29 to 58 ngms.) and highly susceptible to dibrom (LD_{90} was 4 to 8 ngms.). A few mosquitoes of *U. lowii* were also tested. Since these are very delicate and small, one wondered if they could be successfully injected. There was no mortality in the control, but the results were incomplete because *U. lowii* mosquitoes were not tested below the dosage of 29 ngms of malathion per mosquito and at this dosage there was 100 percent mortality. A summary of the results obtained from the 11 field-collected populations and 1 laboratory population with test insecticides is presented in Table 6. *A. sollicitans* and possibly *U. lowii* were susceptible to both the insecticides, while other populations were considerably more susceptible to dibrom as indicated by malathion/dibrom ratio in the last column of Table 6.

DISCUSSION. In injecting the insecticides under the cuticle, the physiological responses of mosquitoes to the test insecticide were measured. In other words, the authors tried to determine the minimum physiological lethal dose which should approximate the topically-applied dosage, should there be rapid absorption through the cuticle with no or minimum loss of active ingredients. There seems to be some reason to believe that this is what happens with the use of biodegradable insecticides, especially when they are applied as ULV concentrates. Field observations indicate that mosquitoes die rapidly, or in a short time after a suitable spray application. The implication is that the insecticide passes rapidly through the cuticle to initiate toxic effects which could not have happened if the insecticide had remained outside. Recently, rapid penetration of the cuticle by an insecticide has been very well documented by Benezet and Forgash

TABLE 3.—Percent kill of 2- to 5-day old *Aedes* mosquitoes after application of technical grade dibrom-14 by SC route.

Species	Strain	Nanograms per mosquito					
		0	0.2	1	2	4	8
sollicitans	PL–F†	0 (7)*	0 (16)	3 (30)	38 (29)	90 (29)	100 (18)
aegypti	NO–F	...	0 (14)	NT	35 (17)	100 (14)	NT

* Number in parentheses represents the number of mosquitoes injected.
† F indicates that test mosquitoes were reared from field collected larvae and pupae.
NT Not tested at that dosage.

TABLE 4.—Percent kill of 2- to 5-day old *Culex* mosquitoes after application of of technical grade of malathion by SC route.

Species	Strain	Nanograms per mosquito						
		0	6	12	29	58	88	117
quinquefasciatus	BR-L *	6 (17)	0 (11)	48 (29)	100 (26)	100 (27)	NT	100 (15)
	NO-L	4 (27)	0 (12)	36 (25)	50 (32)	88 (35)	NT	96 (25)
	SB-F †	5 (20)	0 (40)	3 (34)	12 (34)	21 (34)	NT	95 (20)
	PL-F	0 (30)	NT	15 (40)	55 (40)	88 (40)	NT	98 (20)
	JF-F	0 (30)	NT	30 (20)	75 (40)	83 (52)	95 (19)	100 (30)
salinarius	NO-F	0 (12)	NT	0 (20)	62 (21)	76 (17)	NT	100 (16)
	SB-F	0 (9)	NT	5 (21)	38 (29)	63 (49)	88 (40)	96 (24)
	SB-F-I	..	NT	NT	NT	96 (24)	100 (25)	NT

* L indicates that test mosquitoes were from laboratory colony.
† F indicates that test mosquitoes were reared from field collected larvae and pupae.
NT Not tested at that dosage.

(1972). They studied penetration of radio-isotope-labelled malathion through the cuticle of the common house fly by use of radioautography. Their conclusions were: "The malathion moved through the cuticle and into the hemolymph within 15 seconds . . . the malathion being distributed by the hemolymph." Elsewhere

TABLE 5.—Percent kill of 2- to 5-day old *Culex* mosquitoes after application of technical grade dibrom-14 by SC route.

Species	Strain	Nanograms per mosquito					
		0	0.2	1	2	4	8
quinquefasciatus	BR-L *	17 (6)	6 (16)	NT	67 (15)	NT	100 (16)
	SB-F †	..	8 (12)	NT	0 (12)	NT	100 (12)
	PL-F	0 (19)	0 (20)	NT	36 (39)	100 (40)	100 (40)
	JF-F	..	25 (20)	8 (40)	55 (40)	100 (40)	100 (29)
salinarius	NO-F	..	NT	NT	40 (10)	81 (16)	100 (16)
	SB-F	0 (20)	10 (20)	NT	45 (58)	85 (40)	98 (48)
	SB-F-I	..	..	NT	NT	91 (21)	100 (25)

* L indicates that test mosquitoes were from laboratory colony.
† F indicates that test mosquitoes were reared from field collected larvae and pupae.
NT Not tested at that dosage.

TABLE 6.—Susceptibility of mosquitoes to malathion and dibrom-14—Summary at LD_{90-100} level.

Species	Strain	Malathion ngms/mosq.	Dibrom ngms/mosq.	Malathion/Dibrom
A. sollicitans	PL–F†	9	4	2
A. aegypti	NO–F	29	4	7
C. quinquefasciatus	BR–L*	29	8	4
	SB–F	117	8	15
	PL–F	117	4	29
	JF–F	88	4	22
C. salinarius	NO–F	117	8	15
	SB–F	117	8	15
	SB–F–I	58	4	14
An. crucians	SB–F	58	8	7
	SB–F–I	29	4	7
U. lowii	SB–F	<29	4	<7

* L indicates that test mosquitoes were from laboratory colony.
† F indicates that test mosquitoes were reared from field collected larvae and pupae.

in the text it was implied that it was actually considerably less than 15 seconds.

Since this is the first time the mosquitoes have been injected with insecticides, it is not possible to compare the results strictly with the results obtained by others. However, assuming close to 100 percent penetration of malathion through the cuticle, our results are almost identical with the ones obtained by Weidhaas and his colleagues (1970), by exposing mosquitoes in a wind tunnel and later determining the amount of insecticide per mosquito by chemical analysis. The LD_{100} for *A. taeniorhynchus* was 10 ngms as compared to between 9 and 12 ngms by our method. However, it may be pointed out that both the studies using aforementioned methods were done independently at different times and with different populations. Therefore, the possibility of a close agreement as a mere coincidence cannot be ruled out. The implication that the mosquito cuticle is an insignificant barrier still remains to be tested. In fact, the degree to which the cuticle acts as a barrier depends upon the type of insect and nature of insecticide formulation (Wintergham, 1969). Lovell (1963) tested german cockroach *Blatella germanica* and milkweed bug *Oncopeltus fasciatus* individually to malathion. LD_{50} ratios between the topically applied and injected groups were 18 and 2 respectively; these ratios were 2 and 1 respectively for isomalathion.

In our tests no topical application was made. Both malathion and dibrom were injected under the cuticle. The obvious question arises whether these differences between the two insecticides obtained by microinjections only, would remain more or less the same if insecticides were applied topically. This cannot be tested because so far it has not been technically possible to apply topically such small amounts of insecticides to individual mosquitoes as has been done with large insects. However, results obtained by the use of wind tunnel and caged mosquitoes at West Florida Research Laboratory, Panama City, Florida and at USDA Research Laboratory, Gainesville, Florida, indicate that our ratios between the malathion and dibrom for *Culex* and *Aedes* mosquitoes are not unrealistic (Personal communication). This is still circumstantial evidence since the tests were not done on the same population or even on the same species.

As unnatural as the new method may seem, we still believe it can be efficiently used to compare the effectiveness of different biodegradable insecticides which, by definition, must act in a short time, or run the risk of being degraded. The actual method of testing by microinjections is simple, and can be used in the laboratory without any elaborate equipment. It should also satisfactorily measure the toxicity of persistent insecticides that rapidly pass through the cuticle.

With this type of quickly obtained comparative information easily obtainable one can then attempt to use the most efficient, as well as the most economical, insecticide in such a way that the quality of our environment is not jeopardized.

SUMMARY AND CONCLUSIONS. Mosquito populations of the same or different species are selectively susceptible to insecticides. It is essential that, before the start of any mosquito control operation, dominant species to be controlled be clearly identified and only minimum amounts of that insecticide, which on the basis of most recent tests has proven to be effective, safe, and economical, be used.

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References Cited

Benezet, H. J. and Forgash, A. J. 1972. Penetration and distribution of topically applied malathion in the house fly. J. Econ. Ent. 65:53-57.

Gilotra, S. K., Anderson, C. H. and Schulte, W. 1972. Recent studies with ULV applied malathion. Proc. Conf. Mosq. Suppression and Wildlife Management. 1971—in press.

Lovell, J. B. 1963. The relationship of anticholinestrase activity, penetration, and insect and mammalian toxicity of certain organophosphorous insecticides. J. Econ. Ent. 56:310-317.

Neumeyer, J., Gibbon, D. and Trask, H. 1969. C. W. Pesticides Report—Part II. Chemical Week, April 26, 1969:38-68.

Shelton, W. 1971. Winning the battle of the bug. The Humble Way, 10(4):25-31.

Sun, V. P. and Johnson, E. R. 1971. A new technique for studying the toxicology of insecticides with house flies by the infusion method, with comparable topical application and injection results. J. Econ. Ent. 64:75-80.

Weidhaas, D. E., Bowman, M. C., Mount, G. A., Lofgren, C. S. and Ford, H. N. 1970. Relationship of minimum lethal dose to the optimum size of droplets of insecticides for mosquito control. Mosq. News 30:195-200.

Wintergham, F. P. W. 1969. Mechanism of selective insecticidal action. Annual Rev. Ent. 14:409-442.

1972 Mount, G. A., M. V. Meisch, J. T. Lee, N. W. Pierce, and K. F. Baldwin.
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Mosquito News 32: 444-446 (Amvac Ref. #1370)

ULTRALOW VOLUME GROUND AEROSOLS OF INSECTICIDES FOR CONTROL OF RICE FIELD MOSQUITOES IN ARKANSAS[1]

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ABSTRACT. In large-scale tests with ultralow volume (ULV) ground aerosols of insecticides in Lonoke, Arkansas, malathion, naled and chlorpyrifos gave fair to good control of adult rice field mosquitoes, predominantly *Psorophora confinnis* (Lynch Arribálzaga). The minimum effective doses determined from previous tests with caged adult mosquitoes appeared more than adequate against the natural population. All three compounds gave good control after 1 to 2 hours (86 to 100 percent), but at 24 hours posttreatment, applications every other night and every night averaged only 66 and 87 percent control, respectively.

The ultralow volume (ULV) ground aerosol method has received wide acceptance among mosquito control workers during the past several years. Meisch *et al.* (1971) therefore suggested that this economical method could be used in conjunction with a larvicide-oriented mosquito control program against rice field mosquitoes, predominantly *Psorophora confinnis* (Lynch Arribálzaga), in small communities or in Arkansas towns. However, most of the research with the ULV method has had to do with caged mosquitoes; little information is available concerning the effectiveness of the method against natural populations. The main objectives of the present research were therefore: (1) to evaluate the effectiveness of ULV aerosols in large-scale field tests; (2) to determine whether the minimum effective doses of insecticides determined by tests of caged adult mosquitoes would be effective against natural infestations of adult mosquitoes; and (3) to determine how often during the mosquito season such ULV aerosol applications would need to be made for satisfactory control in a typical town in a rice-producing area.

METHODS AND MATERIALS. The town of Lonoke, Arkansas, used as the test area contains about 2,900 people and is located 20 miles east of Little Rock. It consists of about 1,000 acres of flat terrain divided into standard size residential and business lots covered with a moderate amount of vegetation. Most streets in the town are spaced a standard block (about 300 feet) apart, which made fairly complete coverage possible. An untreated area about three-fourths of a mile north of Lonoke was considered the control and was used to obtain estimates of the fluctuations in the untreated population of adult mosquitoes.

The insecticides malathion, naled (10 percent Dibrom® 14 in heavy aromatic naphtha) and chlorpyrifos, were applied from 9 p.m. to 11 p.m. CDST during the first 3 weeks of July 1971, with two Leco ULV aerosol generators, one standard model and one heavy duty model. The instrument panels were mounted in the cabs of the trucks on which the aerosol generators were carried so that insecticide flow, air pressure, and insecticide temperature could be monitored while the applications were being made. With mala-

[1] This paper reflects the results of research only. Mention of a pesticide or a commercial 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 Arkansas Experiment Station and Extension Service.

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TABLE 1.—Results of ultralow volume insecticide aerosol tests against infestations of adult mosquitoes (predominantly *P. confinnis*) at Lonoke, Arkansas, July 1971.

A.I. (lb/gal)	Flow (fl oz/ min)	Air pressure (psi)	Speed (mph)	Amount used (gal)	Dose (lb/acre)[a] Intended	Dose (lb/acre)[a] Actual	Percentage kill[b] of caged mosquitoes at 18 hr	Percentage control of natural population[c] By landing rate at 1–2 hr	By landing rate at 24 hr	By light trap at 24 hr
					Malathion					
9.7	3	2 & 4[d]	10	3.1	0.0375	0.030	92		63	
9.7	3	2 & 4[d]	10	3.2	0.0375	0.031	99		58	
9.7	3	2 & 4[d]	10	3.9	0.0375	0.0378		94	92	94
9.7	3	2 & 4[d]	10	4.2	0.0375	0.040			69	88
					Naled[e]					
1.4	12	1.5	10	15	0.02	0.021		100	62	58
1.4	12	1.5	10	12.5	0.02	0.0175		93	74	90
					Chlorpyrifos					
6	3.2	2	15	2.5	0.0187	0.015		86	96	92
6	3.2	2	20	1.9	0.125	0.0114			80	82

[a] Actual doses varied according to road network which depended on wind direction.
[b] Corrected for check mortality (15 percent) by Abbott's formula.
[c] Calculated from comparison with baseline pretreatment data and adjusted according to fluctuations in the check area by Abbott's formula.
[d] Air pressure was 2 psi for standard Leco machine and 4 psi for heavy duty Leco machine.
[e] Ten percent Dibrom 14 in heavy aromatic naphtha.

thion, flowmeter settings were changed according to temperature changes to maintain a constant flow; however, this adjustment was not necessary with naled and chlorpyrifos because the viscosity of these insecticides varied only slightly.

The effectiveness of the aerosols was evaluated by three methods. 1. Caged adult female *P. confinnis* were exposed to two malathion aerosol applications to correlate caged mosquito kill with control of the natural infestation of rice field mosquitoes (predominantly *P. confinnis*). Caged mosquitoes were collected from natural infestations in the check area and exposed in 16-mesh screen wire cages (approximately 25/cage) suspended about one foot above the ground. These cages were placed around several abandoned houses and a church located in the town. Also, additional cages were placed in the check area to determine the amount of mortality, if any, that might occur because of the handling procedures. 2. The natural infestations of adult mosquitoes were sampled by making landing counts at each intersection on two streets perpendicular to each other, a total of 26 count stations. Also, five landing count stations were established in the check area. 3. Overnight light trap collections were made with New Jersey light traps at three locations within the town and compared with similar collections made outside the treated area.

RESULTS AND DISCUSSION. The results (Table 1) indicated fair to good control of adult rice field mosquitoes. In the first two tests with malathion 92 and 99 percent of the caged mosquitoes were killed, which correlated well with the control of the native population at 1 to 2 hours after treatment with all three compounds (86–100 percent). Also, the control of the native population at 24 hours posttreatment, as determined by landing counts and light trap collections, correlated well but averaged about 15 percent less than at 1 to 2 hours, apparently because of reinfestation from nearby untreated areas.

From research with caged mosquitoes (Mount *et al.*, 1970; Mount and Pierce, 1971; Mount and Pierce, in press) the doses of insecticide used at Lonoke were about the lowest which would give good control. However, such a high degree of control was obtained at 1 to 2 hours posttreatment with malathion and chlorpyrifos (these insecticides usually require 3 to 6 hours for complete knockdown with minimum effective doses) there is a possibility that even lower doses of all three insecticides might have been adequate. We also observed a fast knockdown (½ to 1 hour) of the caged mosquitoes exposed to malathion, which likewise suggested overkill.

Reinfestations of rice field mosquitoes occurred almost nightly in Lonoke during the entire test period; thus adequate mosquito control would require repetitive applications. Our tests were not designed specifically to evaluate the effect of applications made every night or every other night, but we did note that the average control with applications made every other night (two with malathion and two with naled) was only 66 percent (range 58–82 percent); nightly treatments (two with malathion and two with chlorpyrifos) gave an average 87 percent (range of 79–94 percent). These data therefore suggest that for good control of a rapidly migrating species such as *P. confinnis*, nightly applications of insecticide are necessary.

References Cited

Meisch, M. V., Lancaster, J. L., Jr. and Meek, C. L. 1971. Value of a mosquito control program in a small community in the rice area. Arkansas Farm Res. 20(2):1.

Mount, G. A., Pierce, N. W., Lofgren, C. S. and Gahan, J. B. 1970. A new ultralow volume cold aerosol nozzle for dispersal of insecticides against adult mosquitoes. Mosq. News 30(1): 56–59.

Mount, G. A. and Pierce, N. W. 1971. Eleven promising insecticides evaluated as ultralow volume cold aerosols against *Aedes taeniorhynchus* (Wiedemann). Mosq. News 31(1):77–80.

Mount, G. A. and Pierce, N. W. 1972. Adult mosquito kill and droplet size of ultralow volume ground aerosols of insecticides. Mosq. News (In Press).

1972 Mount, G. A. and N. W. Pierce.
Adult Mosquito Kill And Droplet Size Of Ultralow Volume Ground Aerosols Of Insecticides.
Mosquito News 32: 354-357 (Amvac Ref. #1369)

Literature Cited

Jakob, W. L. and Schoof, H. F. 1971. Studies with juvenile hormone-type compounds against mosquito larvae. Mosq. News. 31:540–543.

Leech, H. B. and Chandler, H. P. 1968. Aquatic Coleoptera, p. 293–371. *In*: R. L. Usinger, Aquatic Insects of California. University of California Press, Berkeley and Los Angeles.

Sacher, R. M. 1971. A mosquito larvicide with favorable environmental properties. Mosq. News. 31:513–516.

Spielman, A. 1970. Synthetic juvenile hormones as larvicides for mosquitoes. Industry and Trop. Hlth. 7:67–69.

Spielman, A. and Skaff, V. 1966. Inhibition of metamorphosis and of ecdysis in mosquitoes. J. Insect Physiol. 13:1087–1095.

Spielman, A. and Williams, C. M. 1966. Lethal effects of synthetic juvenile hormone on larvae of the yellow fever mosquito, *Aedes aegypti*. Science 154:1043–1044.

Wheeler, C. M. and Thebault, M. 1971. Efficiency of synthetic substances with hormonal activity against IV instar larvae of *Culex pipiens quinquefasciatus* Say in an outdoor insectary. Mosq. News. 31:170–174.

ADULT MOSQUITO KILL AND DROPLET SIZE OF ULTRALOW VOLUME GROUND AEROSOLS OF INSECTICIDES[1]

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ABSTRACT. Ground applications of ultralow volume insecticide aerosols against caged adult female *Aedes taeniorhynchus* (Wiedemann) showed that Pennwalt TD-8550 (methyl (mercaptoacetyl)methlycarbamate *S-ester* with *O*-methyl methylphosphonodithioate), synergized pyrethrins, Dowco® 214 (*O,O*-dimethyl *O*-(3,5,6-trichloro-2-pyridyl) phosphorothioate), chlorpyrifos, Plant Protection PP-511 (*O*-[2-diethylamino)-6-methyl-4-pyrimidinyl] *O,O*-dimethyl phosphorothioate), naled, and resmethrin were the most effective of 13 chemicals tested. Correlation of droplet size with adult mosquito kill indicated an optimum size range of 11 to 20 μ for naled, chlorpyrifos, and Plant Protection PP-511 with mass medium diameters (mmd's) from 8 to 17 μ.

We have continued to evaluate promising insecticides for adult mosquito control with the ultralow volume (ULV) ground aerosol method. This report gives the results obtained with an additional 13 chemicals tested during 1971.

TESTS WITH CAGED MOSQUITOES. These tests were conducted in an open field near Gainesville, Florida, in April, May and June. The tests were performed between 6 and 9 pm when climatic conditions were favorable. Temperatures 5 feet above the ground ranged from 74° to 84° F and averaged about 79° F. Wind velocities ranged from <2 to 10 miles per hour (mph) and averaged about 4 mph.

The insecticides tested were as follows:

Chevron RE-11775 (58 percent *m-sec*-butylphenyl methyl(phenylthio)-carbamate mixture with 29 percent and 5 percent *O*-isomers)
Chlorphoxim
Chlorpyrifos
Dichlorvos
Dowco® 214 (*O,O*-dimethyl *O*-(3,5,6-trichloro-2-pyridyl)phosphorothioate)
Lethane® 348 (2-(2-butoxyethoxy) ethyl thiocyanate)
Malathion
Naled

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Resmethrin
Pennwalt TD-8550 (methyl (mercaptoacetyl)methylcarbamate *S*-ester with *O*-methyl methylphosphonodithioate
Plant Protection PP-511 (*O*-[2-(diethylamino)-6-methyl-4-pyrimidinyl] *O*, *O*-dimethyl phosphorothioate)
Propoxur
Pyrethrins

A Leco ULV (Model HD) cold aerosol generator was used to disperse the concentrated insecticides. The machine instrument panel was located in the cab of the truck on which the machine was carried so that insecticide flow rate, air pressure, and insecticide temperature could be monitored while test applications were being made. All flow meter calibrations were made for a temperature range of 76° to 82° F so the viscosity of the insecticides would be about the same as during actual application.

The dose of each insecticide was changed by varying either flow rate and/or vehicle speed. Flow rates ranged from 0.57 to 7 fluid ounces per minute, and vehicle speeds ranged from 5 to 20 mph.

Initially, we planned to evaluate all of the insecticide formulations with a nozzle air pressure of 4 pounds per square inch (psi). It soon became apparent that several of the formulations were being overatomized at this air pressure; therefore, additional tests were made using air pressures of 2.5 and 1.5 psi with some of the insecticide formulations.

Adult female *Aedes taeniorhynchus* (Wiedemann) 2- to 5-days-old were exposed in 16-mesh galvanized screen wire cages (25 per cage) suspended on stakes 150 and 300 feet downwind in two rows perpendicular to the line of travel of the generator. After the passage of the generator, the mosquitoes were transferred to plastic tubes lined with clean paper. Except during exposure to the aerosols, the mosquitoes were held in insulated chests containing ice in cans and moist cotton. Absorbent cotton pads moistened with 10 percent sugar-water solution were placed on the holding tubes when they were returned to the laboratory. Mortality counts were made 18 hours after the mosquitoes were exposed to the aerosols.

Droplet Size Estimates. Droplet sizes of some of the insecticide formulations were estimated to study the effect of nozzle air pressure and flow rate on atomization and correlate size with kill of adult mosquitoes. Thus, droplets were collected on silicone (General Electric SC-87 Dri-Film) treated glass microscope slides by rapidly waving the slides through the aerosol at a distance of 3 to 6 feet from the point of discharge. Two glass slides were used for each treatment, and a sample of 200 droplets (100 per slide) was measured with an ocular micrometer at 450× magnification. Also, diameters of the original spheres were estimated by correcting the diameter of the droplets impinged on the glass slides. Spread factors were determined by a direct measurement method similar to that used by Anderson and Schulte (1971) and described in detail by Mount and Pierce.[2] Spread factors were as follows: malathion (0.51), chlorpyrifos (0.49), 10 percent Dibrom 14 in Heavy Aromatic Naptha (HAN) (0.42), and Plant Protection PP-511 (0.49).

Results and Discussion. The mortalities and estimated LD_{90}'s for each insecticide are presented in Table 1. Pennwalt TD-8550 was the most effective compound tested with an LD_{90} of 0.0048 pound per acre. Pyrethrins synergized with piperonyl butoxide was more effective than pyrethrins synergized with Tropital® (piperonal bis[2-(2-butoxyethoxy)ethyl] acetal) (LD_{90} of 0.008 vs. LD_{90} of 0.015 pound per acre). Dowco 214 and chlorpyrifos were slightly more effective than previously reported by Mount and Pierce (1971) and were just as efficient when atomized at 1.5 psi as when atomized at 3.5 to 4 psi. Plant Protection PP-511 was

[2] G. A. Mount and N. W. Pierce. Droplet sizes of ultralow volume ground aerosols as determined by three collection methods. (In manuscript)

TABLE 1.—Effectiveness of ultralow volume cold aerosols of insecticides against caged female *Aedes taeniorhynchus*.

Insecticide	A.I. (lb/gal)	Air pressure (psi)	No. of tests	Percentage mortality at 18 hours posttreatment with indicated dose (lb/acre)[a, b] 0.1	0.05	0.025	0.0125	0.006	0.003	LD_{90} (lb/acre)
Pennwalt TD-8550	8.5	4	6	...	..	..	100	95	67	0.0048
Pyrethrins+piperonyl butoxide (1:5 w/w)[c]	.7	4	7	...	..	..	95	84	74	.008
Pyrethrins+Tropital (1:5 w/w)[c]	.7	4	8	...	..	..	87	84	75	.015
Dowco 214	6	1.5	5	...	..	88	93	73	..	.0125
Chlorpyrifos	6	4	6	...	..	99	70	82	..	.0125
	6	1.5	6	...	..	94	92	69	..	.013
Plant Protection	3.9	1.5	6	...	..	95	76	66	..	.018
PP-511	3.9	4	5	...	..	68	78	..	..	>.025
10% (v/v) Dibrom 14	1.4	1.5	7	...	..	94	80	..	..	.019
(naled) in HAN	1.4	2.5	2	...	..	67	..	..	..	>.025
	1.4	4	5	...	..	64	28	..	..	>.025
10% (v/v) Dibrom 14	1.4	1.5	2	...	..	92	..	..	..	.022
(naled) in mineral seal oil	1.4	4	1	...	..	53	..	..	..	>.025
10% (v/v) Dibrom 14 (naled) in soybean oil	1.4	4	5	...	..	88	60	..	..	.027
Dibrom 14 (naled)	14	4	5	...	..	89	73	..	..	.025
	14	2.5	2	...	..	86	..	..	..	.03
Resmethrin	3.36	1.5	4	...	..	84	54	..	..	.045
	3.36	4	6	...	87	71	60	..	..	.058
Malathion+Lethane 384 (1:0.4 w/w)[d]	9.7	4	4	...	85	90	58	..	..	.045
Malathion	9.7	4	4	...	85	70	52	.	.	.06
Propoxur[e]	1.25	4	3	...	..	..	67	..	..	>.0125
Chlorphoxim	2	1.5	3	...	..	79	..	..	..	>.025
	2	4	1	...	..	57	..	..	..	>.025
Chevron RE-11775	4	5	3	...	..	69	..	..	..	>.025
	4	4	1	...	..	30	..	..	..	>.025
Dichlorvos	11.9	1.5	4	100	67	20	..	..	..	.078
Lethane 384	4	4	1	...	..	0	..	..	..	>.025

[a] The average mortality at distances of 150 and 300 feet; the average mortality of unexposed mosquitoes was 4 percent.
[b] Based on active ingredient (A.I.) used over a 300-foot swath.
[c] Indicated dose based on pyrethrins only.
[d] Indicated dose based on malathion only.
[e] Wettable powder (75%) suspended in No. 2 fuel oil.

equally as effective as naled and slightly more effective at 1.5 psi than at 4 psi. The most effective formulation of naled was 10 percent (v/v) Dibrom 14 in HAN; the LD_{90} was 0.019 pound per acre at 1.5 psi air pressure. (This formulation gave much poorer kill at higher pressures.) The 10 percent Dibrom 14 formulations in mineral seal oil and soybean oil were about equal to Dibrom 14. Resmethrin was much less effective than naled but was about equal to malathion. The effectiveness of resmethrin was about equal when atomized at 1.5 or 4 psi air pressure. The effectiveness of malathion was only slightly enhanced by the addition of Lethane 384, and Lethane 384 was completely ineffective when it was used alone. Propoxur, chlorpyrifos, Chevron RE-11775, and dichlorovos were only moderately effective and do not appear promising. However, the effectiveness of dichlorvos was en-

TABLE 2.—Effect of nozzle air pressure and flow rate on the droplet size of insecticides atomized with an ultralow volume cold aerosol generator.

Insecticide	Flow rate (fl oz/min)	Air pressure (psi)	Percent of total mass in indicated range of droplet size (μ)					Mass median diameter (μ)
			<5	5–10	11–20	21–40	>40	
Malathion	3	5	6	28	50	16	0	14
	3	4	3	14	47	35	1	18
	1.5	4	7	29	51	13	0	14
	3	2.5	3	10	35	48	4	21
	1.5	2.5	2	7	38	49	3	22
10% Dibrom 14 (naled)	7	4	37	59	4	0	0	5
in HAN	7	1.5	8	26	36	28	0	15
Chlorpyrifos	3.2	4	12	38	47	3	0	10
	3.2	1.5	4	18	45	33	0	17
	1.6	4	15	47	38	0	0	9
	1.6	1.5	4	21	48	27	0	15
Plant Protection PP-511	2.5	4	27	52	21	0	0	8
	2.5	1.5	4	26	39	29	2	15

hanced considerably at an air pressure of 1.5 psi compared with previous results at air pressure of 3.5 psi (Mount and Pierce 1971).

Droplet size estimates are presented in Table 2. The mmd's for malathion ranged from 14 to 22 μ depending on insecticide flow rate and air pressure. These estimates were slightly higher than those reported previously by Mount *et al.* (1970) because of the difference in the spread factor determination, rather than from any real difference in atomization. With 10 percent Dibrom 14 in HAN, there was a distinct difference in droplet sizes between air pressures of 1.5 and 4 psi (5 μ mmd for 4 psi vs. 15 μ mmd for 1.5 psi), and the kill of caged mosquitoes (Table 1) indicated over-atomization at 4 psi. Chlorpyrifos and PP-511 also showed considerable differences in droplet size at air pressures of 1.5 and 4 psi (mmd's ranged from 8 to 17 μ), but the efficiency of chlorpyrifos was unaffected though PP-511 appeared to be slightly overatomized at 4 psi. Except for 10 percent Dibrom 14 in HAN and PP-511 atomized at 4 psi, the average percentage of total mass of droplets in the 11 to 20 μ size range was 44 percent, and the data suggest that this range was optimum for Dibrom 14 diluted in HAN, chlorpyrifos, and PP-511. Mount (1970) previously suggested an optimum range of 5 to 10 μ mmd based on results with technical malathion. In the present test, the average percentage of total mass in the 5 to 40 μ size range was 93 percent, which indicated a narrow droplet spectrum being produced by the Leco ULV (Model HD) cold aerosol generator.

References Cited

Anderson, C. H. and Schulte, W. 1971. Teflon® as a surface for deposition of aerosol droplets. Mosq. News 31(4):499–504.

Mount, G. A. 1970. Optimum droplet size for adult mosquito control with space sprays or aerosols of insecticides. Mosq. News 30(1): 70–75.

Mount, G. A. and Pierce, N. W. 1971. Eleven promising insecticides evaluated as ultralow volume cold aerosols against *Aedes taeniorhynchus* (Wiedemann). Mosq. News 31(1): 77–80.

Mount, G. A., Pierce, N. W., Lofgren, C. S. and Gahan, J. B. 1970. A new ultralow volume cold aerosol nozzle for dispersal of insecticides against adult mosquitoes. Mosq. News 30(1): 56–59

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UNITED STATES AIR FORCE AERIAL SPRAY ACTIVITIES IN OPERATION COMBAT VEE[1]

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ABSTRACT. From July 8 through August 8, 1971, U.S. Air Force aircraft specially equipped for the dispersal of insecticides battled against the spread of Venezuelan equine encephalitis (VEE) in South Texas. Over 3.5 million acres, total, were sprayed by U.S. Air Force aircraft using the ultra low volume (ULV) technique and two insecticides, malathion and naled (Dibrom), for the control of adult mosquito vectors of VEE.

Early in July 1971 communications from the U.S. Public Health Service (USPHS) and the U.S. Department of Agriculture (USDA) requested assistance from the U.S. Air Force (USAF) in combating an outbreak of Venezuelan equine encephalitis (VEE) in South Texas. On July 6 operations personnel from the Special Aerial Spray Flight (SASF) based at Langley AFB, Virginia, and the Special Operations Forces (SOF) located at Hurlburt Field, Florida, and a SASF medical entomologist met with USDA and USPHS officials in Harlingen, Texas, to discuss the VEE situation. The need for aerial spray efforts to control the spread of VEE in Texas was established. On July 7 SASF was directed by Headquarters USAF to participate in Operation Combat VEE. Two UC–123K Provider aircraft specially equipped for ultra low volume (ULV) insecticide spraying were in place in Brownsville, Texas, in the lower Rio Grande Valley on July 8. Rain delayed the first aerial spray flights until July 11.

The aerial application of insecticide was aimed at the direct control of adult mosquitoes carrying the sleeping sickness virus across the Rio Grande River from Mexico into Texas and at indigenously infected mosquitoes. Target mosquito vectors included some 12 species from which VEE virus was isolated, with *Aedes sollicitans* (Walker), *Psorophora confinnis* (Lynch-Arribálzaga) and *Psorophora discolor* (Coquillett) yielding the greatest number of VEE-like isolates (Sudia and Newhouse, 1971). As designated by USPHS officials, population centers along the Rio Grande within 10 to 30 miles from the international border were the initial spray target areas.

Malathion (95 percent) supplied to the aircraft in bulk tankers was disseminated as a mosquito adulticide at 2.6 fl oz/acre from an altitude of 200 feet for an effective 1,000-foot swath. Aircraft speed was 130 knots (150 mph). Twenty-two Tee-Jet® nozzles with 8003 flat fan tips were used with a system pressure of 40 psi to achieve the necessary flow rate.

An appropriate flow of insecticide was achieved by an initial calibration and maintained by periodic recalibration. During each calibration run insecticide was sprayed for a 30- or 60-second interval through 6-foot lengths of plastic hose which were attached to each spray boom nozzle and which exited into 13-liter plastic buckets. The amount of chemical delivered was measured using a clear plastic, 1-liter, graduated cylinder, and system pressure was adjusted on subsequent calibration trials to achieve a desired, calculated volume of flow. Clear plastic hose sections used for nozzle attachment allowed viewing of each nozzle orifice and facilitated detection of clogged or leaking nozzles.

The initial two SASF planes were joined between July 12 and 17 by five additional UC–123K aircraft, modified for aerial spraying, from Hurlburt Field, Florida. Each of these aircraft was equipped

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[1] Mention of a pesticide or a proprietary product in this paper does not constitute a recommendation or an endorsement of the item by the author or the U.S. Air Force.

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with 14 nozzles with 8004 tips and operated with a spray system pressure of 45 psi. The nozzles on the Hurlburt aircraft were positioned downward at a 45 degree angle into the forward line of thrust of the aircraft as in the SASF arrangement to achieve maximum particle breakup. The deposition droplet spectra of all aircraft were checked by flying each plane with its spray system operating over red oil dye indicator cards. The following conditions were desired, and were obtained, as indicated by tests with silicone-coated slides and dye cards: (1) droplets with a mass median diameter of 30–50 microns; (2) few if any droplets of the 100-micron, or greater, range; (3) droplet coverage at least 10 drops per sq. in. All aircraft dispersal systems were monitored continuously to insure appropriate insecticide flow rates and most effective droplet sizes.

Between the 11th and 20th of July morning missions of approximately 2 hours' duration were accomplished, with each aircraft covering close to 30,000 acres while meteorological conditions were favorable. Increasing wind velocity (considered out of limits over 8 knots) and temperature (upper boundary: 80–85° F) each day limited morning sprays to 2 hours. In addition to frequently unfavorable wind conditions, crew duty day restrictions ruled out late afternoon-early evening flights. While operating out of Brownsville, USAF aircraft sprayed 19,620 gallons of technical malathion over 982,000 acres in Cameron and Hidalgo counties.

Suspected cases of VEE reported north of the Brownsville area prompted relocation of the USAF aerial spray force to Ellington AFB, near Houston, Texas. USDA officials designated a spray target area approaching 3 million acres in size for USAF Combat VEE aircraft. The spray area included Wharton, Fort Bend, Harris, Brazoria, Matagorda, Liberty, Chambers, and Galveston counties which surround the city of Houston. A USDA official was designated as liaison officer between the Combat VEE force and USDA planners in coordinating primary and secondary target area information. USAF information personnel arranged news releases on Combat VEE activities and notified civilian communities through public communications media of upcoming spray missions in their local areas.

From Ellington AFB the two SASF planes disseminated 85 percent naled (Dibrom® 14), another mosquito adulticide, at .75 fl oz/acre. Other aircraft involved in the USAF aerial spray effort around Houston dispersed malathion. These aircraft included the six UC–123K planes from Hurlburt Field, a single UC–123K from USAF Southern Command, Panama, and nine C–47 aircraft deployed from England AFB, Louisiana, to Texas. The C–47's employed a newly developed, short boom (T-bar) spray system which required significant on-site modification prior to becoming operational.

Personnel safety was a foremost concern. The SASF entomologist briefed all crews on the nature of the chemicals being sprayed, symptoms of organophosphate poisoning, and emergency safety procedures. Copies of the SASF Pesticide Information and Safety Pamphlet were distributed. A flight surgeon was available to the Combat VEE task force to handle routine sick call matters and emergencies. Each aircraft was equipped with a medical kit containing items for the treatment of minor skin and eye irritations as well as major pesticide overexposure. Five-gallon capacity, plastic water containers were provided for emergency washdown purposes. Protective equipment provided for personnel included chemical resistant rubber overalls, boots, and gloves and face shields for the insecticide loading crew, surgical rubber gloves for all personnel working on the spray systems, and respirators for flight engineers.

A total of 3,436 gallons of naled were disseminated over 586,287 acres and 40,335 gallons of malathion were applied to 2,016,060 acres by USAF aircraft in the Houston area. In this region as also in the majority of areas covered in the lower Rio Grande Valley significant reduction of most adult mosquito populations was achieved. Landing rate counts indicated 94 percent to 98 percent or better control in most spray target areas. An exception occurred near Brownsville where coastal wind conditions were less favorable for aircraft spraying and rapid mosquito re-infestations were encountered.

In view of the excellent initial adult mosquito kills, limited and isolated larval reinfestation areas, and increasing civilian aerial spraying involvement an anticipated second treatment of the target area by USAF aircraft was not made. During this South Texas campaign 3,584,347 acres were sprayed by USAF aircraft. A total of 59,955 gallons of malathion and 3,436 gallons of naled were disseminated. It is felt that aerial mosquito adulticiding combined with equine vaccination and quarantine programs did much to control the spread of VEE during the summer of 1971.

Literature Cited

Sudia, W. D. and Newhouse, V. F. 1971. Venezuelan equine encephalitis in Texas, 1971 Information Report. Mosq. News 31(3):350-351.

ULTRA LOW VOLUME TESTS OF SBP-1382 APPLIED BY GROUND EQUIPMENT FOR THE CONTROL OF ADULT MOSQUITOES

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The authors previously reported on the use of ULV malathion by ground equipment for the control of adult *Aedes taeniorhynchus* and *Culex nigripalpus* (Rathburn and Boike, 1972a). This research showed that *C. nigripalpus* required approximately twice the dosage necessary to give satisfactory kill of *A. taeniorhynchus*. Because of the high dosage of malathion required and the importance of *C. nigripalpus* as a vector of St. Louis encephalitis in Florida, other suitable insecticides were investigated for possible use against this species. Laboratory tests (Rathburn and Boike, 1972b) showed that SBP-1382,[1] a synthetic pyrethrin, was highly toxic to *C. nigripalpus*. The following tests were made to establish effective field dosages of this insecticide applied at ultra low volume by ground equipment.

[1] (5-benzyl-3-furyl) methyl 2,2-dimethyl-3-(2 methylpropenyl) cyclopropanecarboxylate. S. B. Penick and Company, New York, New York

METHODS. All tests were made in the early evening hours after sunset. The temperatures at 6 feet ranged from 69 to 85° F and averaged 78° F. The wind velocities at 6 feet ranged from 1 to 11 miles per hour (mph) and averaged 6 mph. The test plot was in a fairly open beach residential area with a few houses and large pine trees but with sparse ground vegetation.

Four cages of mosquitoes, two of *A. taeniorhynchus* and two of *C. nigripalpus*, each containing 25 females, were attached to a metal pole. One cage of each species was hung at 6 feet and another at 2 feet above ground. The poles with the cages of mosquitoes attached were placed at 165 and 330 feet downwind and perpendicular to the line of travel of the first swath of the aerosol generator. The second and third swaths were applied at one and two blocks (300 and 600 feet) upwind of the first swath. Each test or replicate con-

1972 Rathburn, Jr., C. B. and A. H. Boike, Jr.
Laboratory Thermal Aerosol Tests Of New Insecticides For The Control Of Adult Mosquitoes
Mosquito News 32: 179-183 (Amvac Ref. #156)

156

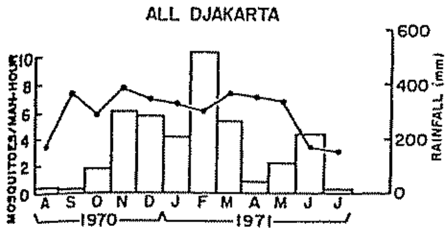

FIG. 2.—Monthly abundance of female *Aedes aegypti*, all areas combined, Djakarta. Bars show monthly rainfall. Measured by number collected per man-hour.

A further reason for the apparent lack of distinct seasonal patterns of abundance may be related to technics used. Inadequate length of time spent collecting biting mosquitoes, and attention only to indoor collections, may have biased collection data. However, collections were uniformly conducted throughout the year; and checks on peaks of man-biting activity were made periodically. It is therefore unlikely that important seasonal changes in densities were missed, particularly of sufficient magnitude to correlate with the seasonal changes in DHF morbidity in Djakarta.

Literature Cited

Halsted, S. B. 1966. Mosquito-borne haemorrhagic fevers of South and Southeast Asia. Bull. Wld Hlth Org. 35:3–15.

Kho, L. K., H. Wulur, A. Karsono and S. Thaib. 1969. Dengue haemorrhagic fever in Djakarta. J. Indonesian Med. Assoc. 19:417–437.

Russell, P. K., D. V. Quy, A. Nisalak, P. Simasathien, T. M. Yuill and D. J. Gould. 1969. Mosquito vectors of dengue viruses in South Vietnam. Amer. J. Trop. Med. Hyg. 18:455–459.

Scanlon, J. E. 1966. Bangkok haemorrhagic fever investigations: the 1962–63 mosquito collection. Bull. Wld Hlth Org. 35:82–83.

Tonn, R. J., P. M. Sheppard, W. W. MacDonald and Y. H. Bang. 1969. Replicate surveys of larval habitats of *Aedes aegypti* in relation to dengue haemorrhagic fever in Bangkok, Thailand. Bull. Wld Hlth Org. 40:819–829.

LABORATORY THERMAL AEROSOL TESTS OF NEW INSECTICIDES FOR THE CONTROL OF ADULT MOSQUITOES

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The West Florida Arthropod Research Laboratory conducts tests of candidate insecticides of low mammalian toxicity in a continuing program to develop new mosquito adulticides for the Florida mosquito control program. Those which show promise in laboratory tests and which are or will be commercially available are further tested in the field. The following report contains the results of laboratory thermal aerosol tests conducted with nine insecticides and compares their effectiveness to malathion as a standard.

METHODS. All tests were conducted using a laboratory thermal aerosol generator (Figure 1) developed at the West Florida Arthropod Research Laboratory (Rathburn, 1969). One-half milliliter of the insecticide solution, diluted to predetermined concentrations in Number 2 diesel oil or kerosene, was sprayed at 15 psi into a heater operated at a temperature of 850 ° F. The aerosol was drawn through the wind tunnel, which contained the 6-inch diameter screened test cages, at an air velocity of 3 mph. Check or control mosquitoes were exposed in the same manner to an aerosol of only diesel oil or kerosene.

Each test cage contained 25 female mosquitoes and each concentration of each insecticide, including the check, was

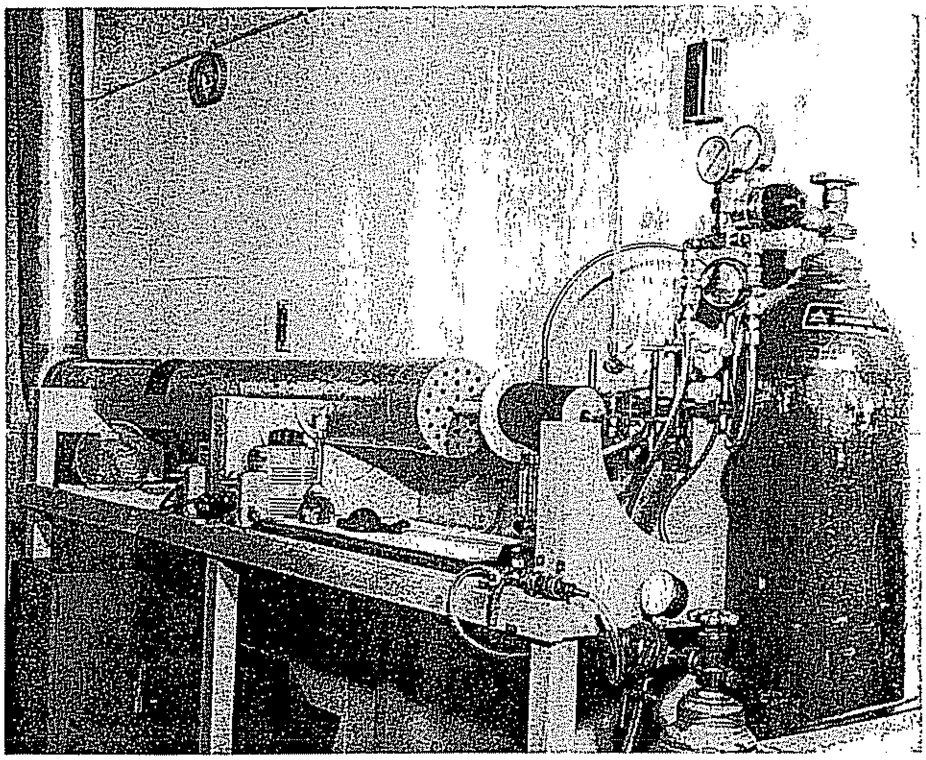

FIG. 1.—The laboratory thermal aerosol generator and wind tunnel.

replicated 5 to 29 times. LC_{50} and LC_{90} dosages were determined from dosage mortality curves of 3 to 5 concentrations of each insecticide. The mosquitoes used in the tests were from laboratory colonies and were 2 to 8 days old at the time of testing. Two species of mosquitoes, *Aedes taeniorhynchus* and *Culex nigripalpus* were used in all tests since it had been previously determined that these two species usually are not equally susceptible to a particular insecticide. Treated mosquitoes were changed to clean cages and held for 24 hours with access to sugar water.

The insecticides tested were C–9491 (Ciba Agrochemical Company), Dowco 214 and Dursban (Dow Chemical Company), EL–400 (Eli Lilly and Company), fenthion (Chemagro Corporation), malathion (American Cyanamid Company), naled (Chevron Chemical Company), SBP–1382 (S. B. Penick and Company), Sevin (Union Carbide Corporation), and TH–3461 (Thompson-Hayward Chemical Company). The chemical composition of the coded experimental insecticides are shown in Table 1. Thiosperse at 0.5 percent was used in all dilutions of malathion in diesel oil and Ortho Additive at 1 percent in all dilutions of naled in diesel oil to control the formation of sludge.

RESULTS. Results of the thermal aerosol tests are shown in Table 2. All treatment mortalities were corrected by Abbott's formula for check mortalities which averaged 1.1 percent for 207 replications with *A. taeniorhynchus* and 1.2 percent for 215 replications with *C. nigripalpus*.

Initially, No. 2 diesel oil was used as the diluent in all tests, but because of erratic results possibly due to variations

TABLE 1.—Chemical composition of coded experimental insecticides.

Insecticide	Chemical Composition
C–9491	o,o-dimethyl o-(2,5-dichloro-4-iodophenyl) phosphorothioate
Dowco 214	o,o-dimethyl o-(3,5,6-trichloro-2-pyridyl) phosphorothioate
EL–400	o-(4-bromo-2, 5-dichlorophenyl) o, o-dimethyl phorothioate
SBP–1382	(5-benzyl-3-furyl) methyl 2,2-dimethyl-3-(2 methylpropenyl) cyclopropanecarboxylate.
TH–3461	ethyl o,o-dimethyldithiophosphoryl 1-phenylacetate

between different lots of diesel oil, the diluent was changed to kerosene in later tests. In general the insecticides diluted in kerosene were more toxic to the adult mosquitoes than when diluted in diesel oil. Although diesel oil is preferred in actual control operations because of its lower cost, kerosene appears better suited for comparative laboratory testing because of its uniformity between lots.

Against *A. taeniorhynchus*, only Sevin, C–9491, SBP–1382, and EL–400 were shown to be less toxic than malathion, while fenthion, naled, and TH–4361, were considerably more toxic than malathion. Against *C. nigripalpus* SBP–1382, fenthion, naled, TH–3461 and Dursban were considerably more toxic than the malathion standard. The differences in insecticide susceptibility between the two species, shown in the last column of Table 2, is very noticeable. While malathion, fenthion, Dowco 214, Sevin, and TH–3461 were more effective against *A. taeniorhynchus* than *C. nigripalpus*, the reverse was true with naled, SBP–1382, EL–400, and C–9491. When compared to malathion, SBP–1382 was extremely toxic to *C. nigripalpus* but considerably less toxic than malathion to *A. taeniorhynchus*.

STABILITY OF FORMULATIONS. The stability of insecticide solutions stored in clear glass volumetric flasks at room tem-

TABLE 2.—Toxicity of insecticides applied as thermal aerosols in the laboratory to caged adult *Aedes taeniorhynchus* (Wied.) and *Culex nigripalpus* Theob.

	Milligrams a.i. per milliliter						Reciprocal LC_{90} ratio to malathion		
	Aedes			*Culex*					
Insecticide	Reps	LC_{50}	LC_{90}	Reps	LC_{50}	LC_{90}	*Aedes*	*Culex*	LC_{90} ratio of *Culex* to *Aedes*
In kerosene									
fenthion	17	0.34	0.70	19	0.85	1.33	7.00	21.93	1.90
naled	14	0.53	0.80	10	0.48	0.78	6.13	37.40	0.98
TH–3461	10	0.95	1.27	10	1.59	2.55	3.86	11.44	2.01
Dowco 214	18	1.44	2.80	20	3.88	11.50	1.75	2.54	4.11
Dursban	14	1.37	2.88	15	2.01	4.17	1.70	7.00	1.45
malathion	16	3.50	4.90	28	16.34	29.17	1.00	1.00	5.95
C–9491	14	4.50	9.40	14	3.70	6.60	0.52	4.42	0.70
SBP–1382	12	4.90	15.00	16	0.25	0.88	0.33	33.15	0.06
In diesel oil									
naled	16	1.93	2.77	12	1.34	2.10	2.36	18.34	0.76
Dursban	10	1.73	3.24	9	1.73	3.24	2.02	11.89	1.00
TH–3461	5	2.86	3.92	5	4.14	6.89	1.67	5.59	1.76
malathion	29	4.43	6.53	25	17.50	38.51	1.00	1.00	5.90
Sevin	13	5.27	11.03	13	5.27	12.46	0.59	3.09	1.13
C–9491	15	7.10	17.50	10	5.90	12.50	0.37	3.08	0.71
EL–400	12	25.50	84.00	8	16.25	40.50	0.08	0.95	0.48

TABLE 3.—Reduction in toxicity of formulations of naled in kerosene to adult *Culex nigripalpus* with increasing age of formulation.

Formulation age in days	Reps.	0.50	0.67	0.83	1.25	LC_{50}	LC_{90}
		Average percent mortality at indicated miligrams a.i./milliliter kerosene					
0	10	51.8	80.4	90.6	99.2	0.48	0.80
1	12	2.0	5.7	30.4	94.0	0.92	1.20
2	13	2.0	2.3	16.9	82.9	1.02	1.33
3–8	10	0.3	1.8	20.6	76.0	1.03	1.40
10	10	0	0.4	5.6	71.4	1.13	1.43

perature was not a problem with any of the insecticides used, with exception of naled. As shown in Table 3, there was almost a two-fold reduction in toxicity of naled solutions in kerosene after 10 days, and a reduction in toxicity was noticed even with 1-day-old solutions. As a result, all dilutions of naled used in obtaining the data presented in Table 2 were prepared immediately prior to use. Test solutions of TH–3461, fenthion, Dursban, Dowco 214, EL–400, Sevin, C–9491, and milathion, were used up to a maximum age of 2 days, 1, 2, 3, 4, 5, and 8 weeks respectively with no indication of a reduction in mosquito mortality. Dilutions of SBP–1382 were prepared just prior to use as instructed in the manufacturer's technical bulletin; therefore, no data on the stability of this insecticide were obtained.

Of importance in the laboratory testing of insecticides for future field use is the conversion of laboratory dosages to effective field dosages. In Table 4 currently recommended rates of fenthion, malathion, and naled for use as thermal aerosols in Florida were obtained from field research with various dosages of these insecticides. From dosage-mortality curves of these data the LC_{90} field dosages shown in column 2 were calculated. Comparing the recommended field dosage to the LC_{90} field dosage results in a ratio of 1.1 to 1 for all insecticides against both mosquito species.

Fenthion was omitted from the data for *C. nigripalpus*, because the maximum labeled dosage is not effective against this species; therefore, there is no recommended dosage of this insecticide against this species in Florida. Field LC_{90} data for malathion and naled against both mosquito species and for fenthion against *A. taeniorhynchus* were obtained from 2 to 4-point dosage-mortality lines.

Also shown in Table 4 are the field LC_{90} to laboratory LC_{90} ratios. In general, the LC_{90} field dosage is from 2 to 15 times more than the LC_{90} laboratory

TABLE 4.—A comparison of field and laboratory dosages of three insecticides, applied as thermal aerosols against adults of two species of mosquitoes.

	Field dosage—wt. oz. a.i. per gal.		Ratio of Recommended to LC_{90}	Lab. dosage—mg. a.i. per ml. of		Ratio of LC_{90} field dosage to LC_{90} lab. dosage	
Insecticide	Recommended	LC_{90}	field dosage	Diesel	Kerosene	Diesel	Kerosene
Aedes taeniorhynchus (Wied.)							
fenthion	1.25	1.10	1.1	.....	0.70	...	11.7
naled	1.50	1.40	1.1	2.77	0.80	3.7	13.1
malathion	6.00	5.50	1.1	6.53	4.90	6.3	8.4
Culex nigripalpus Theob.							
naled	1.75	1.60	1.1	2.10	0.78	5.7	15.4
malathion	8.00	7.10	1.1	38.51	29.17	1.4	1.8

dosage, the ratio varying with the insecticide and being greater with the more toxic insecticides. The lower LC_{90} obtained in the laboratory is probably due to better coverage since all the aerosol produced must pass through the cage containing the mosquitoes.

SUMMARY. Against both mosquito species only fenthion, naled, and TH-3461 were appreciably more toxic than the malathion standard; and only Sevin, C-9491, SBP-1382, and EL-400 tested against *A. taeniorhynchus* were less toxic than malathion. SBP-1382, while extremely toxic to *C. nigripalpus,* was considerably less toxic than malathion to *A. taeniorhynchus.* Although not as pronounced as with SBP-1382, a difference in species susceptibility was also noticed with most of the other insecticides tested.

Almost a two-fold reduction in toxicity of naled solutions in kerosene was noted after 10 days. With the exception of dilutions of SBP-1382 which were only tested as freshly made solutions, none of the other insecticides tested showed any reduction in toxicity with increasing age.

Field to laboratory LC_{90} ratios vary with the insecticide, being greater with the more toxic insecticides. In the field, a 2 to 15 times higher concentration than that required in the laboratory is necessary for comparable kill.

Literature Cited

Rathburn, C. B. Jr. 1969. A laboratory thermal aerosol generator for the testing of insecticidal aerosols. Mosq. News 29(1):1-6.

ULTRA LOW VOLUME TESTS OF MALATHION APPLIED BY GROUND EQUIPMENT FOR THE CONTROL OF ADULT MOSQUITOES

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Insecticides applied as thermal aerosols for the control of adult mosquitoes have been widely used for many years. Although this method has given excellent results, it has several inherent disadvantages, the main one being the hazard to automobile traffic caused by the dense fog.

Mount, *et al.* (1968) reported on a technique for dispersing ultra low volumes (ULV) of undiluted insecticides as nonthermal aerosols, and showed that technical grade malathion applied at 0.68 gallon per hour (gph) was as effective against caged adult mosquitoes as dilute formulations applied as thermal aerosols dispersed at 40 gph. These results coupled with the commercial development of ULV application have produced considerable interest in this new technique for adult mosquito control. As with any new technique, however, many questions arise which must be answered before it can be successfully used in routine control operations. This paper deals with some of the more important aspects of the use of this technique, including accurate control of discharge rates and effective dosage of malathion against caged adults of two species of mosquitoes, *Aedes taeniorhynchus* and *Culex nigripalpus.*

METHODS. All tests were conducted in the early evening hours after sunset. Temperatures at test time ranged from

1972 Rogers, A. J., B. W. Clements, Jr., C. B. Rathburn Jr., A. H. Boike, Jr., and N. E. Thomas, Jr.
ULV Strip Spraying Of Naled By Aircraft For Control Of Adult Stable Flies And Mosquitoes
28-32 (Amvac Ref. #1372)

1972

1372

ULV STRIP SPRAYING OF NALED BY AIRCRAFT FOR CONTROL OF ADULT STABLE FLIES AND MOSQUITOES

by

A. J. Rogers,[1] B. W. Clements, Jr.,[1] C. B. Rathburn, Jr.[1] A. H. Boike, Jr.,[1] and N. E. Thomas, Jr.[1]

Operational notes on tests against natural populations of mosquitoes:

1. The formulation is percent Dibrom 14 by volume in soybean oil

2. All tests were conducted between 5:00 and 7:00 p.m., at 75-foot altitude, 80 mph; 200-foot swaths; 32-800067 flat spray nozzles at 40 psi boom pressure; 8 fl ounces per acre under airplane, 2.6 to 2.8 fluid ounces per acre overall plot dose. Wind average 2 to 8 mph at 40 feet; temperature was 76° to 84°F. and R. H was 49% t 80% at 5 feet above ground.

3. Plot size was approximately 2700 acres. Four traps were placed in the tre ment area and four in the check area for each test except the last one, for which f traps were used. The principal species were Aedes mitchellae, Psorophora confinnis Culiseta melanura with fewer number of Anopheles crucians, Culex nigripalpus and Cu (Melanoconion) spp. The percent control shown was corrected for the change in mosq collections in the check area.

4. All cages of mosquitoes were hung vertically 2 to 4 feet above ground in tl same location for each test. The percent kill of each species in each area is the average of two cages of mosquitoes placed in each of two different areas or a total four cages of mosquitoes of each species in each habitat type. The percent kill wa: corrected for check mortality. The cages in the first two tests were picked up one hour after the end of treatment; in all other tests the cages were left in place ov night.

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[1] West Florida Arthropod Research Laboratory, Florida Division of Health, Panama City, Florida

percent Dibrom 14 by volume	per acre	per acre	No. swaths	@40' mph.	@5' °F	@5' %	No. tests	On open roadway avg.	On open roadway range	avg.	range
50	1.8	0.098	6	3	76	87	1	5200		5200	-
35	1.8	0.069	6	3	77	80	3	3600	2400-5000	4200	3600-5000
25	1.8	0.049	6	5	79	81	3	3700	2500-5000	3000	2500-3500
25	1.5	0.041	5	6	66	68	5	3200	2000-4000	2600	1500-4000
25	1.3	0.036	4	4	73	87	4	3500	2500-5000	3000	2000-4300
25	0.9	0.025	3	5	82	67	3	1700	1500-2000	1300	1000-1500
15	1.3	0.022	4	4	78	76	3	3000	2000-3900	1000	0-2000

[1] Operational notes on tests against caged flies and mosquitoes

1. Tests conducted 8 p.m. to 10 p.m.
2. Flat spray nozzles: 29 to 36, size 800067; 50-55 psi at boom.
3. Altitude 150'; 80 mph; flight centers of 200' applied only at upwind side of plot.
4. Cages placed on stakes 3' above ground 500' apart on open roadway and in adjacent vegetation.

Table 2. Aerial strip spraying of ULV naled in soybean oil against caged adults of *Aedes taeniorhynchus* and *Culex nigripalpus*, 1970-71[1]

Mosquito species	Vol. fl.oz./a.	Dosage lb./a.	No. 200 ft. swaths	Avg. wind @ 40 ft. mph.	Avg. temp. @ 5 ft. °F.	Avg. R.H. @ 5 ft. %	No. tests	Distance downwind of 90 + percent kill avg.	Distance downwind of 90 + percent kill range
Culex	1.8	.049	6	5	79	81	1	2500	-
	1.5	.041	5	6	66	68	3	2300	2000-3000
	1.3	.036	4	4	71	90	2	2400	2300-2500
	0.9	.025	3	7	82	67	1	1500	-
Aedes	1.3	.036	4	3	75	85	2	800	600-1000
	0.9	.025	3	4	82	62	2	1200	1000-1500

[1] All cages in vegetation; see notes Table 1 for methods.

[illegible] Aerial strip spraying of ULV naled in soybean oil for control of natural [illegible]
stable flies, *Stomoxys calcitrans* (L.) on Gulf Beaches, 1970-71

Test period from	Test period to	Avg. wind mph.	Avg. temp. °F.	Percent fly reduction at indicated hours post-treatment: 0.12	Range	13-24	Range
9:30 a.m.	4:30 p.m.	8.0	80.4	86	24-96	79	61-100
4:30 p.m.	9:30 a.m.	6.4	67.0	97	91-100	86	81-98

Operational notes

1. Average volume of 3.6 fl.oz./a; average dosage of 0.1 lb, a.i./a; 5 replications per test period.
2. Flat spray nozzles; 29-36, Size 800067;40-50 psi at boom.
3. Altitude 100-150', speed 80 mph.; 5 swaths each test, 200 ft. centers, first swath placed 2000 ft. upwind of beach.
4. Formulation all tests 25% Dibrom 14.
5. Percent fly reduction corrected to check populations; fly landing rates determined by counting number of flies landing on person within one minute.
6. Test plots were 8 to 25 miles in length.

Table 4. Aerial strip spraying of ULV naled in soybean oil against natural populations of mosquitoes - - 1971[1]

Form % naled	Dose lb. a.i./a.	Dist. in ft. between swath groups	No. of swaths per group	Trapping % control 1 day	Trapping % control 2 day	Caged mosquitoes - % kill: A. taeniorhynchus pine	A. taeniorhynchus cypress	A. taeniorhynchus titi	C. nigripalpus pine	C. nigripalpus cypress	C. nigripalpus titi
25	0.07	2600	6	65	57	100	--	--	100	--	--
35	0.10	2600	6	89	48	100	99	92	--	--	--
35	0.10	2000	5	94	77	100	53	56	100	83	100
35	0.10	2000	5	93	59	100	100	92	--	--	--
35	0.10	(20-600 ft. swath)		95	80	100	52	96	100	89	100

[1] See operational notes

1971 Mount, G. A., D. A. Dame and C. S. Lofgren.
Susceptibility Of A Florida Strain Of Aedes Taeniorhynchus (Weidemann) To Insecticides.
Mosquito News 31: 438-440 (Amvac Ref. #1364)

(B64)

SUSCEPTIBILITY OF A FLORIDA STRAIN OF *AEDES TAENIORHYNCHUS* (WIEDEMANN) TO INSECTICIDES[1]

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ABSTRACT. The larvae and adults of the F_1 generation of a field-collected strain of *Aedes taeniorhynchus* (Wiedemann) from Brevard County, Florida, were 46 and 23 times, respectively, as resistant to malathion (LC_{90} level) as compared with a susceptible laboratory strain of the same species. However, no resistance to naled, fenthion, propoxur, tetramethrin, or Abate® (*O,O'* (thiodi-*p*-phenylene) *O,O,O',O'*-tetramethyl phosphorothioate) was shown by the field-collected strain.

Because of the widespread use of malathion and naled for control of adult mosquitoes in Florida, there is continued interest in the susceptibility of various species of mosquitoes to insecticides. We are especially interested in populations of *Aedes taeniorhynchus* (Wiedemann) in Brevard County because of our extensive field testing with promising insecticides and equipment in this area of Florida.

Resistance of *A. taeniorhynchus* to malathion in Brevard County was first reported by Gahan *et al.* (1966) and was confirmed by Rathburn and Boike (1967) and by Lofgren *et al.* (1967). However, more recent tests by Boike and Rathburn (1969) suggested that *A. taeniorhynchus* in this area might be showing an increase in susceptibility to malathion. Then in August 1970, we attempted to use malathion against *A. taeniorhynchus* in field tests with a new rotary atomizer (Mount *et al.* 1971). In these tests, malathion gave no control so we changed to fenthion and obtained good control with the equipment. Because of these poor results with malathion, we decided to reappraise the susceptibility of *A. taeniorhynchus* from Brevard County to various insecticides.

PROCEDURES. Adult female mosquitoes were collected in a citrus grove near Allenhurst and returned to the Gainesville laboratory. Here they were offered a blood meal, and eggs were collected on moist oviposition medium (sphagnum moss). After two months, the eggs were hatched and reared by using the same procedures used for our laboratory strain of *A. taeniorhynchus*. These F_1 progeny were then used in all the susceptibility tests reported in this paper. Our susceptible laboratory strain of *A. taeniorhynchus* was included in the tests for comparison.

Tests of susceptibility to larvicides were made by placing groups of 25 fourth instar larvae in glass jars containing 250 ml of 0.3 percent saline water (our standard rearing medium for *A. taeniorhynchus*) that had been treated with various concentrations of insecticides in acetone solution. Mortality of the larvae was observed and recorded after 24 hours. Larvae not exposed to chemicals showed less than 1 percent mortality. Duplicate jars of each concentration were tested; however, only one test was made because of the limited numbers of larvae of the Allenhurst strain.

Tests of adult susceptibility were made by exposing groups of 25 adult female mosquitoes in a wind tunnel to contact sprays containing a range of concentrations of each insecticide. A description of the wind tunnel and procedures used is given by Mount *et al.* (1970). Knockdown and mortality counts were taken 1 and 24 hours after exposure, respectively. Adult female mosquitoes not exposed to chemicals showed only 2 percent mortality. Three tests were made with malathion, and either one or two tests were made with the other adulticides.

[1] This paper reports results of research only. Mention of a pesticide or a proprietary product in this paper does not constitute a recommendation or an endorsement of this product by the U. S. Dept. of Agriculture.

TABLE 1.—Susceptibility of a native strain of *A. taeniorhynchus* (Allenhurst, Brevard Co., Fla.) to larvicides compared with the Gainesville laboratory strain of the same species.

Larvicide	Strain	Twenty-four hour lethal concentration (ppm) LC50	LC90	LC99
Malathion	Allenhurst	0.88	2.6	6.4
	Laboratory	.03	.06	.09
Naled	Allenhurst	.1	.2	.3
	Laboratory	.06	07	.09
Fenthion	Allenhurst	.003	.005	.008
	Laboratory	.003	.005	.007
Abate	Allenhurst	.0017	.0026	.0036
	Laboratory	.0011	.0015	.002

RESULTS AND DISCUSSION. The tests of the larvicides (Table 1) indicated that the Allenhurst strain of *A. taeniorhynchus* was still highly resistant to malathion (28, 46, and 71 times as resistant as the Gainesville laboratory strain at the LC_{50}, LC_{90}, and LC_{99} levels, respectively). However, the LC_{90} of 2.6 ppm for the Allenhurst strain is not nearly as high as the LC_{90} of 17.4 ppm reported by Gahan *et al.* (1966); however, this difference may result from extrapolation of the data in the earlier report rather than from any real change in the native population of *A. taeniorhynchus*. (In our tests, the larvae from both strains were exposed to concentrations of malathion that produced a complete range of mortality; therefore, extrapolation was unnecessary.) The susceptibilities of the Allenhurst and Gainesville laboratory strains of *A. taeniorhynchus* to naled, fenthion, and Abate® (*O,O'*-(thiodi-*p*-phenylene) *O,O,O',O'*-tetramethyl phosphorothioate) differed only slightly.

The tests of adulticides (Table 2) also showed a high degree of resistance to malathion in the Allenhurst strain of *A. taeniorhynchus* (13, 23, and 36 times as resistant as the Gainesville laboratory strain at the LC_{50}, LC_{90}, and LC_{99} levels, respectively). There were no substantial differences in the susceptibilities of adults of the two strains to naled, fenthion, propoxur, and tetramethrin.

TABLE 2.—Susceptibility of a native strain of *A. taeniorhynchus* (Allenhurst, Brevard Co., Fla.) to adulticides compared with the Gainesville laboratory strain of the same species.

Adulticide	Strain	One hour knockdown concentration (%) KC50	Twenty-four hour lethal concentration (%) LC50	LC90	LC99
Malathion	Allenhurst	1.9	0.24	0.79	2.1
	Laboratory	.058	.019	.034	.055
Naled	Allenhurst	.032	.013	.027	048
	Laboratory	.035	.016	.031	054
Fenthion	Allenhurst	>.025	.007	.014	.024
	Laboratory	>.025	.006	.011	.019
Propoxur	Allenhurst	012	.008	.013	.019
	Laboratory	.013	.008	.014	.021
Tetramethrin	Allenhurst	.013	.014	.031	.06
	Laboratory	.01	.014	.028	.05

We concluded that the population of *A. taeniorhynchus* in the Allenhurst area of Brevard County has changed little in its susceptibility to malathion in the past five years. Our data show levels of resistance to malathion similar to those reported by Gahan *et al.* (1966) and Lofgren *et al.* (1967). Therefore, from our results and those reported during the past five years, the population of *A. taeniorhynchus* in Florida (excluding northwest Florida) is from 1.4 to 74 times as resistant to malathion as laboratory strains that have never been intentionally exposed to this insecticide. The average resistance in larvae is about 20 times greater; in adults, it is 14 times greater. Research with a colonized strain of *A. taeniorhynchus* that is resistant to malathion could yield valuable information about the degree of resistance that could be developed to malathion and adult cross-resistance patterns to other insecticides.

References Cited

Boike, Arthur H., Jr., and Rathburn, Carlisle B., Jr. 1969. Laboratory tests of the susceptibility of mosquito larvae to insecticides in Florida. Rpt. 40th Ann. Mtg. Fla. Anti-Mosq. Assn. pp. 61–65.

Gahan, James B., Smith, Carroll N. and Glancey, B. Michael. 1966. Resistance in Florida and countermeasures involving chemicals. Mosq. News 26(3):330–337.

Lofgren, C. S., Ford, H. R., Glancey, B. M. and Mount, G. A. 1967. Resistance of *Aedes taeniorhynchus* (Wiedemann) to malathion. Rpt. 38th Ann. Mtg. Fla. Anti-Mosq. Assn. pp. 53–58.

Mount, G. A., Baldwin, K. F. and Lofgren, C. S. 1970. Effectiveness of seven promising mosquito adulticides. Mosq. News 30(2):213–214.

Mount, G. A., Pierce, N. W., Lofgren, C. S. and Salmela, Jack. 1971. Droplet size and kill of adult mosquitoes with ultralow volume aerial sprays dispersed from a rotary-cylinder atomizer. Mosq. News 31(3):326–330.

Rathburn, Carlisle B., Jr. and Boike, Arthur H., Jr., 1967. Studies in insecticide resistance in Florida mosquitoes. Mosq. News 27(3):377–382.

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Field Evaluation of Slow-Release Mosquito[1] Larvicides[2,3]

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ABSTRACT

Selected concentrations of Abate® (*O,O*-dimethyl phosphorothioate *O,O*-diester with 4,4′-thiodiphenol), Dursban® (*O,O*-diethyl *O*-(3,5,6-trichloro-2 pyridyl) phosphorothioate), fenthion, and naled formulated in polyvinyl chloride (PVC) and of Dursban formulated in polyethylene and in charcoal were evaluated as mosquito larvicides in polyethylene-lined field pools. Initial doses of 0.5, 1.0, and 2.5 ppm were replicated 3 times for all formulations. In addition, effectiveness of Dursban in polyethylene and Dursban in charcoal was compared with Dursban emulsifiable concentrate at 0.1 lb active ingredient per acre. All doses were calculated on a theoretical immediate release. Effectiveness of test materials was determined by weekly sampling of natural larval populations and by periodic in-pool bioassays using laboratory-reared larvae of southern house mosquito *Culex pipiens quinquefasciatus* Say.

Treatments of Dursban in polyethylene and Dursban in charcoal at rates of 0.5, 1.0, and 2.5 ppm gave effective control for 20 to 26 weeks of the test period. Fenthion in PVC at 2.5 ppm provided control for 20 weeks. Control obtained with other formulations did not exceed 8 weeks. At 0.1 lb AI/acre, charcoal and emulsifiable formulations of Dursban were more effective than Dursban in polyethylene.

The slow-release of pesticides from a variety of substrates has been investigated by Raley and Davis (1949), Elliot (1955), Evans and Fink (1960), Barnes et al (1967), and Shultz and Webb (1969). Whitlaw and Evans (1968) reported that polyvinyl chloride (PVC) and polyamide formulations of mosquito larvicides gave excellent control of larvae of the southern house mosquito, *Culex pipiens quinquefasciatus* Say, over an extended period in the laboratory. In the present investigation the insecticides Abate® (*O,O*-dimethyl phosphorothioate *O,O*-diester with 4,4′-thiodiphenol), Dursban® (*O,O*-diethyl *O*-(3,5,6-trichloro-2 pyridyl) phosphorothioate), fenthion, and naled were impregnated into PVC. Dursban was also formulated with polyethylene and charcoal with a polymeric binder. The purpose of this investigation was to determine: (1) effectiveness of various formulations against natural populations of mosquito larvae in polyethylene-lined field pools, (2) field dosage required for control of mosquito larvae, (3) longevity of control attained from a single application, and (4) to make cursory observations of effects of slow-release formulations upon the non-target organisms found in the test pools.

Methods.—Testing was conducted in artificial polyethylene-lined pools in a wood lot at Edgewood Arsenal, Md., from 15, Apr. to 15 Oct. 1969. Eighty-two holes ca. 4×5×1.5 ft were lined with 6 mil, black polyethylene into which an initial test volume of 100 gal of tap water was added.

Abate, Dursban, fenthion, and naled were formulated at the rate of 10% active ingredient (AI) in PVC. Pellets were made in the laboratory using the following procedure: a pre-mixed plastisol composed of the PVC resin Geon 135 and the plastizer, dioctylphthalate (DOP), at the ratio of 2:3 was mixed with technical grade insecticide and cured in molds at 120–130°C for 1 hr. The average pellet weight was 70 mg. Dow Chemical Co., Midland, Mich., furnished formulations of 8.8% Dursban in PVC beads, 10% Dursban in polyethylene pellets, and 1% Dursban in charcoal granules which contained a polymeric binder. The Dow beads had a mass median diameter of 200–300 μ. The polyethylene pellets measured ca. ⅛×⅛ in., with an average pellet weight of 15 mg.

The major portion of this study evaluated slow-release materials at rates of 0.5, 1.0, and 2.5 ppm. In a separate portion of the study, which commenced 1 week after the main study, Dursban in polyethylene and Dursban in charcoal were compared with Dursban EC at the rate of 0.1 lb AI/acre. The 0.5 ppm dose (189 mg AI/pool) is ca. 8 times that of the 0.1 lb AI/acre (23 mg AI/pool). Each treatment level was replicated 3 times for the entire test. Test doses for all the slow-release formulations were calculated on a theoretical immediate release. Doses were obtained by hand broadcasting predetermined amounts of each slow-release formulation onto the pool surface. The EC dose was obtained by premixing a stock emulsion in water and applying it directly to the test pools. The entire test consisted of 72 treated pools + 10 untreated controls.

Pretreatment sampling was conducted to determine the numbers and species of mosquito larvae and the depth of each pool to the nearest ½ in. Species determinations were made periodically throughout

[1] Diptera: Culicidae.
[2] Received for publication Mar. 27. 1970.
[3] The opinions contained herein are those of the authors and should not be construed as official or reflecting the views of the Department of the Army.

with other slow-release materials or 10% Dursban in polyethylene at the rate of 1.0 and 0.5 ppm.

The slow-release formulations of Dursban do not appear to be as toxic to nontarget organisms as the EC. EC Dursban at 0.1 lb AI/acre caused noticeable mortality to backswimmers, water striders, and adult beetles. After 9 weeks, water striders were the only organisms observed populating these pools. No immature stages of midges were observed in the post-treatment sampling of this treatment. In contrast, no mortality to nontarget organisms was observed in pools treated with 10% Dursban in polyethylene and 1% Dursban in charcoal at 0.1 lb AI/acre or at 1.0 ppm which contained 16 times more active ingredient than the 0.1 lb AI/acre dose.

CONCLUSIONS.—Results indicate that mosquito larvae may be controlled throughout a 6-month breeding season using a single application of insecticide-impregnated polymer pellets or granulated charcoal without harmful affects to nontarget organisms. The most effective materials at the rates tested were 10% Dursban in polyethylene and 1% Dursban in charcoal. These materials will remain on test through the 1970 mosquito season to determine the length of effective control.

A recommended rate of application for each material tested was not determined. The initial dose rates which provided continuous control in this investigation may be reduced because an approximate 2-fold dilution in the pools occurred during the test period without affecting the control. Formulations which proved ineffective may have given prolonged control if the dilution had not occurred or if field dosage had been increased.

Future field tests are planned in which an attempt will be made to control water volumes, determine a dose rate for specific formulations, and monitor residues. Also the effect of test materials on nontarget organisms will be observed more closely.

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REFERENCES CITED

Barnes, W. W., A. B. Webb, and L. B. Savage. 1967. Laboratory evaluation of Abate and malathion insecticidal briquettes Mosquito News 27 (4): 488–90.

Elliott, R. 1955. Larvicidal control of periodomestic mosquitoes. Trans. Roy. Soc. Trop. Med. Hyg. 49 (6): 528–42.

Evans, B. R., and E. J. Fink. 1960. Dieldrin cement briquettes in controlling *Aedes aegypti* in fire barrels. Mosquito News 20 (4): 388–9.

Raley, T. G., and E. D. Davis. 1949. Observations on the use of toxic briquettes for mosquito control. Ibid. 9 (2): 68–71.

Shultz, H. A., and A. B. Webb. 1969. Laboratory bioassay of pesticide-impregnated rubber as a mosquito larvicide. Ibid. 29 (1): 38–41.

Whitlaw, J. T., Jr., and E. S. Evans. 1968. Selected plastic formulations for use as mosquito larvicides. J. Econ. Entomol. 61 (4): 889–92.

Fungus as Food for Some Stored-Product Insects[1]

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ABSTRACT

Nine species of stored-product insects representing 8 genera in 6 families of Coleoptera and 1 genus of Psocoptera were exposed to 23 species of seed-borne fungi and 1 actinomycete cultures on potato-sugar agar in the laboratory. Some feeding by all 9 species was observed on *Cladosporium cladosporioides* (Fresenius) de Vries, *Nigrospora sphaerica* (Saccardo) Mason, and *Alternaria alternata* (Fries) Keissler. Most insects rejected *Streptomyces griseus* (Krainsky) Waksman and Henrici, *Cochliobolus sativus* (Ito and Kurib.) Drechsler ex Dastur, and *Aspergillus* spp. The granary weevil, *Sitophilus granarius* (L.); and the lesser grain borer, *Rhyzopertha dominica* (F.), fed lightly on a few but failed to reproduce on any microorganism. The psocid *Lepinotus reticulatus* (Enderlein) and the beetles *Lathridius minutus* (L.) and *Microgramma arga* (Reitter) were the most successful fungivores.

Insects that infest stored grain rarely occur in the absence of fungi. Several of these species have been shown (Sinha 1965, 1966, 1968; Sikorowski 1964; Lenz 1968a, b) to be capable of feeding and surviving on selected fungal diets. Although fungi and other microorganisms contribute significantly to the field biology of insect pests the relationship between many economically important or common stored-product insects and certain microorganisms in stored grain is still unknown. An understanding of these relationships might be useful in determining the causes of deterioration of stored cereals and other foods and would permit an understanding of the structure and function of ecosystems in stored grain which are being studied under field conditions (Sinha et al. 1970).

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Some of the common secondary stored-product insects are extremely difficult to rear in the laboratory, since suitable culture media are unknown. Because of this difficulty little work on the biology and behavior of these species has been done. Determination of fungal diets characteristic of each species of these little-known insects is likely to eliminate this difficulty and make way for further biological research on these species.

This paper reports on the feeding and reproduction of each insect species on each species of microorganism. The experiments had to be carried out and repeated during a 7-year period, since sufficiently large numbers of live adults of each species of insect were not available until outbreaks were detected in isolated farm granaries.

MATERIALS AND METHODS.—Twenty-three species of fungi and 1 actinomycete isolated from insect-infested grain from farm granaries in Manitoba during 1962–

1971 Rathburn, C.B. Jr., Rogers, A.J., Boike, A.H. Jr., and R.M. Lee
The Effectiveness of Aerial Sprays For The Control of Adult Mosquitoes In Florida As Assessed By Three Methods
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145

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THE EFFECTIVENESS OF AERIAL SPRAYS FOR THE CONTROL OF ADULT MOSQUITOES IN FLORIDA AS ASSESSED BY THREE METHODS[1]

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The degree of control of adult mosquitoes obtained with aerial sprays is usually assessed by one of three methods: caged mosquitoes, trap collections, or landing rates. Each method may be prone to serious errors. Obviously, cages offer some protection to the mosquito as well as limiting flight activity. The protection afforded by the cage, however, may not be nearly as much as that offered by vegetation, structures, etc., where mosquitoes rest during the daytime, the time that most aerial sprays are applied. Nevertheless, the cage is not a natural place for mosquitoes to be when exposed to sprays. Landing rates are prone to serious errors associated with the activity and natural behavior of mosquitoes. Meteorological conditions, especially light intensity, as well as variations in the degree of attraction of different individuals may lead to erroneous conclusions when landing rates are the only means of assessing the degree of control obtained. Also, the time involved in obtaining most landing rates is extremely short and may not give a true picture of the presence or absence of mosquitoes in a particular area. Traps are also prone to many of the errors associated with landing rates, but since the sample is collected over a very much longer period of time the chances of obtaining a more reliable estimate of the population are significantly better. Since each method is subject to serious errors, it is more likely that a combination of all three methods may lead to the most reliable estimate of the degree of control obtained. The following series of tests were designed to determine the relative merit of the use of caged mosquitoes, traps, and landing rates for assessing the degree of control obtained by aerial sprays.

Methods. All tests were conducted with a 220 h.p. Stearman airplane flown at 80 miles per hour at an altitude of 75 to 100 feet. All swaths were marked by flagmen at each end. Flat spray nozzles positioned at a 45 degree forward angle at the trailing edge of the wing were used in all tests. The center of the treated area was fairly high, open and sandy and was partly overgrown with rows of planted pines and scattered turkey oaks 4 to 8 feet high. Surrounding this center area were small cypress ponds, open grassy areas, and some low swampy areas.

The traps, miniature CDC light traps baited with dry ice, were situated about 1,000 feet apart in both the higher center area and in the adjacent lower area. Check areas were located about 3 miles upwind in a habitat similar to that of the treated area. In tests 1 and 2 there were three traps in the treated area and three in the check area. In tests 3 and 4 there were four traps in each area. Trap collections were made each night for two nights before treatment and the night after treatment except in the case of test 1, where traps were set each night for two nights both before and after treatment.

In all tests, sprays were applied between 6:10 and 7:45 a.m. The landing rates were taken at the trap stations by the same individuals. In test 1, pretreatment landing rate counts were taken 10 to 25 minutes before sunrise and post-treatment counts were taken 5 minutes after conclusion of spraying (35 to 45 minutes afer sunrise).

[1] Presented at the 26th annual meeting of the American Mosquito Control Assn., February 22–25, 1970, Portland, Oregon.

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No landing rates were made in the check area for this test. In test 2, landing rates were taken 35 to 50 minutes before sunrise on the morning of treatment and at the same time the morning after the treatment. In tests 3 and 4, landing rates were taken immediately after dark one and two nights before treatment and at the same time the night after treatment.

The caged mosquitoes used in the tests were obtained from laboratory colonies and were from 2 to 8 days old. Three to four cages of each species, *Culex nigripalpus* and *Aedes taeniorhynchus*, each containing approximately 25 female mosquitoes were hung close to the ground in pairs (one *Aedes* and one *Culex*) in the vicinity of each of the traps in the treated area. The mortality of the untreated mosquitoes, which were placed in the check area during the treatment time, averaged 0.3 percent for *A. taeniorhynchus* and 1.2 percent for *C. nigripalpus*.

Shown in Table 1 are the operational data for all tests. It should be noted that because of the volume per acre discharged in tests 2 and 3, it took two plane loads to cover the treated area. The time interval between loads was approximately 45 minutes. Since the wind velocity, temperature, and relative humidity varied greatly between the time that the first and the second loads were applied, they are shown separately as averages for each time period in that sequence.

The formulation used in test 1 consisted of 6 gallons of Dibrom 14 plus 12 gallons of Ortho Additive in 82 gallons of diesel oil. For tests 2 and 3, it was 2 gallons 7½ pints of Dibrom 14 plus 2 gallons 7½ pints of Ortho Additive in 94 gallons 1 pint of diesel oil. The fourth test was conducted with Dibrom 14 only. The dosage of naled was 0.1 lb./a for all tests.

RESULTS. The results of all tests are shown in Table 2. Where pre- and post-treatment trap collections or landing rates were made on two nights, the figures shown are the averages of the two nights. The mosquitoes obtained by trapping were predominantly *Aedes mitchellae*, *Psorophora confinnis*, and *Culiseta melanura* with fewer numbers of *Anopheles crucians*, *Culex nigripalpus*, and *Culex* (*Melanoconion*) spp. There appeared to be no significant variation in the relative numbers of each species trapped before and after treatment, therefore, no selective mortality of species was noted. It is evident that good to excellent control of caged mosquitoes was obtained in these tests, but there was no significant reduction in the number of trapped mosquitoes in any of the tests. In tests 1 and 3, the trap counts increased in both the treated and check areas after treatment, although the increases were not as great in the treated area. This indicates perhaps some slight reduction due to the treatment. The apparently good reduction in landing rate in test 1 probably only reflects the reduction in mosquito activity with time since pre-treatment landing rates were taken before sunrise on the morning treated and post-treatment counts were taken 55 minutes later, which was well after sunrise. The landing rates in test 3 increased in both the treated and check area as did the trap collections. Landing rates taken before sunrise and just prior to spraying in test 3 showed no difference between the treated and check areas, averaging 11 and 13 per man per 3 minutes respectively (data not included in Table 2).

In test 2 the reduction in the trap count in the treated area was accompanied by a greater reduction in the check area and, therefore, was not a result of the treatment. Also, a significant reduction in the landing rate in the treated area was accompanied by an increase in the check area. Since the apparent control as assessed by landing rates was not substantiated by the trap collections, the treatment cannot be considered effective. In test 4, with 1 fluid ounce of Dibrom 14 per acre, a 58 percent reduction in the trap collection in the treated area was accompanied by a 38 percent increase in the check area. This might seem significant if it were not for the fact that there was a 22 percent increase in the landing rate in the treated area and a 72 percent reduction in the check area. Pretreatment landing rate counts taken before sunrise and just prior to spraying in test 4 showed

TABLE 1.—Operational data for aerial spray tests of naled against adult mosquitoes.[1]

Test no.	Volume fl. oz. per acre	Nozzle			Swath		No. acres	Wind at 40 ft. mph	Temp. at 6 ft. ° F	R.H. at 5 ft. %	Spray time			Sunrise
		no.	size	psi	ft.	no.					min.	start	stop	
1	16	10	6508	43	400	12	575	3	67	92	26	0610	0636	0605
2	32	7	6515	25	200	31	800	4–5	78–82	87–73	40	0620	0745	0609
3	32	7	6515	25	200	27	800	4–3	64–76	89–53	43	0615	0740	0612
4	1	6	8001	57	200	29	1400	2	69	92	42	0607	0649	0618

[1] All tests: 0.1 lb/a naled; plane speed 80 mph; altitude 75–100 ft.

TABLE 2.—Summary of results of aerial spray tests with naled, as assessed by caged mosquitoes, trap collections, and landing rates.

Test no.	Percent kill of caged mosquitoes		Trap collections-avg. no./trap/night						Landing rate-avg. no./man/3 min.					
			Treated area			Check area			Treated area			Check area		
	Culex	*Aedes*	Pre.	Post.	% red.	Pre.	Post.	% red.	Pre.	Post.	% red.	Pre.	Post.	% red.
1	84	58	103	162	(+57)	122	281	(+130)	69	0	100	..	..	.....
2	100	100	95	56	41	159	78	51	63	6	90	1	5	(+400)
3	98	89	82	112	(+37)	51	117	(+129)	28	30	(+7)	11	18	(+64)
4	90	77	137	57	58	176	243	(+38)	9	11	(+22)	18	5	72

no difference between the treated area and check areas, averaging 5 per man per 3 minutes in each area (data not shown in Table 2). Although obviously a result of population fluctuations and/or the influence of weather conditions on mosquito activity, it is not possible to further explain these differences based upon the data acquired in these tests. It is evident, however, that treatment 4 did not result in satisfactory control of the natural population. Also of importance is the fact that all four treatments were applied to the same area over a period of 1 month (August 7 to September 4) with no noticeable reduction in mosquito population, as measured by trapping.

DISCUSSION. In assessing the control of natural populations of mosquitoes, there is always the question of infiltration into the treated area between the time of treatment and the time of evaluation. In tests 3 and 4, where sprays were applied just after sunrise and post-treatment landing rates were taken immediately after dark, the period of possible infiltration was limited to the daylight hours immediately following treatment. Since mosquito activity is minimal for the species concerned during this period, the landing rates taken at dusk or immediately after dark before and after treatment should offer a good indication of the control obtained.

Owing to the longer period of exposure and to the larger numbers of mosquitoes taken, it would appear that trapping might be the best method of assessing the effects of an insecticidal treatment on natural populations of mosquitoes. The treated area, however, must be of sufficient size that the traps can be placed a considerable distance from its edge so as not to be influenced by infiltration. Obviously, the mosquito species in question must be attracted to the type of trap or bait used and in sufficient numbers to be meaningful.

The considerably higher mortality obtained with caged mosquitoes as compared to that obtained with the natural population as assessed by traps and landing rates was undoubtedly due to the positioning of the cages. During the daylight hours, the time at which the treatments were applied, most mosquitoes are at rest in moist protected areas on or very near the ground. The cages of mosquitoes, although placed as close to the ground as possible, were not actually on the ground amongst the litter as were those of the natural population, because of the threat of ants. The cages were only sheltered from the spray by the vegetative barriers that happened to be in the line of drift and, therefore, undoubtedly obtained a higher dosage than would have been possible if they were on the ground and well protected by the litter or thick grass.

Caged mosquitoes are very useful for assessing the toxicity of a formulation where good contact of the spray with the mosquitoes is obtained, but this method might not accurately assess kill of natural populations. It has been stated by Bidlingmayer (1967), Provost (1955) and others that no single sampling method will give a true estimate of the total population of mosquitoes because of differences in response due to various biological and environmental factors. It is also apparent that under the conditions of these tests none of the methods used was completely reliable in assessing control of the natural population. This might not apply to all conditions where aerial sprays are used, but these results require that additional studies of this kind be made at various times, against other species, and in different habitats.

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References Cited

Bidlingmayer, W. L. 1967. A comparison of trapping methods for adult mosquitoes: Species response and environmental influence. J. Med. Ent. 4(2):200–220.

Provost, M. W. 1955. Leesburg sampling studies in 1954. Fla. Anti-Mosquito Assoc. Rept. 26th Ann. Mtg. pg. 112–119.

1970 Berry, R. A., S. R. Joseph, and J. Mallack
The Status Of ULV Sprays For Adult Mosquito Control In Maryland
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THE STATUS OF ULV SPRAYS FOR ADULT MOSQUITO CONTROL IN MARYLAND

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The use of ultra-low-volume sprays for adult mosquito control studies in Maryland has involved both aerial and ground applications. Aerial treatments have been favorably received by the public and control has been good to excellent over populated areas. On the other hand ground applications have been proven to give good control of adult mosquitoes, but their use is currently restricted to unpopulated areas because of inherent difficulties involving the use of particular insecticides.

An intensive evaluation of ground-applied ULV insecticides has been made in Maryland during the past 5 years, (George *et al.* 1968, Berry, *et al.* 1969). This has required modification or adjustment of available equipment so that insecticides could be dispersed in appropriate droplet size. Mr. E. Elwood Lynch and Mr. Lester F. George, mosquito control engineers of the Maryland State Board of Agriculture have cooperated and gave the engineering assistance and guidance essential for this equipment modification. Among the equipment tried were a modified John Bean Rotomist Model 100-E, an Ag King Cannon, a Micro-Gen, and a modified Leco 120. Studies during 1969 centered on the modified Leco 120 which was a standard unit fitted with its commercially available ULV attachment. The other units had some good features but the modified Leco 120 was overall the most desirable for our needs.

A variety of ULV insecticide formulations have been tried with 95% malathion and naled 14 receiving the most attention. The highlights of our evaluation studies have been reported to this Association in the previous two years. Basically it was found that two ounces of 95% malathion or one-half to one ounce of naled 14 produced consistently excellent kill of adult mosquitoes 200 feet downwind from the point of discharge. In limited trials good kill has been obtained up to 1,000 feet downwind from the sprayer at one-half ounce naled 14 per acre. Attempting to figure a per-acre dosage is difficult since, depending upon weather conditions the effective swath width coverage can vary considerably. The discharge rate per minute may be a more meaningful figure. As with thermal fogs, spraying is done downwind with a wind velocity under 10 mph needed to obtain good results. Unlike thermal fogging the ULV unit may be used in the daylight hours.

The use of naled 14 or 95% malathion as a ground ULV spray has been restricted to non-populated areas such as dumps or land fills, primarily for fly control, and on golf courses and in rural areas for adult mosquito control. In populated areas naled 14 at one fluid ounce per acre will produce an intense respiratory irritation to people near the discharge. With 95% malathion, spotting of certain car manufacturers' paint finishes has resulted from the use of two fluid ounces per acre. There is some reason to believe that a restriction of the particle size of malathion into the range of 5 to 15 microns with no more than 10 percent of the droplets being 50 microns or larger would eliminate the paint-spotting hazard. Particle size emitted by the currently used unit has not been adequately evaluated primarily because the unit has been available only one season in its present modification.

It should be mentioned that metal paint panels representative of the finishes used on the automobiles of General Motors, Ford Motor Company, Chrysler-Plymouth Corporation and American Motors were obtained to evaluate the effect of certain insecticide sprays on paint surfaces. Eleven different color panels were numbered, washed, rinsed, dried and mounted on a wooden board four feet above ground level. Ultra-low-volume applications were made downwind at a distance of 8-15 feet from the paint panels. Panels were allowed to dry, observed for spotting, washed with warm detergent solution, rinsed, dried and results were recorded. Ninety-five percent malathion applied at the rate of 1.96 fluid ounces per acre produced severe spotting on almost all panels. Spotting was most pronounced on General Motors panels, particularly red and white. Naled 14 at a dosage rate of .55 fluid ounces per acre was negative for spotting on 11 color panels. Vapona 10 E.C. at an application rate of 1.16 fluid ounces per acre produced spotting on only the General Motors red panel.

A number of insecticides not previously utilized as ULV sprays were tried experimentally in 1969. The mosquitoes used for evaluation were *Culex pipiens* adults placed in screen wire cages 50, 100 and 200 feet downwind from the line of travel of the spray unit. Mortality counts were made at one-, two-, four- and eight-hour intervals following treatment. Highlights of this work are presented.

Vapona E. C. containing 10 pounds actual toxicant per gallon produced 100 percent mortality of caged *Culex pipiens* in one hour at 200 feet distance at a dosage rate of 1.58 fluid ounces per acre. Dosage levels of .85 fluid ounce per acre, 1.16 fluid ounces per acre and 1.19 fluid ounces per acre gave good results, but required more time to produce the results as the rate used decreased.

A diazinon LV spray formulation containing 7.9 pounds actual toxicant per gallon gave excellent results at dosage levels varying from .75

3.7 fluid ounces per acre. At a rate of 1.41 ounces per acre 100 percent mortality was obtained in all test cages in 4-8 hours. Dosage levels above 2 fluid ounces per acre gave 100% kill in 2-4 hours.

Evaluations of housefly control at two public dumps revealed that excellent reduction of fly populations could be obtained within 30 minutes following spraying. Numerical counts of 15 seconds each were made of flies landing on a 2'x3' fly grid at selected sites on the dumping areas and repeated 30 minutes after treatment. The average of all pre-treatment counts was 78 flies per count. Truck speed was under 5 mph with a maximum output of 5.41 fluid ounces per minute of naled 14. Percent reduction was slightly over 90 percent in 30 minutes. At one of the two dump sites this figure had improved to 94 percent control two hours after spraying. These types of treatment afford a quick reduction in housefly numbers in a limited geographical area, but are not at present practiced on a regularly scheduled basis.

Aerial applications of ULV dosages of insecticides have been used over the communities of Salisbury and Ocean City on Maryland's Eastern Shore and over a sanitary land fill in Baltimore County. All of these areas have utilized one fluid ounce of naled 14 per acre. In the case of Salisbury, two applications in 1969 at peak mosquito annoyance periods has completely supplanted all ground work and was directed primarily at *Aedes sollicitans*, *Aedes vexans*, and *Culex* species with some housefly control. Based on need, the aerial work at Ocean City is a supplement to the mist blowing program and was utilized to suppress broods of salt-marsh mosquitoes. Two applications were made in Ocean City in 1969. Sixteen weekly applications were made to 690 acres of sanitary land fill along the Patapsco River in Baltimore County. *Culex pipiens* was the prime target. It should be noted that a twin-engine Beachcraft was used in all cases. Acreage being treated included 2,000 acres at Salisbury, 3,000 at Ocean City and 690 in Baltimore County for a grand total of 5,690 acres receiving aerial ULV treatments.

Evaluation of the aerial work indicated that naled 14 at one fluid ounce per acre gave excellent control of adult mosquito populations and fair control of houseflies and blowflies. Caged mosquitoes and flies placed in exposed and protected sites, and before and after landing rate counts were used in evaluation procedures. Ninety-nine to 100 percent control of caged, exposed *Culex pipiens*, *Culex salinarius*, *Aedes sollicitans*, *Aedes taeniorhynchus* and *Anopheles crucians bradleyi* was obtained within two hours after treatment. Caged mosquitoes placed under a tree canopy required a longer period of time to reveal acceptable mortality counts. Eight hours were usually required, but in most cases control was over 90% for the previously mentioned species. *Culiseta melanura* was not placed in exposed sites, but caged adults under a tree canopy had 94-100 percent mortality eight hours after spray application.

Landing counts taken in Ocean City prior to treatment revealed an average of 4.27 mosquitoes per minute for 26 counts, mostly *Aedes sollicitans*. Six to eight hours following treatment all counts were negative. There was some indication that reinfestation to original levels occurred 24 to 36 hours following treatment.

Houseflies, blowflies and other Diptera species proved somewhat more difficult to control. In exposed locations there was a wide variance between cages in the percent mortality. Considering all flies in exposed cages the percent mortality in 1968 was 74% and 93% in 1969. For cages under a tree canopy, the overall mortality count was only 30% in 1968 and 62% in 1969.

The Army Corps of Engineers carries out regular ULV spray applications on hydraulic fills adjacent to the Chesapeake and Delaware Canal and possibly in other sections of Maryland. The work along the Chesapeake and Delaware Canal was primarily for the control of *Aedes sollicitans* broods. While no evaluation of this work has been done by State personnel it has undoubtedly contributed to the comfort of the local populace.

Summary

The question arises, where do we go from here? It is expected that the use of aerially applied ULV insecticides will continue to grow. A minimum of technical problems and public acceptance of aerial treatments will encourage this phase of our program to expand.

There are several aspects involved in obtaining a workable ground ULV unit including discharge rate, particle size, safety, economy, and label clearance for the insecticide. If all these problems can be solved, the economic advantages which would accrue to a practical ground ULV program in poulated areas would enable our control activities to grow tremendously. For this reason we will continue to explore opportunities which offer a reasonable chance of success.

Literature Cited

Berry, R. A., Joseph, S. R., and Lynch E. E. 1969. Adult mosquito control with ULV ground equipment. N. J. Mosq. Exterm. Assoc. Proc. Vol. 56:137-141.

George, L. F., Berry, R. A. and Mallack, J. 1968. Ultra low volume application with ground equipment for adult mosquito control. N. J. Mosq. Exterm. Assoc. Proc. Vol 55:206-212.

PRESIDENT HALLIGAN: Thank you very much, Mr. Berry. Our next paper is entitled "A Preliminary Study of the Mosquito Fauna of Silver Lake, Dover, Delaware"and will be presented by Paul R. Sandridge, Biology Department, Delaware State College, Dover, Delaware.

1970 Mount, G. A., N. W. Pierce, C. S. Lofgren, and J. B. Gahan
A New Ultra-Low Volume Cold Aerosol Nozzle For Dispersal Of Insecticides Against Adult Mosquitoes
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SUMMARY AND CONCLUSIONS. Temperature during the period that a light trap is operated is an important factor and should be considered if light traps are to be used in a quantitative manner in ecological studies. Above 62° F a rise of 1 degree F increased the trap catch by 1.2 times.

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References Cited

HUFFAKER, C. B. and BACK, R. C. 1943. A study of methods of sampling mosquito populations. J. Econ. Entomol. 36:561–569.

SOUTHWOOD, T. R. E. 1966. Ecological methods. Methuen. London.

THOMPSON, P. H., and DICKE, R. J. 1965. Sampling studies with *Aedes vexans* and some other Wisconsin *Aedes* (Diptera: Culicidae). Ann. Entomol. Soc. Amer. 58:927–930.

WILLIAMS, C. B. 1939. An analysis of four years' capture of insects in a light trap. Part I. General survey, sex proportion, phenology, and time of flight. Trans. R. Entomol. Soc. Lond. 89:79–131.

WILLIAMS, C. B. 1940. An analysis of four years' capture of insects in a light trap. Part II. Effect of weather condition on insect activity and estimation and forecasting of changes in insect population. Trans. R. Entomol. Soc. Lond. 90: 227–306.

A NEW ULTRA-LOW VOLUME COLD AEROSOL NOZZLE FOR DISPERSAL OF INSECTICIDES AGAINST ADULT MOSQUITOES[1]

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Mount *et al.* (1968) reported that ultra-low volume (ULV) cold aerosols of malathion and naled were highly effective against adult mosquitoes. To further evaluate the potentialities of ULV aerosols a commercially manufactured nozzle[2] that disperses liquid insecticide concentrates from ground equipment has been tested to: (1) determine the droplet size range produced by the ULV nozzle; (2) compare the effectiveness of aerosols produced by the ULV nozzle with aerosols produced by a high-volume thermal nozzle; (3) establish minimum doses for satisfactory adult mosquito kill with ULV cold aerosols of malathion, naled, and fenthion, and (4) determine the effect, if any, of dispersal speed on efficiency of adult mosquito kill with ULV cold aerosols.

METHOD AND MATERIALS. The Leco ULV cold aerosol nozzle was used on both a modified Leco 120 thermal aerosol generator and a modified Curtis 55,000 cold aerosol generator. Maximum air pressure with the Leco 120 at 3350 r.p.m. was 3.5 p.s.i. The Curtis 55,000 was also operated at 3.5 p.s.i. even though air pressures as high as 6 p.s.i. can be produced with this unit. Mount *et al.* (1968) showed greater atomization of technical malathion with increased air pressure using similar type venturi nozzles. A

[1] Mention of a proprietary product in this paper does not constitute an endorsement of this product by the USDA.

[2] Developed by Lowndes Engineering Co., Inc. (Leco), Valdosta, Georgia.

[3] Roger Gilmont Instruments, Inc., Great Neck, New York 11021.

Gilmont[3] flowmeter and a small brass needle valve were used to regulate the flow of concentrated or technical liquid insecticide from <1 to about 6 fluid ounces per minute at 3.5 p.s.i. tank pressure. No insecticide pump is necessary with the ULV system.

Droplet size estimates were made for flow rates of technical malathion ranging from 0.715 to 5.7 fluid ounces per minute. Droplets were collected on silicone (General Elecric SC-87 Dri-Film) treated glass microscope slides by waving the slides through the aerosol at a distance of 25 feet from the point of discharge. A sample of 200 droplets for each flow rate was measured with an ocular micrometer at 400× magnification. Diameters of the original spheres were estimated by correcting the diameter of the droplets impinged on the slides for the amount of spread that had taken place. (The spread factor for technical malathion was 0.4.) Mass median diameters were computed according to the methods presented by Yeomans (1949) for estimating size of impinged droplets.

Two series of tests were conducted with caged adult female *Aedes taeniorhynchus* (Wiedemann). The first series compared the effectiveness of ULV cold and high volume thermal aerosols of malathion. The cold aerosols were dispersed with the ULV nozzle mounted on the Curtis 55,000 (after high-volume nozzle assembly had been removed and insecticide pump disconnected). A Leco 120 calibrated to deliver 40 gallons of fluid per hour and operated at a burner temperature of 850° F was used to disperse the thermal aerosols. The ULV cold aerosols were dispersed at speeds of either 10 or 20 m.p.h., whereas the high-volume thermal aerosols were dispersed at 5 m.p.h. The doses of malathion tested ranged from 0.009 to 0.036 pound per acre based on amount of active ingredient used over a 600-foot swath. Since these are not residual treatments, we do not believe there is any need to be concerned about that portion of the insecticide which is deposited in the plot. However, those involved in mosquito control operations have to know how much insecticide is needed for a given acreage to obtain satisfactory mosquito kill.

The second series of tests was conducted to establish minimum effective doses of naled and fenthion that could be used for adult mosquito control. The ULV nozzle was mounted on the Leco 120 for these tests (after thermal nozzle and burner assembly were removed and insecticide pump was disconnected). Aerosols of naled and fenthion were dispersed at 15 m.p.h. Dosages tested were 0.006 and 0.012 pound per acre with naled and 0.0036 and 0.0072 pound per acre with fenthion.

In both series of tests the mosquitoes were exposed to the aerosols by placing cages 5 feet above the ground on stakes 150, 300, and 600 feet downwind of the path (¼ mile in length) of the aerosol generator. From 2 to 3 replications of 6 cages of 25 mosquitoes each were tested with each dose of each insecticide and each type of aerosol. Percent mortality was determined 18 hours posttreatment. Mosquitoes taken to the field and handled in the same manner, but not exposed to the insecticide aerosols, showed an average mortality of 5 percent.

Weather conditions were about the same for both series of tests against caged mosquitoes. Air temperatures ranged from 72° to 83° F and averaged about 80° F. Wind speeds at 5 feet above the ground ranged from <1 to 6 m.p.h. and averaged about 2.5 m.p.h.

Results and Discussion. Droplet size data for technical malathion dispersed from the Leco ULV cold aerosol nozzle operated at 3.5 p.s.i. are presented in table 1. With flow rates from 0.715 to 5.7 fluid ounces per minute, mass median diameters ranged from 11 to 16 μ. These droplet size estimates indicated that the Leco ULV nozzle was about equal in atomization efficiency (ability to produce small droplets) to the 3-nozzle head used by Mount *et al.* (1968) and the double air-liquid vortical nozzles used by Stains *et al.* (1969). With the exception of the 5.7

TABLE 1.—Droplet sizes produced by 4 flow rates of technical malathion (95 percent) dispersed from a Leco ULV cold aerosol nozzle operated at an air pressure of 3.5 p.s.i.

Flow rate (fluid ounces/ minute)	Percent of total mass in indicated droplet size range					Maximum diameter (μ)	Average diameter (μ)	Mass median diameter (μ)
	$<5\ \mu$	$5-10\ \mu$	$11-15\ \mu$	$16-20\ \mu$	$>20\ \mu$			
0.715	5	40	32	20	3	27	9	11
1.43	2	32	38	17	11	30	10	12
2.85	3	23	34	24	16	27	11	13
5.7	2	12	28	28	30	39	14	16

fluid ounces per minute flow rate, droplet spectra were close to the optimum of 5 to 10 μ mass median diameter as suggested by Mount (1970).

Table 2 shows a comparison between ULV cold- and high-volume thermal aerosols of malathion against caged mosquitoes. Higher kills were obtained consistently with the ULV cold aerosols with all three doses of malathion. Estimated LD_{90}'s were 0.025 and >0.036 pound per acre for ULV cold- and high-volume thermal aerosols, respectively. Kills obtained with ULV cold aerosols of malathion dispersed at speeds of 10 and 20 m.p.h. were about equal at identical doses.

Table 3 gives the results obtained with ULV cold aerosols of naled and fenthion dispersed at 15 m.p.h. against caged mosquitoes. The doses tested were based on LC_{90}'s for 300-foot swaths which were reported by Mount *et al.* (unpublished data) for high-volume cold aerosols. For naled the dosage of 0.012 pound per acre (2 fluid ounces per minute) is equivalent to a 1.3 percent (w/v) formulation dispersed at 40 gallons per hour and at 5 m.p.h. The dosage of 0.0072 pound per acre (1.73 fluid ounces/minute) for fenthion is equivalent to an 0.8 percent (w/v) formulation dispersed at 40 gallons per hour and at 5 m.p.h. Using the ULV cold aerosol nozzle, naled and fenthion gave average kills of 90–94 percent over 600-foot swaths with these dosages (0.012 and 0.0072 pound per acre, respectively). At one-half the LC_{90} for high-volume aerosols, naled produced from 97 percent to 98 percent kill and fenthion produced from 83 to 90 percent kill at distances of 150 and 300 feet.

Based on results presented in tables 2

TABLE 2.—Comparison of ultra-low volume cold- and high-volume thermal aerosols of malathion against caged female *Aedes taeniorhynchus* (Wiedemann).

Dosage (pound/ acre[a])	Dosage (fluid ounces/ acre)	Malathion concentration (percent)	Flow rate (gallons/ hour)	Flow rate (fluid ounces/ minute)	Vehicle speed (m.p.h.)	Percent mortality after 18 hours at indicated distance (feet): 150	300	600	Average percentage mortality
			Leco ultra-low volume cold aerosol						
0.009	0.12	95	0.68	1.43	10	88	46	72	69
.009	.12	95	1.36	2.85	20	100	60	70	77
.018	.24	95	1.36	2.85	10	93	93	93	93
.018	.24	95	2.72	5.7	20	80	84	95	86
.036	.48	95	2.72	5.7	10	89	88	99	92
			Leco 120 high-volume thermal aerosol						
.009	14	1	40	85	5	74	82	40	65
.018	14	2	40	85	5	51	61	66	59
.036	14	4	40	85	5	93	88	74	85

[a] Based on A.I. used over a 600-foot swath.

and 3, estimated LD_{90}'s for malathion, naled, and fenthion were 0.025, 0.0095, and 0.0072 pound per acre, respectively. For a dispersal speed of 15 m.p.h. the respective flow rates for 300- and 600-foot swaths are as follows: malathion (9.7 pounds A.I./gallon)—3 and 6 fluid ounces per minute; naled (14 pounds A.I./gallon)—0.8 and 1.6 fluid ounces/minute; and fenthion (9.67 pounds A.I./gallon)—0.87 and 1.73 fluid ounces minute.

Our tests were not designed to determine maximum swaths possible with ULV cold aerosols. We believe that swath width is a function of insecticide dose, droplet size, and weather conditions. Stains *et al.* (1969) demonstrated that it is possible to obtain swaths up to 1–2 miles with high wind conditions (6–8 m.p.h.) and flow rates of 33 and 37.2 ounces per minute of naled (Dibrom® 14) and Dursban ® (*o*, *o*-diethyl *o*-3,5,6-trichloro-2-pyridyl phosphorothioate) (6 pounds A.I./gallon), respectively, dispersed at 5 m.p.h. Taking into consideration the difference in dispersal speed, this represents a flow rate of Dibrom 14 which is 50 times greater than what we used to obtain a 600-foot swath under low wind conditions (2.5 m.p.h.).

SUMMARY. A commercially available ultra-low volume (ULV) cold aerosol nozzle was used to disperse malathion, naled, and fenthion against caged adult female *Aedes taeniorhynchus* (Wiedemann). Droplet size estimates of technical malathion ranged from 11 to 16 μ mass median diameter, depending on flow rate. Aerosols of malathion produced by the Leco ULV nozzle were consistently more effective than those produced by high-volume thermal nozzle. The estimated LD_{90}'s for malathion, naled, and fenthion were 0.025, 0.0095, and 0.0072 pound per acre, respectively, based on the amount of active ingredient used per acre. There was no difference in the effectiveness of ULV cold aerosols of malathion dispersed at 10 and 20 m.p.h.

TABLE 3.—Effectiveness of ultra-low volume cold aerosols of naled and fenthion dispersed at 15 m.p.h against caged female *Aedes taeniorhynchus* (Wiedemann).

Dosage[a]		Insecticide concentration	Flow rate		Percent mortality after 18 hours at indicated distance (feet)			Average percentage mortality
(pound/acre)	(fluid ounce/acre)	(percent)	(gallon/hour)	(fluid ounces/minute)	150	300	600	
Naled (Dibrom ®—14 pounds A.I./gallon)								
0.006	0.056	85	0.475	1	98	97	33	76
.012	.112	85	.95	2	99	99	83	94
Fenthion (Baytex ®—9.67 pounds A.I./gallon)								
.0036	.049	93	.412	.87	90	83	64	79
.0072	.097	93	.824	1.73	99	94	78	90

[a] Based on A.I. used over a 600-foot swath.

Literature Cited

MOUNT, G. A. 1970. Optimum droplet size for adult mosquito control with space sprays or aerosols of insecticides. Mosq. News 30(1):70–75.

MOUNT, G. A., LOFGREN, C. S., PIERCE, N. W., and HUSMAN, C. N. 1968. Ultra-low volume nonthermal aerosols of malathion and naled for adult mosquito control. Mosq. News 28(1):99–103.

MOUNT, G. A., PIERCE, N. W., and LOFGREN, C. S. 1969. New insecticides evaluated as nonthermal aerosols against *Aedes taeniorhynchus* (Wiedemann). Mosq. News 29(1):53–54.

STAINS, G. S., FUSSELL, E. M., KEATHLEY, J. P., MURRAY, J. A., and VAUGHAN, L. M. 1969. Caged insect kills of up to two miles utilizing a new low-volume aerosol ground dispersal unit. Mosq. News 29(4):535–544.

YEOMANS, A. H. 1949. Directions for determining particle size of aerosols and fine sprays. U.S.D.A. Bur. Entomol. Plant Quarantine ET-267.

1970 Taylor, D. J. and C. B. Rathburn.
Large Area Tests Of Ultra Low Volume Naled For Control Of Adult Mosquitoes
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147

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LARGE AREA TESTS OF ULTRA LOW VOLUME NALED FOR CONTROL OF ADULT MOSQUITOES

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Preliminary results of nighttime application of ULV Dibrom (naled) by a C-47 aircraft for the control of adult mosquitoes were presented by Shepard and Gorman (1969) who cited Blanton *et al.* (1950) as reporting more effective kill of adult mosquitoes by nighttime spraying with a C-47 aircraft. The idea of nighttime spraying was further pursued during the summer of 1969. During this time of day under Florida conditions, thermal convection currents and wind speeds are more favorable for maximum fall of droplets and minimum drift away from the target area of the smaller droplets, which are more effective in killing mosquitoes.

MATERIALS AND METHODS Three tests in Hillsborough County, Florida, are reported here: August 13 at Ruskin, August 28 at Citrus Park, and September 11 at Citrus Park. Results were assessed in terms of percent reduction and percent control based on pre- and posttreatment mosquito collections in CDC miniature light traps baited with dry ice, on mortality of mosquitoes exposed in screened cages, on droplet distribution as sampled by 3 x 5 inch potassium iodide-methanol cards, and by pre- and posttreatment landing rates.

Dibrom 14 concentrate was used at rates of 0.55, 0.80, and 0.70 fluid ounces per acre (.05, .09, .08 lb. per acre) respectively for the three tests. All tests were flown at 500 feet altitude and 150 miles per hour (Table 1).

The aircraft was a C-47 equipped with a 165-gallon fiberglass tank, Oberdorfer pump, plastic distribution lines, stainless steel flushing tank, and spray nozzles mounted on the underside of each wing tip.

The application data for all tests are shown in Table 1. For all three tests, the aircraft was flown at a right angle to the wind direction. Applications were made between 3:58 and 5:20 a.m. Starting at the downwind side of the area to be treated, swaths were marked by a flashing "Instant Visual Identification Strobe"[3] light. This white light, operated off the truck battery, was mounted on a telescoping pole 15 feet above the ground on the rear of a pickup truck. When clear of nearby obstacles, the light could be seen 6 to 8 miles by the pilot. The truck was also equipped with a foot-meter for accurate measurement of distances.

TABLE 1.—Application data for aerial spray tests with naled, Hillsborough County, Florida, 1969.

Test No.	Vol. Fl./oz.	Dosage lbs./acre	Nozzle No.	Nozzle Size	Swath Feet	Alt Ft.	Speed mph.	Wind Velocity-mph surface	Wind Velocity-mph 500 ft	acres
1	0.55	0.05	7	80015	600	500	150	2	8	17,920
2	0.80	0.09	7	80015	600	500	150	1	5	2,880
3	0.70	0.08	8	8003	1,000	500	150	<1	5	2,485

[1] Hillsborough County Mosquito Control, Tampa, Florida

[2] West Florida Arthropod Research Laboratory, Panama City, Florida

[3] In-Flight Devices Corporation, Columbus, Ohio.

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RESULTS. The results of all tests are shown in Tables 2 and 3. In test 1, pre- and posttreatment collections from CDC light traps in the target area indicated 81 percent reduction of *Culex nigripalpus*, a St. Louis encephalitis vector, with a corresponding 6 percent reduction in an untreated area as measured by a New Jersey light trap (Table 2). There was only a 44 percent mortality of *Culex nigripalpus* in cages that were placed in varied conditions of vegetation in the target zone. Ten indicator cards averaged 27 droplets per card in the target area; however, ½ to 2 miles downwind from the first swath there were 10 to 39 droplets per card. This showed that much of the spray came to the ground at least 2 miles downwind.

In test 1 (Table 3), *Psorophora confinnis* averaged over 8,000 mosquitoes per trap in the pretreatment counts in the target area and showed an 87 percent reduction; *Psorophora ciliata* averaged 173 per trap at pretreatment and were reduced 85 percent; and *Aedes taeniorhynchus* averaged 1156 pretreatment and showed a 40 percent reduction, but there was only 9 percent kill of the latter species in cages. Percent control of the four species in test 1, shown in Tables 1 and 2, was obtained by correcting the percent reduction of each species to the percent reduction in the control trap by means of Abbott's formula. Since the control trap in test 1 was a New Jersey trap and the traps in the target area were CDC miniature light traps, the figures shown as percent control may not be truly representative.

Landing rate data based on counts made the day before and the day following treatment indicated an overall mosquito reduction of 82 percent in the target area. When the reduction in the control area was considered, however, the landing rate was reduced by only 55 percent. The species sampled by this method were mostly *A. taeniorhynchus* and *P. confinnis*.

In test 2, as shown in Table 2, trap collections in the target area showed a 64 percent reduction of *C. nigripalpus*; however, when corrected for the 58 percent reduction obtained in the control area, this was reduced to 14 percent. Only 3 percent mortality was obtained with caged *C. nigripalpus* in the target area where an average of 34 droplets per card was obtained. One, 1½, and 2 miles downwind of the target area, the percent control of the trapped mosquitoes dropped from 55 to 5 to 0 percent respectively, but the mortality of caged *C. nigripalpus* increased to 58 and 59 percent at 1½ and 2 miles, and the number of droplets per indicator card increased to 101 and 64 droplets respectively. Droplets on the downwind cards were noticeably much smaller than those obtained on the cards in the treated area.

Trap counts of *Psorophora confinnis*, *Aedes infirmatus*, and *Anopheles crucians* in the target area (Table 2) were reduced 93, 81, and 51 percent respectively. Except for *A. infirmatus*, however, the untreated trap counts were also lower, showing generally poor control of these species.

Data of test 3 for the target area were divided into "upwind" and "downwind" portions. The "upwind" portion of the target area, presumably not well covered by the spray due to drift, showed 26 percent control of *C. nigripalpus* by trapping while the "downwind" portion of the target area showed 55 percent control. The mortality of caged *C. nigripalpus* in the "upwind" and "downwind" portions of the target area was 5 and 93 percent respectively, and the number of droplets per card averaged less than 1 and 14 respectively. Trap collections ½ and 1½ miles "downwind" showed 29 and 13 percent control, 100 percent mortality of all caged mosquitoes, and 57 and 67 droplets per card, respectively. At ½ mile west of the target area, trapping showed 48 percent control of *C. nigripalpus*; also, there was 76 percent mortality of this species in cages and 3 droplets per card in that area.

These results demonstrate a condition similar to that experienced in test 2; however, the reduction in trapped mosquitoes

TABLE 2.—Results of ULV aerial spray tests of naled against adults of *Culex nigripalpus* Theob., Hillsborough County, Florida, 1969.

Test No.	Area	C.D.C. Trap Collections: No. Traps	Mosq./trap[1]: Pre	Mosq./trap[1]: Post	Percent Reduction	Percent Control[2]	Caged Mosq.: No. Cages	Caged Mosq.: Percent Mort.	KI Cards: No. Cards	KI Cards: Av. No. drops/card[3]
1	Treated	4	736	141	81	80	10	44[2]	10	27
	0.5 mi. Downwind								2	34
	0.8 mi.								2	10
	1.2 mi.								2	30
	2.0 mi.								2	39
	Control	1	168	158	6	..	14	1	2	4
2	Treated	2	7312	2660	64	14	6	3[2]	16	34
	0.3 mi. Downwind						1	4	2	10
	1.0 mi.	1	2900	540	81	55	1	7	2	64
	1.5 mi.	1	1256	506	60	5	2	58	2	101
	2.0 mi.	1	2036	1656	18	0	2	59	2	64
	2.4 mi.						1	11	2	60
	2.7 mi.						1	6	2	64
	3.4 mi.						3	9	6	28
	Control	1	3056	1292	58	..	12	1	2	0
3	Treated—all	4	2931	473	84	50	18	85[2]	20	9
	"Upwind"—0.3 mi.				77	26	4	5[2]	4	<1
	"Downwind" 0.3 to 1.7 mi.	3	3011	427	86	55	14	93[2]	16	14
	Downwind, 30°									
	0.5 mi.	1	848	185	78	29	1	100	2	57
	1.5 mi.	1	1844	492	73	13	1	100	2	67
	Crosswind, 60°									
	0.5 mi.	1	4808	772	84	48	5	76	5	3
	1.5 mi.	1	2304	1508	35	--0--	11	23	11	<1
	Control	4	5269	1631	69	..	9	14	6	0

[1] Average number of mosquitoes per trap per night. All pretreatment collections in test one and downwind pretreatment collections in test two were picked up at 2 to 4 a.m., all others full night collections. Control trap for test one was New Jersey light trap, all others CDC miniature light traps.
[2] Corrected for percent reduction in control by Abbotts formula.
[3] Three x five inch cards approximately 4 sq. in.

was greater and the mortality of caged *C. nigripalpus* was significantly increased. From the trap, caged mosquito, and card data shown in Table 2, it is apparent that the area covered by the spray began ½ mile south and ½ mile west of the "upwind" edge of the target area and extended at least 1½ miles in a southwest direction from the "downwind" edge of the target area, the spray drifting southwesterly with a northeast wind. In test 3, the surface wind was only 1 mile per hour while for test 2 it was 2 miles per hour. Also, the wind for the third test was only about 30 degrees off the flight direction, while it was variable (45° to 110°) during the second test. This had the effect of shifting the spray pattern in test 3 to the longer dimension of the plot, thereby keeping more of the spray in the target area.

CONCLUSIONS. The results of these tests indicate that the ULV spray contacted the ground from ½ to 3 miles "down-

TABLE 3.—Summary of trapping results of ULV aerial spray tests of naled against several mosquito species, Hillsborough County, Florida, 1969.

Test No	Species	Area	No Trap	Mosq./Trap[1] Pre	Mosq./Trap[1] Post	% Red	% Control[2]
1	*Psorophora confinnis*	Treated	4	8388	1128	87	72
		Control	1	142	65	54	...
	Psorophora ciliata	Treated	4	173	26	85	70
		Control	1	4	2	50	...
	Aedes taeniorhynchus	Treated	4	1156	698	40	29
		Control	1	80	68	15	...
2	*Psorophora confinnis*	Treated	2	483	36	93	56
		Control	1	1072	176	84	...
	Aedes infirmatus	Treated	2	144	28	81	95
		Control	1	4	14	+250	...
	Anopheles crucians	Treated	2	468	228	51	0
		Control	1	420	82	80	...
3	*Psorophora confinnis*	Treated	4	26	2	92	81
		0.5 miles Downwind	1	28	0	100	100
		1.5 miles Downwind	1	6	2	67	23
		0.5 miles Crosswind	1	16	2	87	70
		Control	4	7	3	57	...
	Culex (Mel.) spp.	Treated	4	137	81	41	0
		0.5 miles Downwind	1	164	29	82	28
		1.5 miles Downwind	1	100	60	40	0
		0.5 miles Crosswind	1	328	195	41	0
		Control	4	317	79	75	...
	Anopheles crucians	Treated	4	90	149	+66	0
		0.5 miles Downwind	1	160	48	70	0
		1.5 miles Downwind	1	96	20	79	16
		0.5 miles Crosswind	1	320	83	74	0
		Control	4	177	44	75	...

[1] Average number of mosquitoes per trap night, (CDC Miniature Light Trap with dry ice) except Test No. 1, N.J. Light.

[2] Corrected for percent reductions in control area by Abbott's Formula.

wind" from the "upwind" edge of the target area at surface wind velocities of less than 2 mph. Since some of the spray, particularly the larger droplets, were deposited in the target area, the "downwind" displacement observed had the effect of increasing the size of the area treated, resulting in an under-dosing of the entire area.

It was shown that the three evaluation methods used (CDC light traps with dry ice, caged mosquitoes, and potassium-iodide cards) do not entirely support each other. It appears that trapping resulted in a more accurate indication of the control obtained than either the caged mosquitoes or cards. The cards did not sample the smaller droplets, which are probably responsible for most of the kill of mosquitoes; and kill of caged mosquitoes did not accurately reflect reduction of the natural population as measured by trapping. Nevertheless, these tests have shown that for effective control in a target area with ULV spray, a correlation of the direction and speed of the wind with the altitude and swath width of the plane is necessary. Using this information it may be possible actually to place a desired dosage in a particular target area. However, before this could be done with confidence, many additional data are needed on spray drift of a particular operation at various wind velocities. It must be concluded that the operation used in these tests is still experimental and cannot be recommended at the present time for reliable control of adult mosquitoes in areas similar to those where the tests were conducted.

Literature Cited

BLANTON, F. S., TRAVIS, B. V., SMITH, N. and HUSMAN, C. N. 1950. Control of adult mosquitoes in Alaska with aerial sprays. Jour. Econ. Ent. 43(3):347–350.

SHEPARD, M. and GORMAN, J. D. 1969. The effects of ultra-low volume Dibrom from a C-47 aircraft on adult mosquitoes. Rptr 40th Ann. Mtg of Fla. Anti-Mosq. Assn., pg. 31–36.

1969 Boike Jr., A. H., and C. B. Rathburn.
Laboratory Tests Of The Susceptibility Of Mosquito Larvae To Insecticides In Florida, 1968
Mosquito News 29: 392-395 (Amvac Ref. #1358)

1358

SHLENOVA, M. F. 1938. Vietesse de la digestion du sang par la femelle de l' *Anopheles maculipennis messeae* aux températures effectives constantes. Med. Parasit., Moscow 7:716–735. (In Russian with French summary.)

SNOW, W. E., and PICKARD, EUGENE. 1957. Correlation of vertical and horizontal flight activity of *Mansonia perturbans* with reference to marked changes in light intensity (Diptera, Culicidae). Ann. Entomol., Soc. Am. 50:306–311.

TEMPELIS, C. H., and LOFY, M. F. 1963. A modified precipitin method for identification of mosquito blood-meals. Am. J. Trop. Med. Hyg. 12:825–831.

THOMSON, R. C. M. 1941. Studies on the behaviour of *Anopheles minimus*. Part V. The behaviour of adults in relation to feeding and resting in houses. J. Malar. Inst. India 4:217–247.

WIGGLESWORTH, V. B. 1932. On the function of the so-called "rectal glands" of insects. Quart. J. Micr. Sci. 75:131–150.

ZETEK, JAMES. 1915. Behavior of *Anopheles albimanus* Wiede. and *tarsimaculata* Goeldi. Ann. Ent. Soc. Am. 8:221–271.

LABORATORY TESTS OF THE SUSCEPTIBILITY OF MOSQUITO LARVAE TO INSECTICIDES IN FLORIDA, 1968

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The surveillance program of the Florida State Board of Health for the detection of possible insecticide resistance in Florida mosquitoes was begun in 1963 (Rogers and Rathburn, 1964). Subsequently, two studies were made as a continuation of the program (Rathburn and Boike, 1967; Boike and Rathburn, 1968). This report deals with the further surveillance of Florida mosquitoes for their susceptibility to malathion, naled and fenthion. Initial data for Abate[1] and Dursban[2] are also included.

METHODS. The methods of collecting and handling the mosquitoes and testing procedures were generally the same as described by Rathburn and Boike (1967). With minor modifications the larval tests were performed according to procedures outlined by the World Health Organization (WHO, 1960). Rathburn and Boike (1969) showed that there was no significant difference between 600 ml. glass beakers and 400 ml. polypropylene beakers when using malathion, naled or fenthion; therefore, polypropylene beakers were used in most of the tests with these insecticides. However, they showed that there was a significant difference between the two types of test vessels with Abate; therefore, only glass beakers were used in tests with this insecticide. Tests of Dursban were conducted in glass beakers only.

One replication consisted of five insecticide dosages plus a check, 25 third instar larvae being used for each dosage. Tap water was used in testing all *Culex* species and *Aedes aegypti*, while 25 percent sea water was used with *Aedes taeniorhynchus*. Test beakers were washed with detergent, thoroughly rinsed and passed through two acetone baths after testing. The overall average water temperature was 74.0° F. with an average maximum temperature of 75.3° F. and an average minimum temperature of 72.8° F.

RESULTS. The results of tests with five insecticides against five species of mosquito larvae are shown in Table 1. Although the LC_{50} value of naled for *A. taeniorhynchus* from Mayport Naval Air Station (0.108 p.p.m.) is lower than reported in 1967 (0.196 p.p.m.), this may be due to species differentiation since the 1967 figure refers to tests with *A. taeniorhynchus* while the 1968 figure refers to a mixed population of 90 percent *A. sollicitans* and 10 percent *A.*

[1] American Cyanamid Co.

[2] The Dow Chemical Co.

taeniorhynchus. The LC_{50} and LC_{90} values of the population of *A. taeniorhynchus* and *A. sollicitans* from Merritt Island tested against malathion are somewhat high when compared to other areas. However, when compared to the LC_{50} and LC_{90} values of 0.180 and 0.460 p.p.m. respectively obtained from the same area in 1965 (Rathburn and Boike, 1967), there appears to be an increase in susceptibility to malathion of the mosquitoes from this area. Also, the LC_{50} and LC_{90} values of *A. taeniorhynchus* from Bonita Beach tested against malathion are lower than those previously reported. Except for these three instances, no significant variation in susceptibility was obtained when compared to results of the previous year. Baseline data for laboratory colonies of *A. taeniorhynchus* and *A.*

TABLE 1—Susceptibility of mosquito larvae from various areas of Florida to five insecticides, 1968.

Insecticide	Species	County	Area	Lethal concentrations in p.p.m.		No. of reps.
				LC_{50}	LC_{90}	
Malathion	*Aedes taeniorhynchus*	Lab. Colony	Panama City	.021	.037	18
		Lab. Colony	Vero Beach	.022	.033	4
		Bay	State Park	.017	.038	7
		Brevard	Merritt Is.	.076	.250	12[a]
		Duval	Mayport N.A.S	.046	.070	11[b]
		Duval	Marsh Area	.033	.047	13[a]
		Palm Bch.	W. Palm Bch.	.067	*	2
		Volusia	New Smyrna Bch.	.039	.062	2
		Lee	Bonita Bch.	.072	.280	7
	Aedes aegypti	Lab. Colony	Panama City	090	.146	8
	Culex nigripalpus	Lab. Colony	Panama City	.027	.035	26
		Indian R.	Vero Beach	.038	.054	8
		Lee	Sanibel Is	036	.052	14
		Orange	Lake Apopka	.049	.092	14
		Palm Bch	W. Palm Bch	.032	.071	4
Naled	*Aedes taeniorhynchus*	Lab. Colony	Panama City	.075	.125	4
		Brevard	Merritt Is.	.122	*	12[a]
		Duval	Mayport N A S.	.108	.131	12[b]
		Duval	Marsh Area	.087	.113	23[a]
	Aedes aegypti	Lab. Colony	Panama City	173	.269	16
	Culex nigripalpus	Lab. Colony	Panama City	.068	.087	40
		Indian R.	Vero Beach	076	092	8
		Lee	Sanibel Is.	.075	.094	18
		Orange	Lake Apopka	.068	.087	15
	Culex salinarius	Bay	State Park	081	.098	8
Abate	*Aedes taeniorhynchus*	Lab. Colony	Panama City	00123	.00166	8
		Lab. Colony	Vero Beach	.00073	.00116	4
	Aedes aegypti	Lab. Colony	Panama City	.00157	.00255	8
	Culex nigripalpus	Lab. Colony	Panama City	.00073	.00100	8
		Indian R.	Vero Beach	.00118	.00179	4
		Lee	Sanibel Is.	.00058	.00100	10
	Culex salinarius	Bay	State Park	.00056	.00098	4
Fenthion	*Aedes taeniorhynchus*	Lab. Colony	Panama City	.00094	.00178	8
	Culex nigripalpus	Lab. Colony	Panama City	.00300	.00420	12
	Aedes aegypti	Lab. Colony	Panama City	.00410	.00585	4
	Culex salinarius	Bay	State Park	.00290	.00380	4
Dursban	*Culex nigripalpus*	Lab. Colony	Panama City	.00064	.00079	16

* Insufficient data to accurately determine LC_{90}.
[a] Mixed population—Approx. 50% *A. taeniorhynchus*, 50% *A. sollicitans*.
[b] Mixed population—Approx. 90% *A. sollicitans*, 10% *A. taeniorhynchus*.

aegypti with Abate and fenthion and *C. nigripalpus* with Abate, fenthion and Dursban are also given in Table 1. The control mortality for all 396 replications averaged less than one percent.

Discussion. The recent increase in susceptibility of *A. taeniorhynchus* from Lee County to malathion is of interest since tests performed in 1965 and 1966 indicated an advanced degree of resistance in certain areas of that county (Rathburn and Boike, 1967). In an attempt to correlate this increase in susceptibility with a decrease in usage of malathion, a comparison was made between the amount of malathion dispersed since 1964 and the yearly susceptibility levels of *A. taeniorhynchus* larvae. These figures are presented in Table 2. In general, malathion was used extensively in 1964 and early 1965. When resistance appeared in 1965 its use declined late in that year and also in 1966. Although malathion continued to be used in 1967 and 1968 it was primarily aimed at *Psorophora confinnis* which was the prevalent pest mosquito at that time. Although not conclusive, it appears that the trend in susceptibility of *A. taeniorhynchus* from resistant areas in Lee County was accompanied by a reduction in the amount of malathion dispersed. With the exception of Bonita Beach in Lee County, Mayport N.A.S., and Merritt Island, there appears to be little variation in the susceptibility of *A. taeniorhynchus* and *C. nigripalpus* to either malathion or naled from comparable areas tested the previous year. When tested against Abate, the susceptibility of *C. nigripalpus* from Indian River and Lee Counties was about the same as that of the laboratory colony.

Table 2.—The number of pounds of malathion dispersed as aerial and ground fogs for the control of adult mosquitoes in two areas of Lee County, Florida, and the susceptibility to malathion of *Aedes taeniorhynchus* larvae from these areas, 1964–1968.

Area		1964	1965	1966	1967	1968
		Pounds of malathion dispersed[1]				
Sanibel-Captiva Is.	Aerial fog	18,582	9,576	3,623	10,331	0
	Ground fog	9,000[2]	10,629	1,981	1,208	0
	Total	27,582	20,205	5,604	11,539	0
Bonita Beach	Aerial fog	2,328	3,148	2,668	3,458	880
	Ground fog	7,500[2]	3,110	913	157	0
	Total	9,828	6,258	3,581	3,615	880
		Lethal concentration of malathion in p.p.m.				
Sanibel-Captiva Is	LC_{50}	....	0.457	0.220	0.086	....
	LC_{90}	....	3.400	2.600	0.280	....
Bonita Beach	LC_{50}	....	0.275	0.105	....	0.072
	LC_{90}	....	1.500	1.050	....	0.280
Laboratory Colony	LC_{50}	....	0.029	0.025	0.030	0.021
	LC_{90}	....	0.062	0.050	0.047	0.037

[1] Ground fog dispersed as 4.1 gal. of malathion 95/100 gals. No. 2 diesel oil; aerial fog dispersed as 8 to 12 percent malathion by weight in No. 2 diesel oil.
[2] Estimated

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References Cited

BOIKE, A. H., JR., and RATHBURN, C. B., JR. 1968. Tests of the susceptibility of Florida mosquitoes to insecticides, 1967. Mosq. News 28(3): 313–316.

RATHBURN, C. B., JR., and BOIKE, A. H., JR. 1967. Studies of insecticide resistance in Florida mosquitoes. Mosq. News 27(3):377–382.

RATHBURN, C. B., JR., and BOIKE, A. H., JR. 1969. A study of factors affecting the susceptibility of mosquito larvae to insecticides in laboratory resistance tests. Mosq. News 29(3):395–401.

ROGERS, A. J., and RATHBURN, C. B., JR. 1964. Present status of insecticides for mosquito control in Florida. Mosq. News 24(3):286–291.

WORLD HEALTH ORGANIZATION. 1960. Instructions for determining the susceptibility or resistance of mosquito larvae to insecticides. Reprinted from WHO: Technical Report Series, No. 191.

A STUDY OF FACTORS AFFECTING THE SUSCEPTIBILITY OF MOSQUITO LARVAE TO INSECTICIDES IN LABORATORY RESISTANCE TESTS

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The delineation of variables is of great importance to any research and often is itself the object of extensive investigation. The variables encountered in testing the susceptibility of insecticides to mosquito larvae are many but in general are concerned with either the test organism or its environment. Those concerned with the test insects themselves are weight or size, sex, instar, age within instar and the time of year the larvae are tested. These, except for instar, are usually considered random variables and for the most part are uncontrolled. Variables of the other group are environmental in nature and are concerned with the type and quantity of water in which the larvae are tested, the presence or absence of food, the number of larvae per test vessel, the temperature of the test solution, the type of material and dimensions of the testing vessel, the number of replications and the amount and type of insecticide dilution. The importance of many of these variables is generally ignored even though there is considerable evidence to indicate that they may be responsible for large differences in published results.

Standardized tests (WHO, 1960) eliminate many of the above variables and others, such as sex differences and differences in age within instar, are beyond practical consideration. Although WHO procedures stipulate glass testing vessels, many research workers have substituted disposable paper or plastic testing vessels for them without conducting suitable research to first ascertain any difference. Kruse *et al.* (1952) demonstrated a considerably greater loss of DDT in paper than in glass or enameled containers. Curtis (1961), however, obtained little variation in the mortality of mosquito larvae with dilute solutions of DDT between test vessels of aluminum, glass, new polyethylene, paper or enamel vessels although, as he states, there may have been some reduction in toxicity of DDT in used polyethylene test vessels. Bransby-Williams (1965) demonstrated a seven-fold decrease in the effectiveness of fenthion in polyethylene lined containers when compared to unlined enamel pans. Thus it appears that the type of testing vessel may cause significant differences in larval mortality and it is likely that these differences will vary with the type of insecticide used.

World Health Organization procedures also specify that the average temperature of the water should be approximately 25° C. and that it must not be below 20° C. nor above 30° C. This is a wide range of

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1359

…ropalpus in San Antonio—289 traps …ted from May 1 to August 31, and …rom September 1 to October 31. Fort …rth, Texas, had 77 premises with …ypti larvae in 1965, 42 in 1966, 16 in …67, and no positives in 1968. The …kly percent positive ovitraps in the …solidated areas of Fort Worth is in…cated in Figure 3. Of 9,663 ovitraps …posed weekly, *Aedes* spp. were recovered …no *aegypti* were collected in Fort …rth in 1968.

SUMMARY. In an evaluation of ovitrap …ibility, placement under objects, and …ation of the site in relation to the direc…of the sun, no association with posi…vity could be demonstrated. No changes …indicated in the present instructions …placement.

The weekly monitoring of the ovitrap …more effective and economical than …val inspections in detecting *aegypti* …pulations in consolidated areas in …orida, South Carolina, and Texas in …68.

…is evident from experience measuring *aegypti* populations that the ovitrap is a reliable tool for studying container-breeding *Aedes* populations.

ACKNOWLEDGMENTS. The assistance of many personnel in Area, Project, and Program Offices of the Aedes aegypti Eradication Program for collecting much of these data is gratefully acknowledged.

References Cited

FAY, R. W., and ELIASON, D. A. 1966. A preferred oviposition site as a surveillance method for *Aedes aegypti*. Mosq. News 26(4):531–535.

FAY, R. W., and PERRY, A. S. 1965. Laboratory studies of oviposition preferences of *Aedes aegypti*. Mosq. News 25(3):276–281.

JAKOB, W. L., and BEVIER, G. A. 1969. Application of ovitraps in the U. S. Aedes aegypti Eradication Program. Mosq. News 29(1):55–62.

TANNER, G. D. 1969. Oviposition traps and population sampling for the distribution of *Aedes aegypti* (L.). Mosq. News 29(1):116–121.

U. S. Department of Health, Education, and Welfare, Public Health Service. Ovitrap Surveys, Field Guide Series. Aedes aegypti Eradication Program, National Communicable Disease Center, Health Services and Mental Health Administration, Atlanta, Ga. 30333.

A TECHNIQUE FOR ULV INSECTICIDE APPLICATION FROM HIGH ALTITUDES

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The advantages of ultra low volume ap…lication are well known, but operations …nducted from low altitudes (100–150 …et) present a safety problem even for …lti-engine aircraft. Therefore, in June, …68 a preliminary pre-dawn test was con…ucted to determine the feasibility of ULV …ecticide application from high altitude. …iper Pawnee aircraft applied insecticide …ULV rate from an altitude of 1,000 …et. Recovery of spray droplets indicated …at the target area could be treated from …an altitude. With this in mind, it …decided to attempt control of adult *…des sollicitans* (Walker) on two large tracts of land in Orleans Parish, Louisiana, using ULV application from high altitude.

A series of four tests was conducted with a DC-3 aircraft equipped to apply Dibrom at ULV rates (Machado, 1969). Treatments were made between the hours of 2 a.m. and 4 a.m. for the first three tests, and at sunset for the fourth test. There are several advantages gained by night flying. Stable air conditions are often encountered at this time, and lighted streets, towers, etc., provide excellent landmarks for swath placement in urban areas. Rural areas are easily "flagged" by using a flashing light mounted atop a vehicle.

Methods and Materials. Since the aircraft is loaded with insecticide well in advance of spray time (sometimes as much as several weeks prior to use), the corrosive nature of Dibrom must be considered. By filling all available air space of the spray tanks with oil-pumped nitrogen, the problem of metal oxidation and Dibrom crystal formation was greatly reduced. Figure 1 illustrates the small amount of Dibrom crystals collected by an in-line 100-mesh strainer following 90 days' storage of 50 gallons of Dibrom in a 100-gallon system of unlined 10-gallon stainless steel beverage tanks under nitrogen atmosphere.

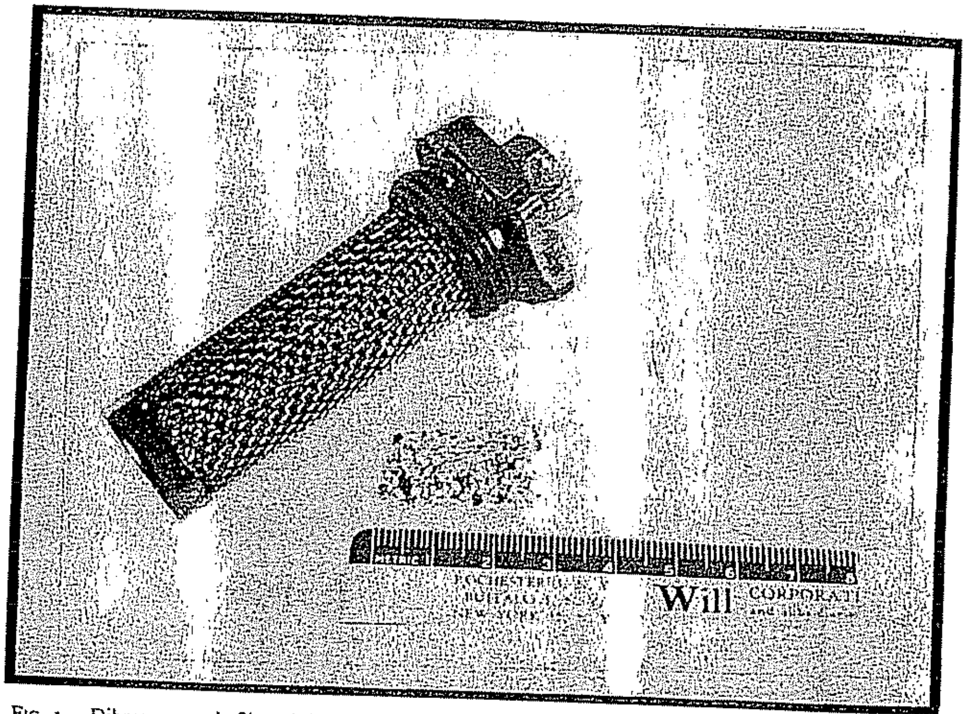

Fig. 1.—Dibrom crystals filtered from 50 gallons Dibrom following 90 days storage in a 100 gal. system of unlined 10 gal. stainless steel beverage tanks under a nitrogen atmosphere.

Tests 1, 2 and 3. Prior to test flights, the spray system was calibrated to deliver Dibrom at a rate of 0.5 to 1.0 ounce per acre in 1,000-foot swaths, using six D-6 disc-type orifices without cores, arranged in a trailing position. Air pressure at the compressor was maintained at 80–100 psi. This yielded an average pressure of 45 psi on the insecticide as it entered the wing boom. Application was made from an altitude of 1,000 feet, at a speed of approximately 150 m.p.h. Temperatures at time of application ranged from 70° to 76° F. Surface winds were at 0 knots, however, smokestacks near the test area indicated a north-northwest drift.

Spray deposition was monitored with Dibrom sensitive dye cards (Koundakjain, 1965). Dye cards, 2.5" x 5", were placed at ground level in both horizontal and vertical positions across the test areas perpendicular to the line of flight.

Adult mosquito density was determined by landing rate counts, each count being taken for a 2½-minute interval. Pre- and posttreatment counts were begun at dusk and continued thereafter for approximately 2 hours during each testing period.

The areas treated, known as Little

Woods and Algiers, comprise approximately 8,000 and 7,000 acres, respectively, and are separated by an average of 7 miles. Each area has sections of urban as well as heavily wooded undeveloped land. The Algiers area was sprayed on the nights of July 17 and 19, 1968 (Tests 1 and 3); the Little Woods area on the nights of July 18, 1968, (Test 2) and October 30, 1968 (Test 4).

TEST 4. Test 4 was conducted on October 30, 1968, in Little Woods. At that time of year, daytime temperatures are warm, but nights are quite cool, and mosquito activity is limited to a short period at or near sunset. Therefore, early morning treatment was abandoned in favor of application at sunset.

The spray system was recalibrated to deliver 1.0 oz. per acre in 1,000-foot swaths by increasing air pressure to yield an average of 50 psi at the wing boom. The same nozzle orifices were used in Test 4 as in the previous tests; however, the arrangement was altered so that nozzles were angled 45° from horizontal into the line of flight. This change was made in an attempt to produce smaller droplets. Temperature at time of application was approximately 72° F. Surface winds were recorded at 8–10 m.p.h. Because of these relatively high winds, it was decided to make application from an altitude of 500 feet.

Spray deposition was again monitored with dye cards. Dye card stations were located at 250-foot intervals along two transects in the test area perpendicular to the line of flight.

Mosquito landing rate counts were taken approximately one hour prior to treatment and again 24 hours posttreatment in both the test area and in an untreated control area. Counts within the test area were made in urban as well as wooded sites. Those taken in the untreated control area were made at wooded sites only.

RESULTS. Dye cards used during the July 17 treatment of Algiers (Test 1) were located at 100-foot intervals. There were 124 card stations with a vertical card at each, and with a horizontal card at every fifth station. Figure 2 shows the average number of particles impinging on cards

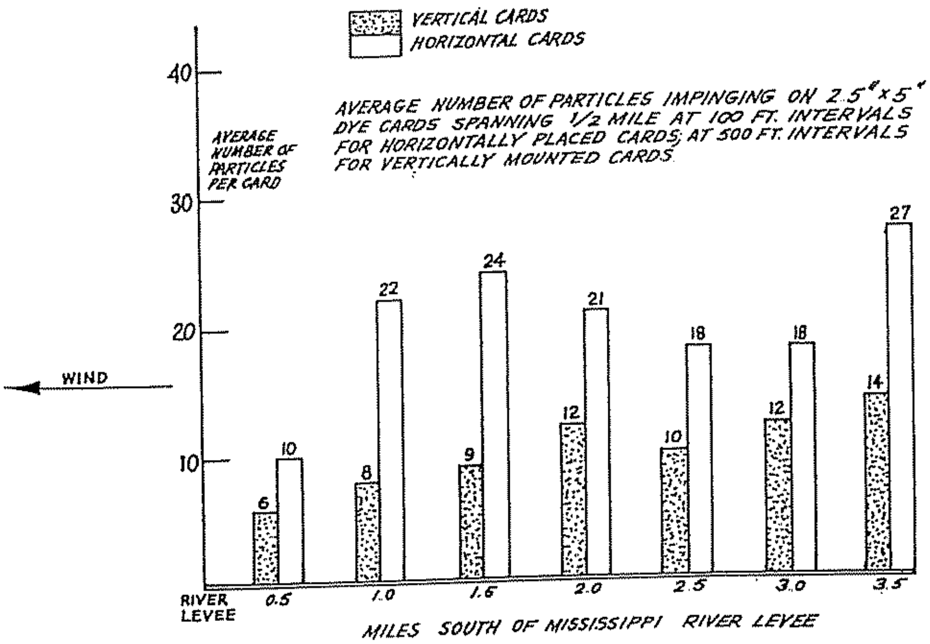

FIG. 2.

at one-half mile intervals for both horizontal and vertical positions: the Mississippi River levee marked the northernmost (downwind) card location (See sketch map, Figure 3). Horizonally placed cards averaged 23 droplets per card, while vertical cards showed an average of only 11 droplets per card. The distribution of particles throughout the entire area was rather uniform, as indicated by cards in both positions.

Two nights later (July 19, Test 3), when

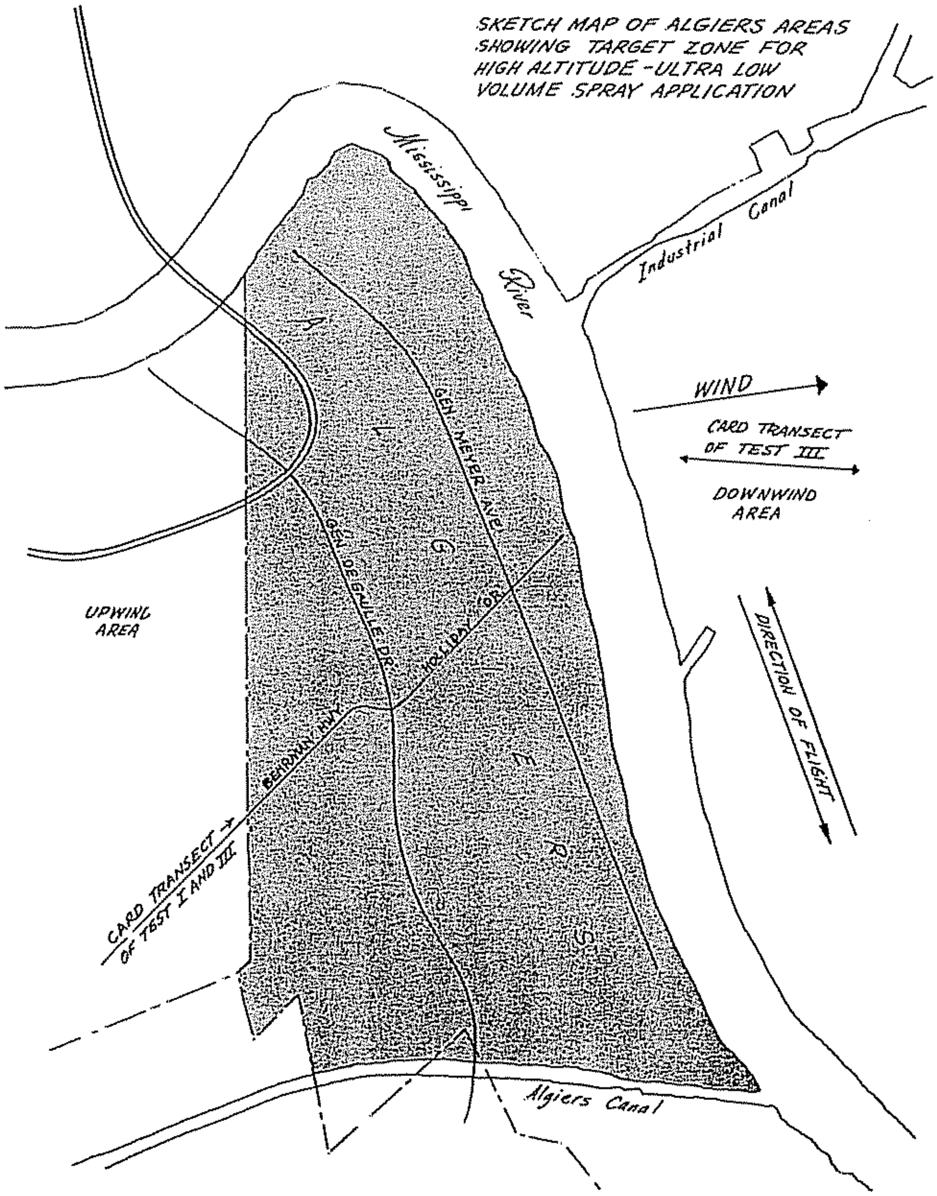

FIG. 3.

Algiers was again treated, cards were placed at 0.1 mile intervals in a horizontal position only. Cards were located as far as 1.1 miles south (upwind) of the target area and continued north (downwind) across the Mississippi River for 0.6 mile (the river at this point is approximately 0.5 mile wide—Figure 3). Figure 4 illustrates the average number of particles recovered at card stations within one-half mile intervals. Recovery within the target zone indicated a uniform application. Several swaths were applied upwind of the target zone to allow for drift. Cards within this 1.1 mile upwind area averaged 13 particles per card, as compared to an average of 24 per card for those within the target zone. Dye cards located downwind of the target zone across the Mississippi River showed an average of 67 droplets per card. The card farthest downwind in this series had an impingement of 49 droplets, indicating that drift continued beyond this point. The river is approximately one-half mile wide in this area; it is possible that rising air currents from the water facilitated drift.

No measurement of particle size was taken; however, those droplets recovered upwind of the target area were quite large, at least three times the size recovered

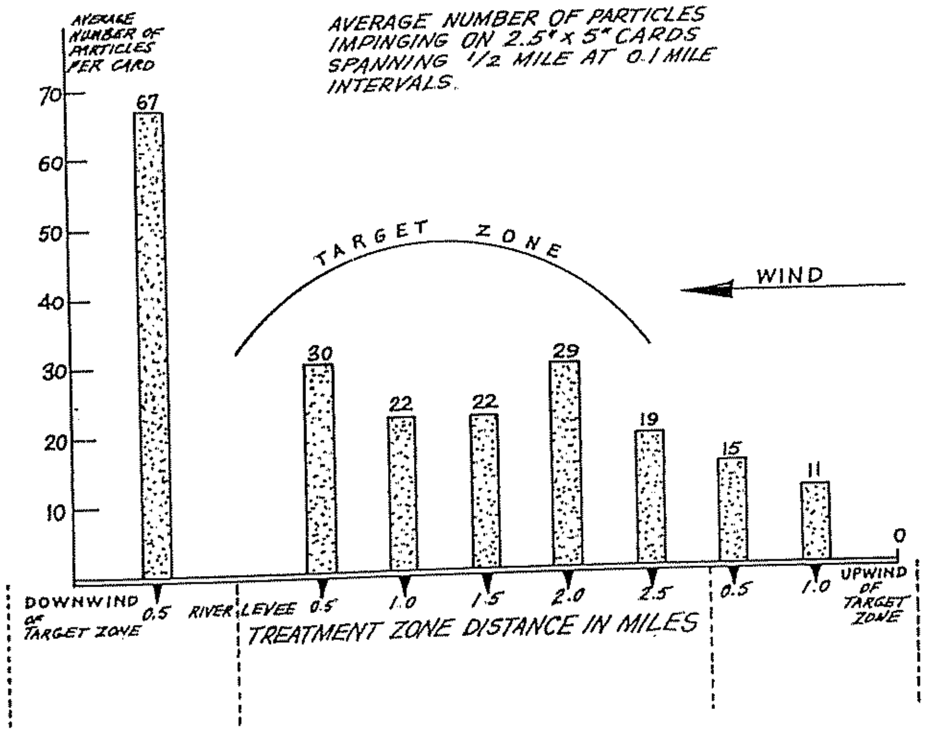

FIG. 4.

within the target zone. Particles recovered across the river (downwind) were less than half the size of those in the target zone.

Treatment of the Little Woods area on July 18 (Test 2) was monitored at 42 dye card stations established at approximately 250-foot intervals. Each station consisted of one horizontally and one vertically placed card. Cards in a horizontal position averaged 35 droplets, whereas those in a vertical position averaged only 11 droplets as indicated in Figure 5.

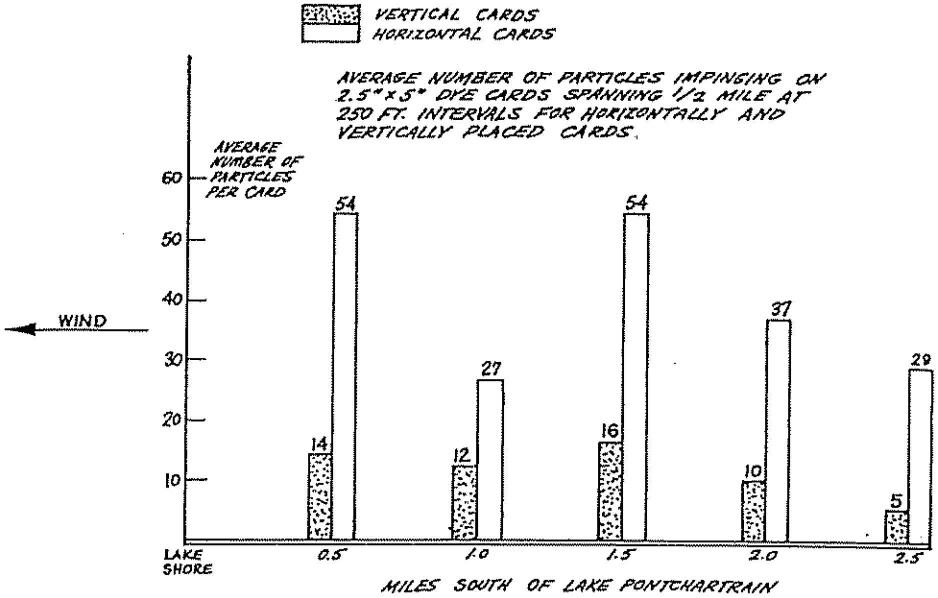

FIG. 5.

When Little Woods was treated on October 30 (Test 4) dye cards were located along two transects. One transect had cards positioned both horizontally and vertically at each station, the former being at ground level and the latter at 3- and 6-foot levels. The second transect, parallel to the first but separated by approximately 3 miles, had cards positioned horizontally at ground level only. Figures 6 and 7 illustrate the average number of droplets recovered at the various card stations. The transect having cards at three levels shows an average of 7 droplets per square inch at ground level (horizontal) and an average of 5 and 6 per square inch at the 3- and 6-foot levels, respectively (vertical). Cards along the second transect (horizontal at ground level) had an average of 6 droplets per square inch. These data indicate that, while impingement was far less than in the previous test, coverage was quite consistent.

Effectiveness of the application made in the Algiers area is shown in Table 1. Zone I is comprised of urban dwellings,

TABLE 1.—Landing rate counts of *Aedes sollicitans* pre & post aerial treatment with Dibrom 14 applied in ULV from an altitude of 1000 feet. (Tests 1 & 3).

	Landing rate counts [a]			
	Pretreatment	Post 1st treatment		Post 2nd treament
	8 hrs.	16 hrs.	40 hrs.	10 hrs.
Zone I [b]	3	1	7	1
Zone II [c]	14	7	11	4
Untreated control	9	10	..	..

[a] Avg. no. of mosquitoes landing on one person in 2½ minutes at 8 individual stations in Zone I, 4 in Zone II, and 6 in the untreated control.
[b] Urban area.
[c] Densely wooded with heavy underbrush.

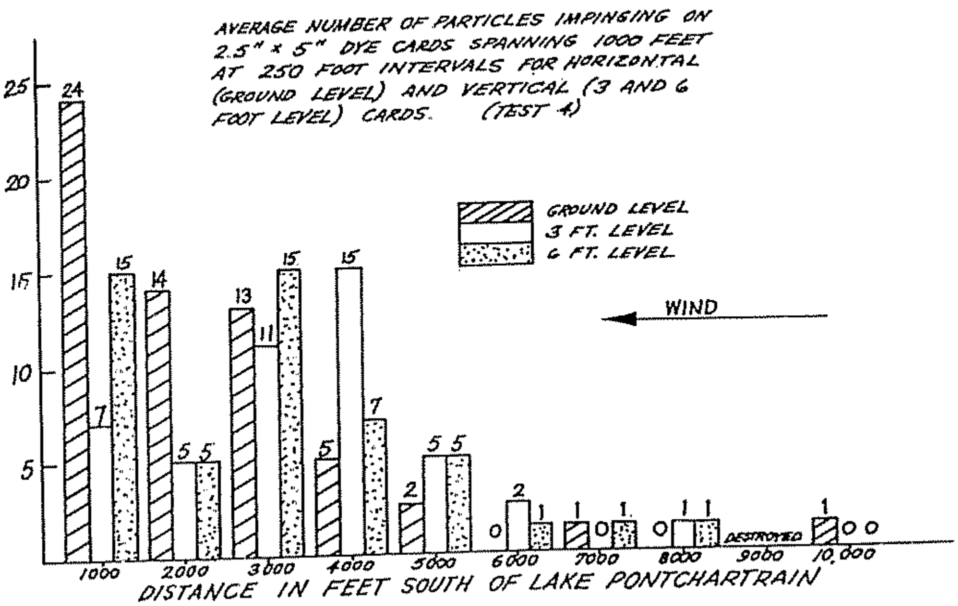
AVERAGE NUMBER OF PARTICLES IMPINGING ON 2.5" x 5" DYE CARDS SPANNING 1000 FEET AT 250 FOOT INTERVALS FOR HORIZONTAL (GROUND LEVEL) AND VERTICAL (3 AND 6 FOOT LEVEL) CARDS. (TEST 4)
GROUND LEVEL
3 FT. LEVEL
6 FT. LEVEL
WIND
DESTROYED
DISTANCE IN FEET SOUTH OF LAKE PONTCHARTRAIN

FIG. 6

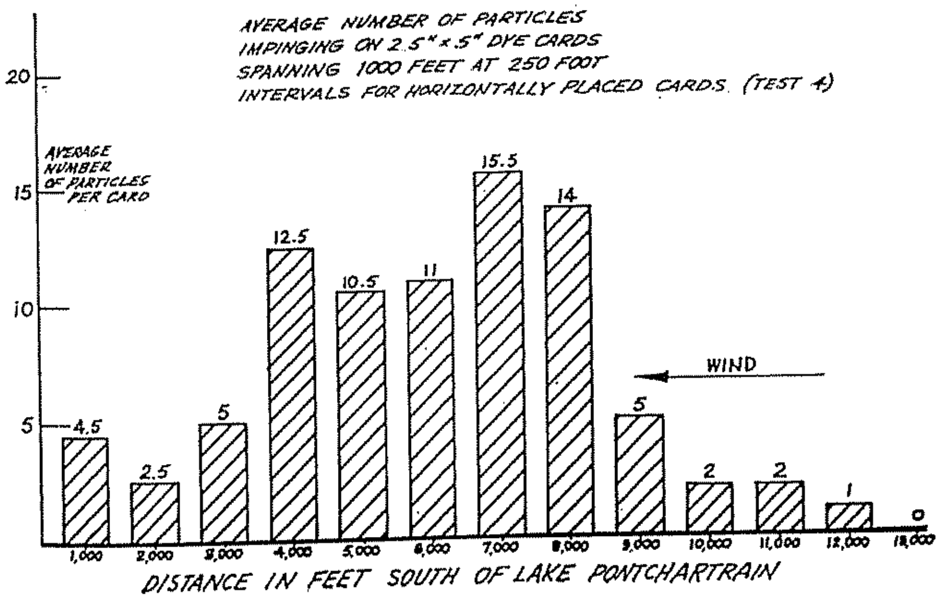
AVERAGE NUMBER OF PARTICLES IMPINGING ON 2.5" x 5" DYE CARDS SPANNING 1000 FEET AT 250 FOOT INTERVALS FOR HORIZONTALLY PLACED CARDS. (TEST 4)
AVERAGE NUMBER OF PARTICLES PER CARD
WIND
DISTANCE IN FEET SOUTH OF LAKE PONTCHARTRAIN

FIG. 7.

while Zone II is a densely wooded area with heavy underbrush, therefore landing rates taken in these areas were viewed separately. Initial treatment (July 17, Test 1) in Zone I yielded a 69 percent reduction in the adult mosquito population within 16 hours; however, the area was reinfested within 24 hours. A reduction of 58 percent was noted in Zone II, followed by a similar reinfestation. The second treatment (July 19, Test 2) of these zones produced a 90 percent and 65 percent mortality, respectively.

Application made in the Little Woods area (July 18, Test 2) produced 71 percent control, and was not followed by reinfestation (Table 2). Landing rate stations in this area were located at sites similar to those found in Zone II of Algiers, but the data indicate a better percentage of control. Although insecticide pressure as it entered the wing booms averaged 45 psi for all three spray applications, a pressure of 50 psi or more was encountered on many of the spray passes made over Little Woods. Since volume of chemical applied is a function of spray pressure, it is logical to assume that a volume of 1.0 oz. per acre was approached during this treatment of Little Woods.

The second treatment of Little Woods (October 30, Test 4) yielded a reduction in the adult mosquito population of 95 percent in the urban zone and 77 percent in the heavily wooded zone of the test area as is indicated in Table 3.

TABLE 2.—Landing rate counts[a] of *Aedes sollicitans* pre & post aerial treatment with Dibron 14 applied in ULV from an altitude of 1000 feet. (Test 2).

	Landing rate counts		
	Pretreatment	Posttreatment	
	8 hrs.	16 hrs.	40 hrs.
Treated area	24	7	6
Untreated control	23	19	..

[a] Average number of mosquitoes landing on one person in 2½ minutes at 10 individual stations in each area.

TABLE 3.—Landing rate counts of *Aedes sollicitans* pre & post treatment with Dibrom 14 applied in ULV from an altitude of 500 feet. (Test 4).

	Landing rate counts[a]	
	1 hr. pretreatment	24 hrs. posttreatment
Zone I[b]	18	1
Zone II[c]	29	7
Untreated control	27	26

[a] Avg. no. of mosquitoes landing on one person in 2½ minutes at 9 individual stations in Zone I, 10 in Zone II, and 5 in untreated control.
[b] Urban area.
[c] Densely wooded with heavy underbrush.

DISCUSSION. In Tests 1, 2 and 3 the problem of insecticide drift was a major concern. For this reason spray nozzles were arranged in a trailing position to minimize shearing action. However, control achieved was less than that desirable. At this point it was thought that possibly drift might be used to an advantage, rather than trying to avoid or compensate for it. It was thought that perhaps the most effective use of ULV spray might be obtained when the material is allowed to drift laterally near ground level, much in the way that thermal fog operates, drifting around objects rather than impinging on them. If this is true, then particles collected on dye cards represent material that has, for the most part, been lost as far as availability to the mosquito is concerned. Therefore, in Test 4 nozzles were angled 45° into the line of flight to produce smaller spray droplets. Data obtained indicate fewer particles per square inch of dye cards, yet a higher percentage of control was achieved even in areas of dense woods with heavy underbrush.

References Cited

KOUNDAKJAIN, T. H. 1965. The detection and measurement of Dibrom LV concentrate aerial spray droplets. Chevron Chemical Company, Ortho Division, Research & Development Department, Richland, Calif. File No. 721:101.

MACHADO, W. C., BLAKE, A. J., BORDES, E. S., and CARMICHAEL, G. T. 1969. Evaluation of a multi-engine aircraft in the ULV application of Dibrom. Mosq. News 29(1):47–52.

1969 Mount, G. A., N. W Pierce, and C. S. Lofgren
New Insecticides Evaluated As Nonthermal Aerosols Against Aedes Taeniorhynchus (Weidmann)
Mosquito News 29: 53-54 (Amvac Ref. #1360)

NEW INSECTICIDES EVALUATED AS NONTHERMAL AEROSOLS AGAINST *AEDES TAENIORHYNCHUS* (WIEDEMANN)

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Six new insecticides were compared with 3 standard insecticides as nonthermal aerosols against *Aedes taeniorhynchus* (Wiedemann). The results probably are also indicative of those that could be expected from thermal aerosols since Mount *et al.* (1966) and Taylor and Schoof (1968) demonstrated that nonthermal and thermal aerosols are equally effective.

MATERIALS AND METHODS. The tests were conducted in an open field near Gainesville, Florida in October and November 1967 and in April and May 1968. The tests were performed between 6 and 10 p.m. during favorable climatic conditions. Temperatures 5 feet above the ground ranged from 74 to 85° F. and averaged about 80° F. Wind speeds ranged from <2 to 12 m.p.h. and averaged about 4 m.p.h.

The insecticides tested were as follows:

Geigy GS-13005	*O,O*-dimethyl phosphorodithioate *S*-ester with 4-(mercaptomethyl)-2-methoxy-Δ^2-1,3,4,-thiadiazolin-5-one
Bay 77488	*O,O*-diethyl phosphorothioate *O*-ester with phenylglyoxylonitrile oxime
Bay 78182	*O,O*-diethyl phosphorothioate *O*-ester with (*o*-chlorophenyl)glyoxylonitrile oxime
Montecatini L561	Ethyl mercoptophenylacetate *S*-ester with *O.O*-dimethyl phosphorodithioate
CIBA C-9643	*o*-(4-methyl-1,3-dioxolan-2-yl)phenyl methylcarbamate
Bromophos	
Fenthion (standard)	
Malathion (standard)	
Naled (standard)	

Commercial emulsifiable concentrates were used with all compounds. The concentrations in pounds per gallon were: Geigy GS-13005 (3.55), Bay 77488 (4.2), Bay 78182 (2.33), Montecatini L561 (4.4), CIBA C-9643 (3), bromophos (4), fenthion (4), naled (12), and malathion (5).

The nonthermal aerosol generator used to disperse the formulations was a Curtis Model 55,000, calibrated to deliver 40 gallons of liquid per hour. The generator was moved at 5 m.p.h. Adult female mosquitoes, 2 to 7 days old were exposed in 16-mesh screen wire cages (25 per cage) suspended on stakes 150 and 300 feet downwind in two rows perpendicular to the line of travel of the generator. Thus, a total of 4 cages per replicate were used, and from 1 to 4 replications were made with each concentration of each insecticide. After the passage of the aerosol generator, the mosquitoes were transferred to plastic tubes lined with clean paper. Except during exposure to the aerosols, the mosquitoes were held in insulated chests containing ice in cans. Absorbent cotton pads moistened with 10 percent sugar-water solution were placed on the holding tubes when they were returned to the laboratory. Mortality counts were made 18 hours after exposure to the aerosols.

RESULTS AND DISCUSSION. The mortalities and estimated LC_{90}'s for each insecticide are presented in Table 1. All compounds gave slightly better kills in the spring tests than in the fall tests, possibly because wind conditions were more favorable. Geigy GS-13005, with an LC_{90} of 0.95 percent, was only slightly less effective than the fenthion standard (LC_{90} value of 0.80 percent). Thus, these results were in agreement with those of Mount *et al.* (1966) who reported previously that Geigy GS-13005 was an effective nonthermal aerosol against *A. taeniorhynchus*. Bay 77488, Bay 78182, and Montecatini L561 (LC_{90}'s ranging from 1.2 to 1.5 percent) were less effective than

TABLE 1.—Mortality of caged adult female *A. taeniorhynchus* after exposure to nonthermal aerosols (water emulsion formulations) of 9 insecticides.

Insecticide	Percentage 18-hr mortality at indicated concentration[a]						LC_{90} (%)
	4	2	1	0.5	0.25	0.1	
			New insecticides				
Geigy GS-13005	99	99	85	86	67	7	0.95
Bay 77488	97	100	73	58	47	..	1.2
Bay 78182	99	91	83	77	30	..	1.4
Montecatini L561	95	93	81	71	67	2	1.5
CIBA C-9643	97	77	69	66	..	..	2.2
Bromophos	89	47	10	..	..	..	4.1
			Standards				
Fenthion	98	100	86	93	53	6	.80
Naled	100	100	57	76	11	..	1.3
Malathion	90	78	40	..	..	..	3.6

[a] Average mortality at 150 and 300 feet; check mortality was 3 percent.

fenthion but about equal to naled (1.3 percent). CIBA C-9643 was much less effective than either fenthion or naled but about 1.5 times more effective than malathion. Bromophos was slightly less effective than malathion. The results with naled at 12 pounds per gallon emulsifiable concentrate (a new formulation provided by the manufacturer) were very similar to those previously reported for the standard (8 pounds per gallon) emulsifiable concentrate of naled by Mount *et al.* (1966) and Mount and Lofgren (1967).

SUMMARY. Nonthermal aerosols of six new insecticides and three standards (fenthion, naled, and malathion) were evaluated against caged adult female *Aedes taeniorhynchus* (Wiedemann). Geigy GS-13005 (*O,O*-dimethyl phosphorodithioate *S*-ester with 4-(mercaptomethyl)-2-methoxy-Δ^2-1, 3, 4,-thiadiazolin-5-one) was only slightly less effective than fenthion. Bay 77488 (*O,O*-diethyl phosphorothioate *O*-ester with phenylglyoxylonitrile oxime), Bay 78182 (*O,O*-diethyl phosphorothioate *O*-ester with (*o*-chlorophenyl)glyoxylonitrile oxime), and Montecatini L561 (ethyl mercaptophenylacetate *S*-ester with *O,O*-dimethyl phosphorodithioate) were less effective than fenthion but about equal to naled. CIBA C-9643 (*o*-(4-methyl-1, 3-dioxolan-2-yl)phenyl-methylcarbamate) was much less effective than either fenthion or naled but was about 1.5 times more effective than malathion. Bromophos was slightly less effective than malathion.

References Cited

MOUNT, G. A., LOFGREN, C. S., GAHAN, J. B., and PIERCE, N. W. 1966. Comparisons of thermal and nonthermal aerosols of malathion, fenthion, and naled for control of stable flies and salt-marsh mosquitoes. Mosq. News 26(2):132–138.

MOUNT, G. A., LOFGREN, C. S., and GAHAN, J. B. 1966. Nonthermal aerosols of new insecticides for the control of *Aedes taeniorhynchus* (Wiedemann). Proc. N. J. Mosq. Ext. Assoc. 53: 131–134.

MOUNT, G. A., and LOFGREN, C. S. 1967. New insecticides as nonthermal aerosols for control of adult mosquitoes. Mosq. News 27(4):470–473.

TAYLOR, R. T., and SCHOOF, H. F. 1968. Evaluation of thermal and nonthermal fogs against four species of mosquitoes. Mosq. News 28(1):8–11.

1969 Shepard, M., and J. D. Gorman
The Effects Of Ultra-Low Volume Dibrom From A C-47 Aircraft On Adult Mosquitoes
Proceedings of the Florida Anti-Mosquito Association 31-36 (Amvac Ref. #1361)

1969

1361

THE EFFECTS OF ULTRA-LOW VOLUME DIBROM FROM A C-47 AIRCRAFT ON ADULT MOSQUITOES

by

Merle Shepard[1] and James D. Gorman[2]

ıere has been increasing attention given to ultra-low volume applications of insecti-ides in recent years. This method has been employed in several areas of insect con-rol, but control of adult mosquitoes has received much of the emphasis (Knapp and ›berts, 1965; Stevens and Stroud, 1966; Glancey et al, 1966; and Mount and Lofgren, 967.) Some authors have experimented with combinations of different insecticides Stevens and Stroud, 1966; Knapp and Gayle, 1967) or compared the effectiveness of ıese materials when applied at various dosages in aerial spray (Mount and Lofgren, 967.)

/aluation of the results of most of the above studies has been based upon adult mos-ıito landing rates or the number of mosquitoes landing on a person in one minute. ıile this technique may give good indications of reduction of adult population, ıere is no allowance made for activity of a given species at a certain time, possible gration of mosquitoes into or out of a treated area or the emergence of a brood 'ter a spray application.

ıe reason for inadequate control of adult mosquitoes in some areas by aerial methods ıs been suggested to be the inability of the aerial spray droplets to penetrate the getation. Thus, application of insecticides at night should give good results as e droplets would be more likely to contact the mosquitoes which are more active at is time. Also, the thermal convections, which may prevent the spray materials from scending during warmer periods, are not as prevalent at night. Blanton, et al 950), using DDT spray from a C-47 aircraft observed a 94 per cent reduction in the ult mosquito population when sprayed at night, while daytime spraying caused no sig-ficant reduction of the mosquito population.

is present work attempts to evaluate the effectiveness of ULV applications of Dibrom concentrate from a C-47 aircraft. Results were obtained using caged mosquitoes, ght traps and mosquito landing rates. These experiments also deal with the altitude the aircraft and time of application of the spray material.

TERIALS AND METHODS

C-47 airplane, equipped with an ultra-low volume spray system, was used for these sts. Each wing supported a boom with four (4) 80015 Tee Jet flat fan nozzles. The essure on the system was either 50 or 60 psi at the tanks. The Dibrom was delivered

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in concentrated form at rates of from 0.05 to 0.076 pounds per acre. A speed of 150 mph and a swath width of 600 feet was maintained by the aircraft. The swath was marked by a strobe light mounted on a telescoping rod which was secured to a pickup truck. All tests except one were conducted at night with wind velocities varying from less than 1 to 8 mph at ground level.

Several experiments were undertaken to establish swath width. Dibrom sensitive (KI-Methanol) cards were placed at intervals perpendicular to the flight passes to determine the drift and swath of the aerial droplets. For these swath tests the aircraft was flown at an altitude of 150 feet with wind from 4-8 mph at the ground level.

The behavior of spray droplets is dependent upon a number of factors such as wind velocity, temperature and amount of vegetation in an area. These factors must be considered with any swath determination, and the degree of variability which may exist between test areas and test periods is tremendous. A knowledge of the swath width could be helpful from a standpoint of general location of spray droplets; however, the results obtained from spraying an area with caged mosquitoes and/or a natural infestation of mosquitoes seemed to be more important than knowledge of a single swath width under a given set of conditions. As an area of known size is sprayed, the insecticide dosage can be calculated by knowing the distance between flight passes, speed of the aircraft, and time required to deliver a given quantity of material. A swath width of 600 feet gave sufficient overlap of spray materials to achieve control of most of the mosquitoes in these experiments.

A total of four experiments are reported in this paper. In the first experiment an area of about 12 square miles was chosen as a test plot. Six stations were established throughout this test zone and a 5½-foot stake was placed at each of the stations. Cylindrical screen cages 2½-inch x 6-inch in size were used to confine from 25-30 wild Culex nigripalpus adults. A cage was placed on each stake two feet from the ground and another was suspended from the top of the stake 5½ feet high. Two other cages of C. nigripalpus mosquitoes were placed in the surrounding vegetation or in the open near each of the stakes. The vegetation consisted mostly of 12-24 inch grass with palmettos scattered throughout. The aircraft maintained an altitude of 300 feet, but in other experiments at night an altitude of 500 feet above obstacles was used. Application of the spray material was made at 3:15 a.m., at a rate of 0.05 pounds per acre (0.5 fl. oz. per acre.)

Five cages of control groups were placed on the ground and on stakes about three miles upwind from the test area. One hour was allowed after spraying before the mosquitoes were anesthetized with CO_2, transferred to clean cardboard holding cages and returned to the laboratory for a 24-hour mortality count. Controls in all caged mosquito tests were also treated in the same manner as the treated groups.

Dibrom sensitive cards were placed beside each cage except for the cages suspended upon the stakes, in which case the cards were placed at the base of each stake. It was hoped that a correlation between droplet deposition and per cent mortality could be established.

In experiment two, two New Jersey light traps located within a 3,000-acre plot were used to determine the results of a ULV application. The traps were run the night of spray application and the night after spray application; however, the application was made at 10:00 p.m., and mosquitoes caught before this time were not removed. The rate of application of the Dibrom and environmental conditions were essentially the same as those in experiment one.

The third experiment involved the use of both C.D.C. light traps and caged C. nigripalpus. This test was conducted at 7:25 a.m., and the aircraft was flown at 150 feet. The test area was 2,900 acres in size. Dibrom was delivered at a rate of 0.076 pounds per acre (0.7 fl. oz. per acre) with wind velocities varying from 5-6 mph at the ground level. The area had a heavy infestation of Aedes taeniorhynchus. Vegetation consisted mostly of high grasses, deciduous trees, and mangroves.

Landing rates were taken at five different sites within the test zone and used as criteria for determining test results for the last experiment. Temperature and wind velocities were about the same as those for previous tests. Insecticide was applied at a rate of 0.069 pounds per acre. Effectiveness of the aerial spray was determined by counting the number of mosquitoes landing on a person per minute. The predominant species in the area was Aedes taeniorhynchus. Landing rates were taken the evening before spray application and again at the same time 24 hours after spraying.

RESULTS AND DISCUSSION

Preliminary experimentation with aerial applications of Dibrom 14 ULV for the control of adult mosquitoes in the Hillsborough County area has provided promising results. All experiments were congruent with mosquito control operations and employed as many different criteria as possible for the assessment of results.

Determination of a definite swath width has proven difficult. Results obtained from one swath test showed visible droplet deposition on (KI-Methanol) Dibrom-sensitive cards of 1460 feet. This same test indicated that the first visible droplets appeared 900 feet downwind from the center of the flight pass.

An attempt to correlate visible droplet deposition on Dibrom-sensitive cards and per cent mortality proved futile as the droplets which cause the highest degree of mortality do not show up on the cards. Mount, et al (1968) working with ground equipment, found a higher degree of mortality in Aedes taeniorhynchus with 6 μ droplets than with 22.4 μ droplets. The Dibrom-sensitive cards in this present work contained from 1 to 8 visible particles per square inch. In one case a card with one visible particle per square inch was beside a cage with 100 per cent mortality.

Table I is the results of the first experiment. Almost 100 per cent mortality of the caged C. nigripalpus was achieved within a $3\frac{1}{2}$-hour period after application of the spray material. This illustrates the rapid knockdown of the concentrated Dibrom. Although only 0.052 pounds per acre (0.5 fl. oz. per acre) of insecticide was used, this was adequate in this experiment to achieve excellent results.

In areas of heavy vegetation, where cages were completely covered by vegetational canopy, there was apparently penetration of the spray material which resulted in good control of the caged C. nigripalpus. All mosquitoes which were contained in cages suspended from stakes both at the $5\frac{1}{2}$ feet and 2 feet level were killed within a $3\frac{1}{2}$ hour period. Dibrom sensitive cards showed a droplet deposition of from 1 to 8 droplets per square inch. A slight drizzle began about one hour after spray application. This apparently did not impair the action of the Dibrom. There was no mortality in the control groups even after 24 hours, which negated the use of Abbott's formula.

The second experiment effected the use of two New Jersey light traps. These traps were run the entire night of spray application and the night after application. It must be noted that the time of application was 10:00 p.m., on the night of initial trapping, and any mosquitoes caught in the traps before treatment were not removed and counted. The total number of female mosquitoes of all species was reduced from 1,114 to 215 or an 81 per cent reduction. The predominant species in this test area was Psorophora confinnis. The P. confinnis females in one trap were reduced from 240 to 85, or a 65 per cent reduction. The other trap showed a reduction of the P. confinnis females of 88 per cent (from 757 to 91.) Results obtained from data of this nature were difficult to assess, as environmental and other factors affect the activity and the numbers of mosquitoes caught in the New Jersey light traps.

Experiment three showed that good control was obtained in all cages of C. nigripalpus except those cages in heavy vegetation (see Table 2.) There was also a reduction in the natural population of most of the species as shown by catches in CDC traps (see Table 3.) Table 3 also shows that the natural population of C. nigripalpus was probably not affected by the ULV treatment. It was not possible to determine the effects of the ULV Dibrom on species other than A. taeniorhynchus, C. nigripalpus, and P. confinnis because the numbers caught in the traps were too low. The CDC traps showed a 73 per cent reduction in the total number of females of all species caught.

Control in the caged C. nigripalpus ranged from 90 to 100 per cent in areas with medium to no vegetation; however, in two cages which were completely covered with dense vegetation, 45 and 48 per cent mortality was achieved. This illustrates the inability of the spray material to penetrate the vegetational canopy and points out that night applications of aerial spray materials were more satisfactory as penetration into the foliage was not as imperative as it would be during periods when the mosquitoes were resting.

Other tests show that the numbers of aerial spray droplets impinging upon Dibrom-sensitive cards from an altitude of 500 feet were equivalent to those deposited at lower altitudes and the results from experiment five show that good control was obtained as determined by landing rates at five stations. Pre-treatment counts ranged from 10 to 42 mosquitoes per man per minute and 100 per cent reduction was achieved when landing rates were taken at the same time 24 hours later.

It is obvious from these findings that much work remains to be done using ULV for the control of mosquitoes. There is much to be learned about the behavior of the spray droplets themselves, the achievement of optimum particle size, critical impingement velocity, etc., however, the ultimate test is the application of ULV on a long range operational basis such as use by a mosquito abatement district.

TABLE 1- Results of Experiment I. Per cent mortality after 3½ hours of caged Culex nigripalpus sprayed with Dibrom ULV at 0.052 pounds per acre (0.5 fl.oz.per acre)

Type of Vegetation	Cage Position	No. Cages	Average Per Cent Mortality*
None	Ground	3	100
	2 feet	6	100
	5½ feet	6	100
Medium	Ground	5	100
Heavy	Ground	4	100

* Control mortality at all stations was 0 per cent.

TABLE 2- Results of experiment III. Effectiveness, based upon 24-hour mortality of caged Culex nigripalpus adults, of aerial applications of ULV Dibrom made from a C-47 airplane from a 150-foot altitude at 7:25 a.m.

Vegetation	No. Cages	Average Per Cent Mortality*
None	4	100
Medium	7	97
Heavy	5	70

* Corrected for control mortality by use of Abbott's Formula

TABLE 3. Results of ULV Dibrom against natural populations of[1] adult mosquitoes as measured by CDC light traps in the third experiment.[1]

Species	average number of mosquitoes per trap		
	pretreatment	24 hours	per cent reduction
Aedes taeniorhynchus	1006	218	78
Culex nigripalpus	86	82	5
Psorophora confinnis	129	33	74

[1] Technical Dibrom applied at 0.7 fl. oz. per acre (0.076 pounds per acre)

REFERENCES

Blanton, F. S., Travis, B. V., Smith, Nelson and Husman, C. N. 1950. ntrol of adult mosquitoes in Alaska with aerial sprays. J. Econ. Entom. (3): 347-350.

Glancy, B. Michael, White, A. C., Husman, C. N., Salmela, J. 1966. w volume applications of insecticides for the control of adult mosquitoes. sq. News 26 (3): 356-359.

Knapp, Fred W., and Roberts, W. W. 1965. Low volume aerial application technical malathion for adult mosquito control. Mosq. News 25 (1): 46-47.

Knapp, F. W., and Gayle, Colburn H. 1967. ULV aerial insecticide applica- on for adult mosquito control in Kentucky. Mosq. News 27 (4): 478-482.

Mount, G. A., and Lofgren, C. S. 1967. Ultra-Low Volume and conventional :rial sprays for control of adult salt-marsh mosquitoes, Aedes sollicitans /alker) and Aedes taeniorhynchus (Wiedemann) in Florida. Mosq. News 27 (4): '3-477.

Mount, G. A., Lofgren, C. S., Pierce, N. W., and Husman, C. N. 1968. tra-Low Volume nonthermal aerosols of malathion and naled for adult mosquito ›ntrol. Mosq. News 28 (1): 99-103.

Stevens, Lewis F., and Stroud, Richard F. 1966. Control of mosquito adults ıd larvae with Ultra-Low Volume aerial applications of Baytex and Baytex-Baygon xture. Mosq. News 26 (2): 124-128.

1969 Stains, G. S., E. M. Fussell, and J. P. Keathley
Caged Insect Kills Of Up To Two Miles Utilizing A New Low-Volume Aerosol Generator
Mosquito News 29: 535-544 (Amvac Ref. #1362)

one-cubic-foot cage, and the females feed avidly on guinea pigs. The eggs hatch after 5 days, larvae begin to pupate in 5 days, and adults emerge in 2 days. Since adult females escape through the normal screen used in cages (18 x 16 mesh), it is very important to use a much smaller mesh screen. Pupae are unusual because they turn very black shortly after pupation.

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Literature Cited

ABOUALY, A., and HORSFALL, W. R. 1968. Bionomics of *Psorophora varipes*, a model laboratory mosquito. J. Econ. Entomol 61(6):1657–1660.

HAIR, J. A. 1968. Observations on two species of *Culex* of the subgenus *Melanoconion*. Mosq. News 28(3):425–429.

TREMBLEY, H. L. 1955. Mosquito culture techniques and experimental procedures. Am. Mosq. Control Assoc. Bull. No. 3, 73 pp.

WALLIS, R. C., and WHITMAN, L. 1968. Colonization of *Culex salinarius* in the laboratory. Mosq. News 28(3):366–368.

CAGED INSECT KILLS OF UP TO TWO MILES UTILIZING A NEW LOW-VOLUME AEROSOL GENERATOR[1]

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INTRODUCTION

The method of dispensing high volume low concentrate insecticides which has been the general practice for many years has been to a large extent very limited in its effectiveness. This is because the relatively large size droplets produced would remain air borne for short distances and thus result in a few hundred feet of effective control. Additionally, the equipment generally was heavy, bulky and required large insecticide reservoirs. In some cases, the weight of the dispersal apparatus plus the insecticide amounted to several thousand pounds and could only be transported by special vehicles on well established roads. Permanent mounting of the equipment often limited the transport vehicle for that use only. The new concept in insect control today is the technique involving ultra low volume dispersal of high concentrate insecticides, thereby avoiding the necessity of using heavy, bulky equipment with a large insecticide reservoir.

The need for a compact, light weight apparatus which could be handled by two men and operated from a jeep over rough terrain in combat zones was a prime factor which prompted the development of the ultra low volume aerosol generator.

Several new techniques and procedures in determining droplet size and distribution have been reported recently by other researchers. One such method is the fluorescent particle (FP) spray tracer technique which gives a quantitative measure of spray deposition by suspending a known number of FP's in a known volume of insecticide (Vaughan *et al.*, 1965;

[1] The opinions and assertions contained herein are those of the authors and are not to be construed as official or reflecting the views of the Navy Department or the Naval Service at large.

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Himel, 1969a). Sampling of airborne spray droplets is possible by means of Rotorod impaction type samplers. Determination of droplet size and number is subsequently made by counting the FP's impinged on the rods' collecting arms. This method also makes it possible to identify pesticide droplets by size and number directly on target insects, foliage or other solid substrates.

The importance of spray droplet size and number for insect control was demonstrated by Himel and Moore (1967). Using the FP tracer method they applied an insecticide to a tract of conifer forest for the control of spruce budworm larvae. Examination of 1113 larvae affected by the spray revealed that 93 percent had not been contacted by any droplets larger than 50 microns in diameter. Himel (1969b) stated that the optimum size for insecticide spray droplets is that size which gives maximum control of the target insect with minimum insecticide and minimum ecosystem contamination. Data from tests reported by Himel and Moore (1969) show that the maximum size for efficient insecticide spray droplets is under 50 microns in diameter. Droplets in the range of 50–100 microns are only marginal in efficiency while those larger than 100 microns have a low probability of contacting the target insects (Himel, 1969b).

Tests to determine the influence of air velocity and particle size on the toxicity of DDT to adult mosquitoes were conducted by Latta *et al.* (1947). Analysis of these results indicates the median lethal dose for female mosquitoes is that amount contained in a single droplet of 10 percent DDT 83 microns in diameter, or a droplet of 100 percent DDT 34 microns in diameter. This is equivalent to 0.03 microgram of DDT.

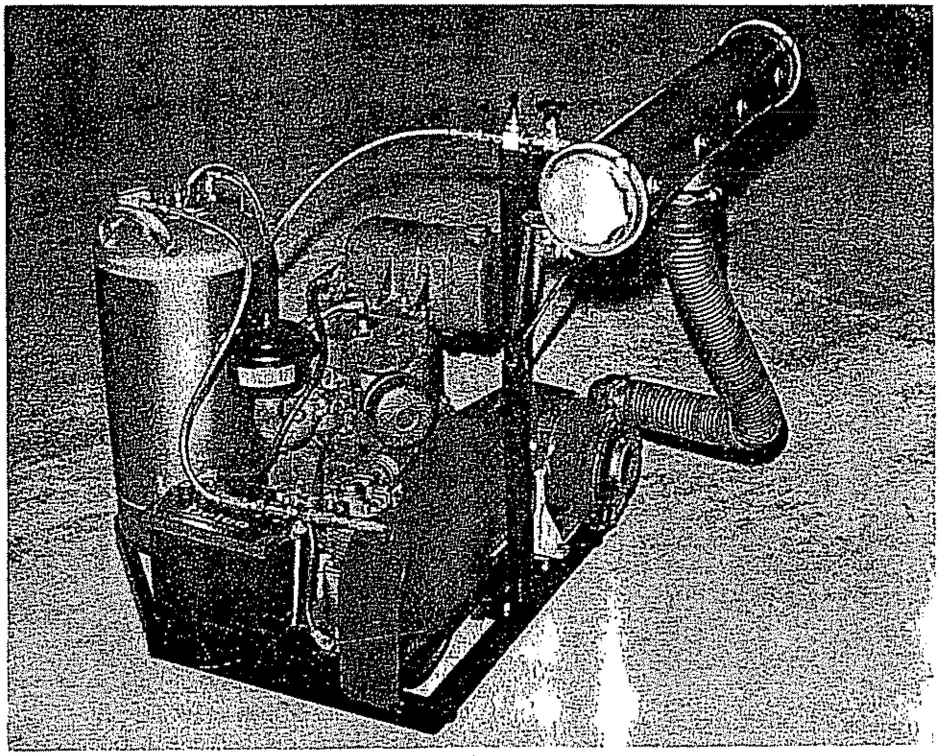

FIG. 1.—Close-up of aerosol generator.

MATERIALS AND METHODS

AEROSOL GENERATOR. This aerosol generator was specifically designed and developed to disperse ultra low volume-high concentrate chemicals. It is powered by a 14-horsepower gasoline engine. Insecticide is drawn from a ten-gallon stainless steel reservoir constantly pressurized at 50–60 psi by a 750 r.p.m. compressor type pump. Droplet breakup occurs in four air-liquid double vortical type nozzles located in the manifold. Air required by the nozzles is produced by a high capacity blower having an output of 500 cfm of air at 4 psi. All parts of the system coming in contact with insecticide are constructed of either stainless steel or teflon to prevent corrosive effects of concentrate pesticides. Net weight of the generator is 350 pounds; light enough for easy handling by two men. The unit is compact (Fig. 1) and can be operated from a vehicle as small as a military type jeep (Fig. 2).

FIELD BIO-ASSESSMENT. All test specimens were from laboratory reared non-resistant colonies. Mosquito species used in the tests were *Culex pipiens* Say and *C. tarsalis* Coquillett. The flies were *Musca domestica* Linnaeus. An arbitrary number ranging from 20 to 50 unsexed adults was transferred to individual cages and transported to the field. The cages were distributed along the test line and suspended 3 feet from the ground on stakes. Control cages were stationed 1 mile upwind from the test site.

Cages utilized in the test were constructed of 16 x 18 mesh screen wire and were 2⅝ inches in diameter by 7 inches long. Cage ends were made from two-piece fruit jar tops in which the lid portion had been replaced by a screen disk. The cages were discarded after each test.

FIG. 2.—Aerosol generator operating from a military jeep.

TEST SITE. The tests were conducted at Skaggs Island, a military reservation in Sonoma County, California. The reservation covers an area of approximately six square miles and has flat terrain of recently harvested grain which was well suited for purposes of these studies. Test lines were laid out in a north-south pattern to take advantage of prevailing winds. The insecticide aerosol was dispersed upwind of the test line and was carried to the caged insects and sampling devices by the wind currents.

In test No. 1 the test line was limited to 5500 feet. Concentrated Dibrom-14 was applied at the rate of 33 ounces per minute for 6 minutes traveling at 440 feet per minute and covering a distance of one-half mile. A 7–8 m.p.h. wind carried the droplets downwind where the specimens and samplers were located. The test line was extended to 10.500 feet in test No. 2. In the latter test Dursban (6) was utilized and was dispersed at a rate of 37.2 ounces per minute. The distance traveled and vehicle speed were the same as in test No. 1. The wind velocity was 6–7 m.p.h., temperatures varied from 70°–80° F.

The insects and sampling devices were collected about 30 minutes after exposure. The specimens were then observed and mortality recorded hourly for a designated number of hours thereafter. Percentage mortality was computed and employed in assessing insecticide effectiveness.

TRACER TECHNIQUE. The fluorescent particle (FP)—spray tracing technique was used to measure quantitatively the size distribution and number of droplets in the aerosol cloud at each downwind site at which a bioassay was made. The FP are insoluble, micron-sized crystals which fluoresce brightly when illuminated by ultra-violet light and viewed through a low-power microscope. The FP are readily distinguishable from almost all naturally occurring particulates. The earliest application of the FP technique dates back to the late 1940's where the FP were employed as gaseous tracers in air pollution studies. (Leighton *et al.* 1965).

In 1965, Vaughan *et al.* applied the FP technique to tracing insecticide droplets. The particulate tracer has many advantages over the soluble dyes. The insoluble particles are not absorbed by the time quantitative assessment is performed. The FP is stable in sunlight and in corrosive insecticide liquids. But most important, the FP-spray technique permits the quantitative assessment of both droplet size distributions and total sample mass for droplets with MMD to less than 10 microns and total mass sampled to less than 10^{-9} grams. Furthermore, airborne concentration and dosage can be quantitatively sampled and assessed.

The essence of this FP-spray tracing technique is to add a known number of FP to the liquid in the spray tank. The number of FP are then distributed throughout the volume of liquid such that each sub-volume of liquid contains its own representative number of FP. This proportionality between number of FP and volume is maintained when the liquid is sprayed. Thus each droplet, depending on its volume, has its proportional number of FP. On a sampling surface, the presence of the droplet is detected by the presence of the FP, and the number of FP associated with that droplet determines its size. Also, the total number of FP on a sampling surface determines the total volume of insecticide present without having to sum the volume contributed by each droplet on the surface.

For these two tests, an FP concentration of 2×10^{9} FP per ml. was used. This concentration yields, on the average, 1 FP in a 10 micron droplet, 8 FP in a 20 micron droplet and 1 FP in one of eight 5 micron droplets. The basic statistical methodology for interpreting the droplet size characteristics when small numbers of FP are present was developed by Vaughan *et al.* In order to maintain uniform concentration of FP throughout the test, the liquid in the spray tank must be agitated. Except for the agitation of the spray tank, the operation of the aerosol generator with the FP is the same as operation without.

The insecticide once aerosolized is carried by the atmospheric movements. A portion of the droplets deposits on the ground and on the foliage, a portion is diffused upward and the bulk of the cloud is carried horizontally downwind. The amount of insecticide deposited is measured directly from the FP counts on fallout plates and foliage. The combined amounts deposited and diffused upward are measured indirectly by observing the reduced amounts of insecticide remaining airborne at subsequent downwind aerosol sampling stations.

The aerosol cloud is sampled by the Rotorod, a small, dry-cell battery powered, rotating rod impactor sampler. The principle of the Rotorod is to drive the collection surface through the air rather than draw an air jet past the impaction surface. The Rotorod is an isokinetic sampler and thus insensitive to problems associated with changes in wind speed and directions. The sampling efficiency of the Rotorod has been calibrated for the size range of droplets encountered in these tests, and this efficiency is nearly constant throughout that range. Therefore, the aerosol samples collected with the Rotorod are representative of both the droplet size distribution and total mass in the ambient cloud.

RESULTS

GENERATOR OUTPUT. Aerosol droplets produced by the generator were very small and had a high degree of uniformity. Utilizing the FP spray tracer technique, it was determined that Dibrom and Dursban had a MMD of 10.4 and 10.9 microns respectively. The mean diameter of all droplets was 7.4 microns for Dibrom, and 8.6 microns for Dursban.

Generator output is specified in terms of ounces dispersed per minute of running time while traveling at a speed of 440 feet per minute (5 m.p.h.). Ounces per acre is an inaccurate designation since no method is known for describing or measuring precisely how many acres were covered by the aerosol cloud. The reason for this is that 100 percent kill of test specimens was observed to the end of the test line and obviously the aerosol remained airborne beyond this point.

TABLE 1.—Percentage mortality to adult *Culex tarsalis*.[a]
Dibrom

Distance (feet)	Hours Following Dispersal				
	2	4	7	10	21
500	100	..	..	..	..
1000	100	..	..	..	..
1500	20	47	73	73	83
2000	100		.	.	..
2500	100	.	..	..	..
2750	92	92	100	..	..
3000	100		..	..	..
3250	100	..	..	..	..
3500	91	91	91	91	100
3750	100		..		..
4000	100	..	.	..	..
4250	88	100	..		..
4500	88	100	..	..	..
4750	91	100	.	.	..
5000	100	..	..	..	..
5250	63	88	88	100	..
5500	40	60	100	..	..
% Cumulative	76	89	95	95	97
Controls	0	0	0	0	0

[a] Dibrom (14) dispersed perpendicular to a 7–8 m.p.h. wind at the rate of 33 oz/min with the Low Volume Aerosol Generator on 24 September 1968.

BIOASSAY. In test No. 1, 100 percent mortality was achieved on *Culex tarsalis* adults at a distance of 5500 feet (Table 1). Two hours following application the percent cumulative mortality was 76 percent, and 95 percent after 7 hours. The only mosquitoes remaining alive after 21 hours were those at the 1500 foot station where, for some unknown reason, 83 percent kill was achieved. This same unexplained phenomenon was noted for the house flies (Table 2), and also for test No. 2 results listed on Tables 3 and 4. In Table 5 it can be seen that a decreased amount of fluorescent material was collected indicating the presence of a reduced amount of insecticide. It is presumed that micrometeorological conditions were responsible for these results since no particular topographical difference was noted between this and other sites along the test line.

Table 2 shows the percent kill of adult house flies. Comparative examination reveals that the percent cumulative mortality closely parallels results listed in Table 1. After 7 hours, 100 percent kill was observed at all stations except 1500 and 5000 feet. Again, micrometeorological conditions apparently prevented an even coverage of the entire test area.

In the second test, the line was extended to 10,500 feet. The results show complete mosquito mortality (Table 3) for the entire distance and a correspondingly high kill of house flies (Table 4). *Culex pipiens* adults showed a 60 percent cumulative mortality after 2 hours and 97 percent after 8 hours. All of the mosquitoes exposed to Dursban were dead after 21 hours. House fly adults showed slightly higher tolerance to the insecticide than did mosquitoes (Table 4). It should be noted, however, in comparing the two tables, that a larger percent of house flies were killed in the first 2 hours than mosquitoes. Five percent of the total house fly test population remained alive 33 hours following exposure.

Control specimens showed no mortality for the duration of the observations except for house flies on test No. 2 which had a 4 percent mortality after 21 hours.

TABLE 2.—Percentage mortality to adult *Musca domestica* [a]
Dibrom

Distance (feet)	Hours Following Dispersal				
	2	4	7	10	21
250	100	..	..	..	
500	100	..	..	..	..
750	94	100	..	..	..
1000	100	..	..	..	..
1500	21	35	35	74	74
2000	100	..	..	..	..
2500	100	..	..	..	..
2750	100	..	..	..	..
3000	94	97	100	..	..
3250	75	100	..	..	..
3500	100	..	..	..	..
3750	81	89	100	..	..
4000	86	86	100	..	..
4250	100	..	..	..	..
4500	100	..	..	..	..
4750	83	89	100	..	..
5000	40	67	92	92	92
5250	32	74	100	..	..
5500	53	69	69	100	..
% Cumulative	78	87	94	98	98
Controls	0	0	0	0	0

[a] Dibrom (14) dispersed perpendicular to a 7–8 m.p.h. wind at the rate of 33 oz/min with the Low Volume Aerosol Generator on 24 September 1968.

TABLE 3.—Percentage mortality to adult *Culex pipiens* [a]
Dursban

Distance (feet)	Hours Following Dispersal				
	2	4	8	11	21
1000	67	100	..	..	..
1500	69	92	100		..
2000	83	100	.	.	..
2500	86	100	..	.	..
2750	79	100		.	..
3000	80	100	.	.	..
3250	79	100	..	..	..
3500	54	93	100		.
3750	100	..	..	..	..
4000	61	100	..	.	..
4250	44	89	89	100	..
4500	62	91	100	.	..
4750	47	82	100	..	..
5000	44	83	94	100	..
5250	46	93	96	96	100
5500	75	100	.	.	..
8000	39	86	92	97	100
11[illegible]0	43	57	71	93	100
% Cumulative	60	92	97	99	100
Controls	0	0	0	0	0

[a] Dursban (6) dispersed perpendicular to a 6–7 m.p.h. wind at the rate of 37.2 oz/min with the Low Volume Aerosol Generator on 27 September 1968.

TABLE 4.—Percentage mortality to adult *Musca domestica* [a]
Dursban

Distance (feet)	Hours Following Dispersal				
	2	4	8	11	21
1000	100	..	..	..	..
1500	86	91	100	..	..
2000	100	..	..	..	..
2500	100	..	..	..	..
2750	100	..	..	..	..
3000	94	100	..	..	..
3250	90	100	..	..	..
3500	61	89	100	..	..
3750	95	95	95	100	..
4000	77	100	..	..	..
4250	60	88	94	94	100
4500	47	84	95	95	100
4750	55	85	95	95	95
5000	60	95	95	95	100
5250	37	53	68	68	74
5500	0	38	56	75	75
8000	50	75	90	95	95
1[illegible]500	45	65	70	70	70
% Cumulative	70	87	93	94	95
Controls	0	0	0	0	4

[a] Dursban (6) dispersed perpendicular to a 6–7 m.p.h. wind at the rate of 37.2 oz/min with the Low Volume Aerosol Generator on 27 September 1968.

FP TRACER RESULTS. At selected downwind sites where caged insects were placed, the aerosol clouds and the ground deposition densities were sampled to determine the degree of exposure to which the insects were subjected. Exposures to the aerosol cloud can be expressed as the number of droplets passing through an "imaginary window" one square inch in size (Table 5). The number of droplets, as determined by the rotating rod samplers, ranged from 15,000 to 125,000. If the "imaginary window" were enlarged to the dimensions of the cage the number of droplets would range from 330,000 to 2,430,000. Ground deposition of Dibrom

TABLE 5.—FP and mortality results of the Dibrom and Dursban Tests [a]

Distance (feet)	Airborne Droplets (thousands): Dibrom Test 1, per in^2	Dibrom Test 1, per cage	Dursban Test 2, per in^2	Dursban Test 2, per cage	Percent Mortality (21 hours): Mosquitoes Test 1	Mosquitoes Test 2	House Flies Test 1	House Flies Test 2	Ground Dibrom Deposit [b] ml/acre
500	120	2430	..		100	..	100	..	0.230
1000	60	1230	70	1420	100	100	100	100	0.120
1500	40	790	70	1420	83	100	74	100	0.050
2000	70	1430	95	1955	100	100	100	100	0.160
2500	50	985	125	2480	100	100	100	100	0.085
3000	35	740	95	1955	100	100	100	100	0.075
3500	45	895	75	1565	100	100	100	100	0.045
4000	35	690	90	1790	100	100	100	100	0.055
4500	50	985	45	905	100	100	100	100	0.090
5000	40	790	95	1955	100	100	92	100	0.085
5500	15	330	70	1420	100	100	100	75	0.055
8000	..	..	50	1220	..	100	..	95	.....
10500	..	..	65	1305	..	100	..	70	.....

[a] Test 1 included distances from 500 to 5500 feet; test 2 from 1000 to 10500 feet.
[b] Only Dibrom deposit recorded.

TABLE 6.—Measured Droplet Size Distributions Resulting from the Low Volume Aerosol Generator.

Droplet Size Distribution for Test 1, Dibrom

Diameter μ	Number %	Number Cumulative %	Number %	Number Cumulative %
<5	12.5	12.5	1.4	1.4
5–10	68.5	81.0	44.1	45.5
10–15	17.0	98.0	40.5	86.0
15–20	1.8	99.8	11.3	97.3
>20	0.2	100.0	2.7	100.0

Droplet Size Distributions for Test 2, Dursban

Diameter μ	Number %	Number Cumulative %	Mass %	Mass Cumulative %
<5	2.7	2.7	0.3	0.3
5–10	67.3	70.0	37.7	38.0
10–15	27.5	97.5	48.8	86.8
15–20	2.4	99.9	11.6	98.4
>20	0.1	100.0	1.6	100.0

was measured at between 0.045 and 0.23 milliliters per acre and represents a loss of less than one percent of the aerosol cloud during the first mile. This low ground and foliage deposition is in agreement with relatively slight decreases in the numbers of droplets measured at increasing downwind distances as given in Table 5, i.e., both the upward diffusion and the deposition are depleting the near ground level aerosol cloud at a low rate at these tests.

Droplet size distribution is given in Table 6. The percentage of droplets less than 15 microns in diameter was 98 percent for Dibrom and 97.5 percent for Dursban.

Table 7 shows the number of droplets

TABLE 7.—Number of Droplets per Milliliter.

Diameter (microns)	Droplets
1,000	1,910
100	1,910,000
50	15,278,100
10	1,910,000,000
6	8,849,557,500

per milliliter of liquid spray at specific micron diameter sizes. A tenfold decrease in droplet diameter yields a thousandfold increase in the number of droplets produced. The laws of probability reveal the greater likelihood for droplets contacting the target insect when a given quantity of insecticide spray is dispersed in small droplets as opposed to larger droplet sizes. Also, since the influence of gravity would be reduced, the smaller droplets could normally be expected to travel greater distances horizontally. A meaningful comparison of insect mortality and aerosol cloud density was not possible since threshold exposures were observed at too few stations. One hundred percent mortality occurred at most sampling sites.

SUMMARY

A new ultra low volume aerosol generator ground dispersal unit has been evaluated in the field and found highly effective in producing high mortality of caged mosquitoes and flies. Low volumes of high concentrate Dibrom and Dursban were dispersed in 10-micron MMD size droplets through four double air-liquid vortical type nozzles. These droplets were carried downwind to sites various distances up to 10,500 feet from the aerosol generator where they contacted caged adult mosquitoes and house flies. Up to 100 percent kill was obtained two miles from the point of insecticide release. The rate of flow for each insecticide was calibrated in ounces per minute with the generator traveling at 440 feet per minute (5 m.p.h.).

A modification of the fluorescent particle (FP) tracer technique was used in these studies. This method consisted of suspending a known concentration of FP in the concentrate insecticide and analyzing the airborne aerosol cloud with specialized rotating rod sampling devices. The number of FP's in each impact pattern is a measure of the original droplet volume. Hence, the total mass, size and distribution of aerosol droplets can be determined. The sensitivity and ease of assessment attainable by this technique made it particularly useful in field testing of insecticide dispersal equipment and in determining the effectiveness of dispersal operations.

CONCLUSIONS

Based on observations and an analysis of data obtained from the evaluation of the ultra low volume aerosol generator, it is concluded that:

(1) The generator will produce effective kills of caged house flies and mosquitoes up to 2 miles as compared to similar tests in which thermal and non-thermal fogging devices generally do not produce effective kills beyond 600 feet.

(2) The unusually long range kill produced by the generator is due primarily to the production of comparatively small sized droplets of about 10 microns MMD.

(3) The FP tracer technique is an excellent adjunct to bioassay in determining

droplet size and distribution, and in the evaluation of insecticidal effectiveness.

(4) The dispersal of ultra low volume insecticides from ground control equipment, especially in the small micron size of about 10 MMD, offers a possible means of controlling adult mosquitoes and house flies over much greater distances than heretofore thought possible.

References

HIMEL, CHESTER M. 1969a. The fluorescent particle spray droplet tracer method. J. Econ Entomol. 62: (in print)

HIMEL, CHESTER M. 1969b. The optimum size for insecticide spray droplets. J. Econ. Entomol. 62: (in print)

HIMEL, CHESTER M., and MOORE, ARTHUR D. 1967. Budworm mortality as a function of aerial spray droplet size. Science 156 (3779).

HIMEL, CHESTER M., and MOORE, ARTHUR D. 1969. Spray droplet size in the control of forest and cotton insect, spruce budworm, boll weevil, bollworm, and cabbage looper. J. Econ. Entomol. 62: (in print)

LATTA, R., ANDERSON, L. D., ROGERS, E. E., LAMER, V. K., HOCHBERG, S., LAUTERBACH, H. and JOHNSON, I. 1947. The effect of particle size and velocity of movement of aerosols in a wind tunnel on the mortality of mosquitoes. J. Washington Acad. Sci. 37 (11):397–407.

LEIGHTON, P. W., PERKINS, W. A., GRINNELL, S. W., and WEBSTER, F. S. 1965. The fluorescent particle atmospheric tracer. Journal of Applied Meteorology, Vol. 4, No. 3 pp. 334–348.

MOUNT, G. A., LOFGREN, C. S., PIERCE, N. W. and HUSMAN, C. N. 1968. Ultra-low-volume nonthermal aerosols of malathion and naled for adult mosquito control. Mosquito News 28(1): 99–103.

VAUGHAN, L. M., MAGILL, P. L. and MCMULLEN R. S. 1965. Application of fluorescent particle tracer technique to forest spray research. Metronics Associates, Inc., Palo Alto, California. Memorandum Report No. 278–1.

IMPORTANT NOTE

Beginning with Volume 30, No. 1, the price of reprints will be increased by 6 percent to correspond with the rise in costs of paper, handling, printing and mailing. The last increase in reprint prices was effective with the March, 1966 issue. Since that time both dues and subscriptions have been increased, but the additional cost of processing the reprints has not been met.

A revised "Prices of *Mosquito News* Reprints" will be published on the inside back cover of the March 1970 *Mosquito News*.

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ADULT MOSQUITO CONTROL WITH ULV GROUND EQUIPMENT

ROBERT BERRY, STANLEY JOSEPH, E. ELWOOD LYNCH, *Maryland State Board of Agriculture Mosquito Control Projects, Salisbury, Maryland*

For the past four years personnel of the Maryland Mosquito Control Program have been working to develop an effective and economical means of dispensing ULV dosages of insecticides from ground equipment for the control of adult mosquitoes. The advantages to our program would be threefold: first, time-consuming stops for water now necessary with mist blower operation would be eliminated; second, a smaller and more mobile unit would be less expensive to operate, and third, a remote control sprayer operation would require only one operator as compared to the two men now required for mist blowers.

Preliminary observations were made in 1965-66 with a John Bean Rotomist 100E modified to dispense undiluted insecticide concentrates. These tests utilized naled 14 and 95% malathion LVC at dosage rates of ½ to 1 fluid ounces per acre and were encouraging enough to persuade

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us to continue our search for a smaller unit. In 1967 a small, lightweight, pickup-truck-mounted unit known as the Ag King Cannon was field-tested using the same two insecticides at 1-2 fluid ounces per acre.

In the summer of 1968 a cold-fog attachment mounted on a Leco 120 thermal fogger was modified with commercially available oil burner nozzles, to dispense liquid insecticides in the ULV range. By varying nozzles and formulation pressure, output could be varied from .33 to 2 gallons per hour. The results obtained with this unit form the basis for this study.

Methods and Materials

Two insecticides were tested, naled 14 lbs./gallon and malathion 9.7. lbs./gallon, both applied as undiluted concentrates. Naled was applied at rates of .35 to 1.17 fluid ounces per acre, the amount of actual toxicant ranging from .038 to .13 lbs./acre. With malathion the range was .92 to 2.01 fluid ounces per acre with an actual toxicant range of .07 to .15 lbs./acre.

Culex pipiens adult females were used as the test mosquito, being reared from field collections of 4th instar larvae and pupae. Screen wire cages containing the adults were attached to stakes 4 feet above ground, at distances of 50, 100 and 200 feet perpendicular to the line of travel of the spraying unit. All spraying was performed downwind in open fields at a truck speed of 5 mph. Mortality counts were made at 1-, 2-, 4-, and 8-hour intervals. Tests were run in the daytime.

The unit used to perform these tests was a Leco 120 fogger modified with a cold-fog attachment. By inserting specified oil burner nozzles into the insecticide line just back of the discharge head the liquid flow was restricted into the range of ULV dosages. This restrictive device was simply a standard furnace nozzle adapter placed in the line for holding the selected size nozzle. The entire unit was mounted within a ¾-inch pipe union. The only tools necessary to change nozzles were a pipe wrench and standard socket wrench. Nozzle cores were removed to allow for free flow of the insecticide, but the regular strainer screens remained in place.

Nozzle output was calibrated by measuring the volume of liquid discharged in a specified time period. Formulation pressure was adjusted between 9 and 20 psi to aid in obtaining the desired amount of insecticide. A flow meter used in cold fogging operations was not accurate enough to measure the dosages used, but did serve as a visual aid to the operator that insecticide was flowing to the discharge head. The engine was set to run at 3000 rpm.

Attempts to measure droplet size were tried by various methods. The one which was preferred consisted of microscope slides coated in a silicone solution (G.E. SC-87 Dri Film) and glazed with the smoke of burning magnesium. These were placed flat on the ground near the stakes holding the test mosquitoes. In comparison, slides mounted vertically did not have as many particles impinged on the surface. Preliminary droplet size determinations were made utilizing the #1.5 and #4.0 oil burner nozzles adjusted to deliver .92 and 2.01 ounces of 95% malathion LVC per acre. Particle size and number counts were made by reading 10 cross sections of slide field, each section being 25 mm x 1½ mm or 3/5 of a square inch total.

When using the #4 nozzle it was found that at the 50-, 100- and 200-foot distances respectively that 60, 80, and 72 percent of the particles were under 50 microns. With the #1.5 nozzle the figures were 73, 89, and 86 percent at the same distances. All particles were below 100 microns at the 100- and 200-foot marks irrespective of nozzle size. At 50 feet 94 and 96 percent were below 100 microns for the #1.5 and #4 nozzles respectively. These figures indicate that the larger particles fall out most rapidly. The range of particle size was considered to be quite satisfactory.

When the number of particles is figured for each distance and nozzle type the following is found. The #1.5 produced 130, 32 and 24 particles per square inch at 50, 100, and 200 feet in that order. The #4 revealed 205, 20 and 19 particles per square inch at the same distances. It should be emphasized that these are preliminary results and were made using only malathion.

Results

Naled at .7 fluid ounce per acre gave 100% mortality of all test mosquitoes in one hour at 50 and 100 feet and within two hours at 200 feet. At a dosage of 1 ounce to the acre all adult mosquitoes in 6 separate tests were killed within 1 hour with the exception of one cage at the 200-foot distance which required 2 hours for 100% kill. Table 1 reveals that in 30 test cages at all dosage levels tested, only two cages had any surviving adult mosquitoes.

Malathion at 2 fluid ounces per acre produced 100% test mosquito mortality back to 200 feet in 4 tests at this dosage. This dosage rate was slower than 1 ounce of naled, requiring 1-2 hours for complete knockdown at 50 feet, 2-4 hours at 100 feet and 4 hours at 200 feet. Good results were also obtained with .9 fluid ounce/acre, 100% kill being recorded at 50 feet in all cages in 4 hours and 3 of 4 cages in 8 hours at the 100- and 200-foot levels. Erratic results in two tests at 1.25 fluid ounces/acre is attributed to shifting winds at the time of testing. A dosage

Results of tests with LECO 120 with ULV attachment

Insecticide	Date treated	Toxicant Fl. oz./acre	Toxicant Lb./acre	Percent mortality — *Culex pipiens*											
				50 feet				100 feet				200 feet			
				Hours				Hours				Hours			
				1	2	4	8	1	2	4	8	1	2	4	8
Naled 14	10-2-68	.35	.038	94	100	—	—	69	100	—	—	9	55	55	—
	10-2-68	.35	.038	33	97	100	—	8	68	96	—	8	94	100	—
	9-18-68	.68	.073	100	—	—	—	100	—	—	—	77	100	—	—
	9-18-68	.68	.073	100	—	—	—	100	—	—	—	91	100	—	—
	9-18-68	1.05	.114	100	—	—	—	100	—	—	—	88	100	—	—
	9-18-68	1.05	.114	100	—	—	—	100	—	—	—	100	—	—	—
	10-2-68	1.07	.116	100	—	—	—	100	—	—	—	100	—	—	—
	10-2-68	1.07	.116	100	—	—	—	100	—	—	—	100	—	—	—
	9-18-68	1.17	.127	100	—	—	—	100	—	—	—	100	—	—	—
	9-19-68	1.17	.127	100	—	—	—	100	—	—	—	100	—	—	—
Malathion 95% LVC	9-17-68	.92	.069	29	98	100	—	0	0	10	35	4	4	58	100
	9-17-68	.92	.069	41	100	—	—	0	52	100	—	0	0	21	53
	9-26-68	.92	.069	55	94	100	—	17	57	90	100	10	20	60	100
	9-26-68	.92	.069	100	—	—	—	90	100	—	—	0	38	75	100
	9-17-68	1.25	.094	6	6	94	100	0	0	0	0	1	1	1	1
	9-17-68	1.25	.094	0	0	12	14	0	0	0	0	0	0	6	6
	9-17-68	1.42	.106	60	100	—	—	3	61	100	—	0	0	28	67
	9-17-68	1.42	.106	3	7	97	100	0	0	27	84	4	8	71	71
	9-19-68	1.42	.106	100	—	—	—	100	—	—	—	0	3	27	89
	9-19-68	1.42	.106	100	—	—	—	64	100	—	—	0	18	45	91
	9-19-68	1.64	.124	84	100	—	—	6	100	—	—	0	25	100	—
	9-19-68	1.64	.124	73	100	—	—	9	100	—	—	0	32	79	100
	9-19-68	2.01	.151	94	100	—	—	32	89	100	—	14	60	100	—
	9-19-68	2.01	.151	43	100	—	—	55	100	—	—	13	74	100	—
	9-26-68	2.01	.151	100	—	—	—	7	100	—	—	87	100	—	—
	9-26-68	2.01	.151	100	—	—	—	0	100	—	—	0	45	100	—

rate of 1.4 ounces per acre produced excellent kill up to 100 feet, but failed to kill all of the test mosquitoes in any cage at 200 feet. A rate of 1.6 ounces per acre showed 100% kill in all cages at 50 and 100 feet after 2 hours and after 8 hours at 200 feet.

Summary

Naled 14 at 1 ounce or 95% malathion LVC at 2 ounces per acre will produce excellent adult mosquito control up to 200 feet downwind from the spray unit. This swath depth may be much deeper according to wind conditions, but was not actually tried. These results were obtained with daytime trials, a distinct advantage over thermal fogging from the point of length of daily operation. Spraying must be done downwind.

The unit proved to be rugged and dependable throughout the field trials and with some modifications could be field tested in a regular mosquito control program. This is currently under consideration. Particle size wns considered to be very satisfactory from the limited studies made.

PRESIDENT THORN: Thank you, Mr. Berry. Since we are running late, we will hold over the last paper on the program this morning for our next session at 1:45 p.m. Thank you.

Adjournment

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1350

blood-sucking arthropods collected from the Malaise traps. Included have been numerous *Tabanus* spp. and *Chrysops* spp., the horn fly, *Haematobia irritans*, and the stable fly, *Stomoxys calcitrans*.

PLANNED FUTURE ACTIVITIES. Once the mosquito population reaches a level such that the test cattle appear to be irritated, insecticidal control measures will be put into effect. This will consist of spray applied to part of the cattle and part of the test area according to a preplanned pattern. At this time, counts will be made of mosquitoes on the test cattle. Numbers of other blood-sucking arthropods on the cattle will also be recorded. The presently employed insect population measurement techniques will be continued throughout the study.

Present wildlife studies will continue and new ones will be incorporated as need may dictate.

Water management by means of ditching to facilitate water movement is planned. This portion of the overall program will be carried out on additional pasture areas located adjacent to an inland bay. Observations will be made on the effectiveness of the drainage program in reducing mosquito populations, possible vegetative species alteration, and possible change in the chemical and physical properties of the soil.

We hope that the result of all of these activities will be an economically feasible means of mosquito management of the salt marsh to the advantage of beef cattle production.

TESTS OF THE SUSCEPTIBILITY OF FLORIDA MOSQUITOES TO INSECTICIDES, 1967

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Although the more important pest mosquitoes in Florida over the years have been salt-marsh *Aedes* and *Psorophora*, the encephalitis epidemic of 1962 in the Tampa Bay area implicated *Culex nigripalpus* as another species of statewide importance (Chamberlain *et al.*, 1964). *Culex quinquefasciatus*, first incriminated in St. Louis in the 1930's, was also the vector in the recent encephalitis outbreaks in Houston and Dallas, Texas, during 1964 and 1966. These events, together with the recent research on arboviruses, have demonstrated an increased importance of these and many other mosquito species in Florida.

The value of obtaining reliable information on the current status of the effectiveness of various insecticides and that of determining the initial susceptibility or baseline of different mosquito species to certain insecticides is well recognized. The surveillance of mosquitoes in Florida to detect possible development of resistance was initiated in 1963 (Rogers and Rathburn, 1964). A recent study (Rathburn and Boike, 1967) demonstrated resistance of *Aedes taeniorhynchus* to malathion in certain areas of the state and also determined the level of susceptibility for several species of mosquitoes from many areas to several insecticides. This report deals with the further surveillance of Florida mosquitoes for areas of possible resistance and includes original baseline data for many additional species within the state.

METHODS. In general, methods of collecting and handling mosquitoes and testing procedures were as described by Rathburn and Boike (1967). Mosquitoes were collected in Bay County in western Florida; Marion, Polk, and Orange counties in central Florida; Levy and Duval counties in north central Florida; Volusia and Indian River counties on the east coast; and Lee County on the west coast. Adults were collected by means of CDC portable light traps supplemented with dry ice or chicks and chick-baited lard can traps. They were transported to the laboratory in styrofoam ice chests. Upon arrival at the laboratory, the mosquitoes were placed in 12- by 9- by 8-inch screened cages, supplied with a sugar solution and blood-fed on anesthetized chicks.

With minor modifications, larval tests were conducted according to procedures outlined by the World Health Organization (World Health Organization, 1960). Glass beakers of 600 ml. capacity were used as test vessels; however, during the latter part of the period 400 ml. polypropylene beakers were used. These were compared with glass beakers for any difference between test vessels. Comparative tests were performed between the two types of beakers using malathion and naled

TABLE 1.—Susceptibility of seven species of mosquitoes from various areas of Florida to malathion, 1966–67.

		Lethal concentrations in ppm					
		1966			1967		
County	Area	LC_{50}	LC_{90}	Reps.	LC_{50}	LC_{90}	Reps.
Aedes taeniorhynchus (Wied.)							
Lab. Colony		.025	.050	14	.030	.047	12
Bay	State Park	...	...	...	.028	.047	20
Levy	Cedar Key	...	...	...	.024	.054	14
Duval	Marsh area	...	...	...	.032	.049	16
Lee	Ft. Myers	...	...	...	.260	.700	2
	Sanibel Is.	.220	2.600	8	.086	.280	4
Aedes aegypti (L.)							
Lab. Colony—Savannah strain		...	...	...	.110	.172	16
Lab. Colony—Panama City strain		...	...	...	.120	.196	16
Aedes canadensis (Theo.)							
Bay	High Point	...	...	...	.020	.077	3*
Culex nigripalpus Theob.							
Lab. Colony		.045	.074	18	.030	.045	24
Bay	State Park	.038	.070	13	.041	.059	16
	Woodlawn Area	...	...	...	.029	.040	8
	Southport	...	...	...	.037	.052	12
Marion	Orange Springs	.034	.044	21	.022	.033	20
Polk	Bartow	.082	.110	3	...	...	...
	Lake Alfred	...	...	...	.049	.061	6
Lee	Ft. Myers	.054	.084	5	.048	.070	16
	Sanibel Is.	.050	.082	6	.043	.058	4
Volusia	New Smyrna Bch.	.044	.066	16	...	...	...
	Daytona Bch.	...	...	...	.034	.043	2
Indian River	Vero Beach	...	...	...	.033	.052	18
Orange	Orlando	...	...	...	.036	.066	26
Culex salinarius Coq.							
Bay	State Park	...	...	...	.045	.063	12
	Magnolia Bch.	...	...	...	.048	.067	4
	West Fla. Res. Lab.	...	...	...	.045	.061	4
Polk	Lake Alfred	...	...	...	.049	.061	6
Volusia	Daytona Bch.	...	...	...	.043	.060	4
Culex quinquefasciatus Say							
Lab. Colony		...	...	...	.046	.069	12
Culex restuans Theob.							
Bay	High Point	...	...	...	.036	.047	2

* Field collected larvae.

against four species of mosquito larvae. No significant difference was detected. Sixteen replications, each consisting of five insecticide dosages plus a check were planned for each species tested. However, owing to variations in the number of larvae available for testing, fewer replications were performed in some instances. The control mortality for all tests averaged less than one percent.

RESULTS. The results of tests with malathion are shown in Table 1. These tests indicate an increase in susceptibility in *Aedes taeniorhynchus* on Sanibel Island in 1967 as compared to 1966. The *Aedes taeniorhynchus* from Fort Myers tested in 1967 exhibit a reduction in susceptibility when compared to tests conducted in 1965 (Rathburn and Boike, *loc. cit.*). All other species tested from comparable areas within the state in 1967 show little change in susceptibility when compared to test results of 1966. After three years of laboratory colonization, *Aedes taeniorhynchus* has shown practically no change in its susceptibility to malathion; the LC_{50} in micrograms per milliliter for 1965, 1966, and 1967 being 0.029, 0.025 and 0.030 respectively. After two years of laboratory colonization, *Culex nigripalpus* likewise has shown little change. The data for *Culex nigripalpus* tested during 1967 from Fort Myers represent an average of adults taken from three areas in Fort Myers. The *Aedes aegypti* colony (Savannah strain) was begun from eggs received from the Public Health Service Laboratory in Savannah, Georgia, while the Panama City strain was established from larvae collected within the city.

Shown in Table 2 are the results of tests with naled. Although only limited comparable data have been obtained from areas within the state, there appears to be no resistance by any species to naled. A possible exception may be the *Aedes taeniorhynchus* from Mayport Naval Air Station in Duval County, where the LC_{50} appears somewhat high in relation to the laboratory colony. Further testing on mos-

TABLE 2.—Susceptibility of five species of mosquitoes from various areas of Florida to naled, 1966–67.

County	Area	Lethal concentrations in ppm					
		1966			1967		
		LC_{50}	LC_{90}	Reps.	LC_{50}	LC_{90}	Reps.
Aedes taeniorhynchus (Wied.)							
Lab. Colony		.103	.185	20	.087	124	18
Bay	State Park	...	...	...	.107	.145	20
Levy	Cedar Key	...	...		.087	.110	4
Duval	Marsh Area	...	...	...	.130	.180	4
	Mayport N.A.S.	...	...	...	.196	....*	4
Aedes aegypti (L.)							
Lab. Colony—Savannah strain		...	...		210	365	28
Lab. Colony—Panama City strain		...	...	...	.162	.240	20
Culex nigripalpus Theob.							
Lab. Colony		051	.067	12	.074	.091	12
Bay	Southport	...	...	...	.070	.096	12
Lee	Ft. Myers	...	...	...	.076	.095	12
Indian River	Vero Beach	...	...	...	.067	.080	12
Culex salinarius Coq.							
Bay	State Park	.060	.082	4	.074	.092	20
	Magnolia Bch.	...	...	...	.078	.092	3
	West Fla. Res. Lab.	...	...	...	.082	.097	8
Polk	Lake Alfred	...	...	...	.086	.120	2
Culex quinquefasciatus Say							
Lab. Colony		...	...	...	.084	.111	8

* Insufficient data to accurately determine LC_{90}.

quitoes from this area is planned. Comparable tests of laboratory colonies of *Aedes taeniorhynchus* and *Culex nigripalpus* for 1966 and 1967 reveal little change in susceptibility to naled. The colony *Culex nigripalpus* used in these tests originated from a wild population at Vero Beach. The data in Table 2 show that, although colonized for over two years, there is no difference in the susceptibility to naled between the original population (Vero Beach) and the laboratory colony.

Discussion. Although it did not encompass the entire state, these data and the comparable data obtained in 1965 and 1966 form a reasonable picture of the susceptibility of these species to insecticides. Except for the increase in susceptibility to malathion of the *Aedes taeniorhynchus* from Sanibel Island and the somewhat high LC_{50} of naled obtained with the *Aedes taeniorhynchus* from Mayport Naval Air Station, there was little variation between areas in the susceptibility to either malathion or naled.

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References Cited

Chamberlain, R. W., Sudia, W. D., Coleman, P. H., and Beadle, L. D. 1964. Vector studies in the St. Louis encephalitis epidemic, Tampa Bay area, 1962. Amer. J. Trop. Med. 13:456–461.

Rathburn, C. B., Jr., and Boike, A. H., Jr. 1967. Studies of insecticide resistance in Florida mosquitoes. Mosq. News 27(3):377–382.

Rogers, A. J. and Rathburn, C. B., Jr. 1964. Present status of insecticides for mosquito control in Florida. Mosq. News 24(3):286–291.

World Health Organization. 1960. Instructions for determining the susceptibility or resistance of mosquito larvae to insecticides. Reprinted from WHO: Technical Report Series, No. 191, 1960.

MOSQUITO CONTROL IN CAPE MAY COUNTY THROUGH WATER LEVEL STABILIZATION

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It has been some years since the concept of water management for mosquito control, which would at the same time serve many other community interests, became an established part of New Jersey county mosquito extermination commission programs. The Fishing Creek pump station and channel improvement project, just north of the town of Wildwood Villas on the Delaware Bay shore, represents one modern example in which a whole series of significant controlling circumstances were present, which in turn affected construction and operational schedules in the interest of mosquito control. This project is the first of its kind in tidewater New Jersey. It may well serve as an example for similar future undertakings.

The Cape May County Mosquito Extermination Commission conceived the project, was responsible for technical design of the beachfront pumping station, arranged for cooperative funding involv-

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1351

Dean, H. A. 1959. Seasonal distribution of mites on Texas grapefruit. J. Econ. Entomol. 52 (2): 228–32.
Dean, H. A., and J. C. Bailey. 1963. Control of Texas citrus mites with various spray oil fractions. J. Rio Grande Valley Hort. Soc. 17: 116–22.
1964. Certain post-bloom treatments for control of Texas citrus mites and their effect on chaff scale parasites. J. Rio Grande Valley Hort. Soc. 18: 29–32.
Dean, H. A., and C. E. Hoelscher. 1966. Indications of resistance of Texas citrus mites to tetradifon (Tedion). J. Rio Grande Valley Hort. Soc. 20: 55–9.
Riehl, L. A. 1961. A routine system for spray application manually to citrus. J. Rio Grande Valley Hort. Soc. 15: 3–9.
Riehl, L. A., J. P. La Due, and J. L. Rodriguez. 1965. Efficiency of a re-formed oil against citrus red mite eggs and California red scale. J. Econ. Entomol. 58 (5): 707–9.
Riehl, L. A., R. T. Wedding, and J. L. Rodriguez. 1956. Effect of oil spray application timing on juice quality, yield, and size of Valencia oranges in a southern California orchard. J. Econ. Entomol. 49 (3): 376–82.
Smith, E. E. 1953. Analysis of lubricating oils: Part I, Correlation of physical properties and structural composition of lubricating oils, p. 1–31. *In* Ohio State Univ. Eng. Exp. Sta. Bull. 152.
Stewart, W. S., L. A. Riehl, and L. C. Erickson. 1952. Effects on citrus of 2,4-D used as an amendment to oil sprays. J. Econ. Entomol. 45 (4): 658–68.

Studies on a Biological and a Chemical Method of Controlling the Dark Rice Field Mosquito in Louisiana[1]

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ABSTRACT

Field tests were conducted to develop a method useful for evaluating biological or chemical control, or both, of *Psorophora confinnis* (Lynch-Arribalzaga).

The top minnow, *Gambusia affinis* (Baird and Girard), stocked in flooded rice plots at ½ fish per square foot reduced the mosquito larvae population 96%. Fish were more effective in reducing the mosquito larvae in rice plots which received herbicide applications and in simulated pasture plots than in rice plots which received no chemical treatments. Averages of 87.4, 88.5, and 58.1% control, respectively, of larvae were obtained. The increased efficiency in control probably was a result of less decumbent vegetation in these plots.

Abate ® (*O,O*-dimethyl phosphorothioate *O,O*-diester with 4,4′-thiodiphenol), and fenthion at 0.5 lb per acre in combination with 3 lb per acre of propanil applied to rice plots 2 days before flooding gave 100 and 99% control, respectively, of *P. confinnis* larvae. These chemicals were not phytotoxic to the rice plant. Neither Abate nor fenthion residues were detected in the mature rice grain. Dursban® (*O,O*-diethyl *O*-3,5,6-trichloro-2-pyridyl phosphorothioate), diazinon, malathion, naled, Furadan® (2,3-dihydro-2,2-dimethyl-7-benzofuranyl methylcarbamate), and bromophos were phytotoxic to rice when used in cooperation with propanil at rates lower than necessary to obtain effective control of *P. confinnis* larvae.

The dark rice field mosquito, *Psorophora confinnis* (Lynch-Arribalzaga), breeds extensively in the rice-producing areas of Louisiana. Approximately 565,538 acres are in rice production in Louisiana (Rice Millers Association 1967) with twice that acreage in native pasture that is rotated with rice. This aggregate provides more than 1,695,000 acres of concentrated breeding grounds that have the potential of producing 1 or more generations of *P. confinnis* each year.

Barney and Anson (1921) found that natural populations of the top minnow, *Gambusia affinis* (Baird and Girard), at Mound, La., rapidly increased from late April to July or August. After August a gradual decrease in their numbers occurred which continued through the fall. Hildebrand (1925) and Russell (1941) reported that *G. affinis* possessed characteristics useful in natural mosquito control.

Geiger and Purdy (1919) stocked rice fields with 1400 *Gambusia*/acre and reduced the anopheline and culicine populations by 70%. In the southeast Ukraine, Asnes (1939) reported the control of *Anopheles maculipennis* (Say) by releasing 2–3 *Gambusia*/10 ft² of water surface. Horsfall (1942) reported the control of common malaria mosquito, *A. quadrimaculatus* (Say), by adding 4000–8000 top minnows/acre in Arkansas rice fields.

Schwardt (1939) stated that use of chemicals for control of mosquitoes in rice fields had not been attempted because the usual oiling operations would cause damage to the rice crop. Horsfall (1942) reported 100% control of mosquitoes with Dendrol at 4 ppm. Excellent mosquito control was achieved by Wisecup et al. (1945), Whitehead (1951, 1952), and Mathis et al. (1954) with several chlorinated hydrocarbons applied by various means.

Gahan (1957) reported control of *Psorophora* larvae by adding 0.05 ppm parathion, 0.5 ppm trichlorfon, or 0.25 ppm mevinphos to the irrigation water as it entered the fields. Wills (1965) described a drip-bucket device for the application of ethyl parathion to rice irrigation water, and Lancaster (1965) reported that a large number of test rice fields equipped with the applicator produced no larvae.

Several insecticides mixed with the herbicide propanil have been reported phytotoxic to rice seedlings (Bowling and Hudgins 1964, 1966; Smith and Fox 1965; Everett 1966).

MATERIALS AND METHODS.—*Biological Control Study.*—Field test plots, 6×12 m, arranged in a randomized block design with 3 replications/treatment were used in an attempt to determine the number of *G. affinis*

[1] Portion of a thesis presented by the senior author in partial fulfillment of the requirements of the degree of Master of Science. Accepted for publication May 28, 1968.

Table 1.—Control of *P. confinnis* by *G. affinis* in plots receiving 3 types of treatment and stocked with ¼ fish/ft² of surface area.

Treatment	Percent control		
	Test 1	Test 2	Avg
Rice—no chemicals	70.9	45.3	58.1
Rice—chemicals	86.4	88.4	87.4
Pasture—no chemicals	95.0	82.0	88.5

necessary to control *P. confinnis* larvae in rice fields. Each test plot could be individually drained or flooded.

Two plots in each block contained Nato rice, water-planted at a rate of 150 lb of dry seed/acre. No insecticide seed treatment, herbicide, fungicide, or fertilizer applications were made during the entire test period.

Four plots in each block consisted of Nato rice, water-planted at a rate of 150 lb/acre of dry seed treated with 0.25 lb of thiram and 0.25 lb of aldrin/100 lb of seed. The plots were sprayed topically with 3 lb of propanil/acre 21 days after planting. Three days later the plots were fertilized broadcast with 500 lb of 16–8–8 fertilizer/acre.

Two plots in each block contained volunteer grass simulating pasture conditions. These plots were flooded and drained the same as the plots which contained rice.

The plots were drained 3 days after planting and reflooded with 4–6 in. of water 24 days later. All irrigation water entering the plots passed through a 32-mesh plastic screen to remove aquatic mosquito predators. At this time known numbers of fish were introduced into the appropriate plots as follows: (1) rice with no chemicals, ⅛ fish/ft² of water surface; (2) rice with chemicals, ⅛ fish/ft² of water surface; (3) simulated pasture, ⅛ fish/ft² of water surface; (4) rice with chemicals, ¼ fish/ft² of water surface; (5) rice with chemicals, ½ fish/ft² of water surface; and (6) 3 controls: rice without chemicals, rice with chemicals, and simulated pastures were not stocked with fish. Additional water was added periodically to compensate for water loss that occurred during the test period.

Fish used in the study were collected from natural populations in the canals and ditches surrounding the test area and were held in a polyethelene tank, 7.5 ft in diam and 2.5 ft deep, 24 hr before they were introduced into the test plots. Two weeks later all plots were drained and the test procedure just described was repeated.

Mosquito counts were made with an enamel dipper, 11 cm in diam and 450 ml capacity, in each test plot 24 hr after each flooding. Four dippers of water were taken from each plot to determine the larval population index.

Table 2.—Control of *P. confinnis* by *G. affinis* at 3 stocking rates.

No. fish/ft² surface area	Percent control		
	Test 1	Test 2	Avg
⅛	84.0	88.4	86.2
¼	86.4	88.4	87.4
½	97.4	95.2	96.3

Table 3.—Population levels of *P. confinnis* larvae in plots receiving 3 different types of treatment.

Treatment	Avg no. larvae/dip	
	Test 1	Test 2
Rice—no chemicals	9.50	0.33
Rice—chemicals	26.25	.33
Pasture	7.5	1.0

Chemical Control Study.—A series of 3 field tests was conducted in 1967 at the Rice Experiment Station, Crowley, La., to determine the feasibility of using an insecticide-herbicide mixture for the control of *P. confinnis* larvae. Test plots, 3×6 m, capable of being individually drained and flooded, were arranged in a randomized block design. Eleven treatments each replicated 5 times were tested. Plots were drilled during mid-May at the rate of 130 lb/acre of Saturn rice seed. The seed was treated prior to planting with 4 oz of thiram/100 lb of seed.

Insecticides were applied in Test 1, 26 days after the rice was planted. Dursban® (*O,O*-diethyl *O*-3,5,6-trichloro-2-pyridyl phosphorothioate) EC, diazinon EC, diazinon EC plus spreader, malathion EC, technical malathion, naled EC, fenthion EC, Abate® (*O,O*-dimethyl phosphorothioate *O,O*-diester with 4,4′-thiodiphenol) EC, Furadan® (2,3-dihydro-2,2-dimethyl-7-benzofuranyl methylcarbamate) EC, and bromophos EC were tested. Each insecticide was applied at the rate of 0.005 lb/acre plus 3 lb propanil. A small-plot logarithmic sprayer (Cialone et al. 1963) was used to apply the treatments. Propanil at the rate of 3 lb/acre was used as the control. Three days after the treatments were applied each plot was fertilized with 500 lb of 16–8–8 fertilizer/acre. The following day all plots were flooded. Density of mosquito larvae was determined 24 hr later.

Prior to plot flooding the rice plants were rated for plant injury, using the following scale: (1) no visible damage, (2) yellowing of the margins and apices of the leaves, (3) yellow spotting of the entire leaf blade, (4) plants with most of the leaves yellowed and with loss of turgidity to the extent that leaves were no longer erect, (5) dead plants present. A plus

Table 4.—Percent control of *P. confinnis* larvae in rice fields treated with propanil[a] insecticide mixtures.

Insecticide	Insecticide concentration (lb/acre)			
	0.005	0.05	0.1	0.5
Abate	22.4		78.6	100.0
Fenthion	0		9.1	99.0
Diazinon EC	0	31.1	10.4[b]	
Diazinon+spreader	36.0	55.9	49.2[b]	
Naled	28.1	56.6	12.1[b]	
Dursban	36.7	83.0	47.8[b]	
Bromophos			54.5	16[b]
Furadan	0	47.8	26.4[b]	
Malathion EC	0	46.8	19.4[b]	
Malathion T	0	57.0	23.7[b]	

[a] Propanil used at 3 lb acre.
[b] Phytotoxic to the rice plants

Table 5.—Average number of mosquito larvae in plots treated with selected insecticides at 0.1 lb/acre.

Insecticides	Treatment means[a]
Abate	9.6 a
Bromophos	20.4 b
Dursban	23.4 bc
Malathion T	34.2 bcd
Naled	39.4 bcde
Fenthion	40.4 cde
Check	44.8 def
Diazinon+spreader	46.6 df
Furadan	51.4 ef
Malathion EC	55.0 ef
Diazinon EC	60.4 f

[a] Means not followed by the same letter are significantly different from each other at the 0.05 level of probability.

or minus value was assigned to each division of the scale to indicate varying degrees of damage within each unit.

After Test 1 was completed the plots were drained and permitted to dry 6 days at which time Test 2 was begun. Plots in Test 2 were treated and flooded as described for Test 1, except no fertilizer was used and the insecticides were applied at a rate of 0.1 lb/acre. Plants were evaluated for phytotoxicity the day the plots were flooded, and 24 hr later the larval population densities were determined.

After treatments in Test 2 were completed the plots were drained and permitted to dry 10 days, at which time Test 3 was begun. The plots were treated as described for Test 1 with the exception that fenthion, Abate, and bromophos were applied at 0.5 lb/acre and the other insecticides at 0.05 lb/acre. Plots were flooded 2 days after the insecticides were applied. Control of mosquito larvae and phytotoxic reactions were evaluated 24 hr later.

After the plants were mature, grain samples were harvested from areas at both ends and from the middle of 4 plots treated with fenthion, Abate, and the control. These grain samples were used to determine insecticide residues.

Abate residues in rice grain were determined by the method described by American Cyanamid (1967). Fenthion residue analysis was performed by the method described by Olson (1967).

RESULTS AND DISCUSSION.—*Biological Control.*—The data in Table 1 show the control of mosquito larvae by fish in relation to treatment when stocked with ¼ fish/ft² of water surface. Abundant low-growing vegetation was observed to interfere with fish feeding on the mosquito larvae. Weed growth was abundant in plots not treated with propanil. The fish were more effective in plots treated with propanil and in simulated pasture plots. Larval control in these plots averaged 87.4 and 88.5%, respectively. The increased efficacy of the fish in plots treated with the weed-control chemical and in simulated pasture plots was considered to be the result of less decumbent vegetation in these plots. Such an environment provided fewer hiding places for mosquito larvae.

Table 2 shows the control of mosquito larvae achieved in rice plots in which 3 stocking rates of *G. affinis* were employed. Control at the rate of ½ fish, ¼ fish, and ⅛ fish/ft² of water surface averaged 96.3, 87.4, and 86.2%, respectively.

These data show that high stocking rates of fish in the test plots did not provide 100% control of mosquito larvae. The data also suggest that large populations of fish under natural conditions will not provide complete control of mosquito larvae. These data agree with those of Hess and Tarzwell (1941) relative to the fish population and food abundance ratio. This thesis was supported by the information obtained in the 1966 control plots (Table 3). Here fewer larvae were produced in the Test 2 flooding, but with the same stocking rate of fish as used in the Test 1 flooding the percent control in both tests was the same (Table 2). Therefore, the number of mosquito larvae present does not appear to be the critical factor that determines the degree of control by *G. affinis*.

Chemical Control.—Data in Table 4 show the control of *P. confinnis* larvae obtained from the use of pre-flood herbicide-insecticide mixtures in rice plots. The percent control was determined by comparing the number of larvae per dip in the treated vs. untreated plots.

Abate and fenthion at 0.5 lb/acre gave 100% and 99% control of larvae, respectively. These 2 insecticides mixed with propanil did not cause any plant injury. All other insecticides combined with propanil caused phytotoxicity at sublethal levels for *P. confinnis* larvae.

Diazinon EC, diazinon plus a spreader, naled, Dursban, Furadan, malathion EC, and technical malathion provided better control in plots which received 0.05 lb/acre than in plots which received 0.1 lb/acre. However, the application at 0.05 lb/acre was made 2 days prior to flooding, whereas the 0.1 lb/acre rate was applied 4 days prior to flooding. Since it is apparent that the insecticides tested break down rapidly after application, the sooner treated fields are flooded after the insecticide is applied the higher the larval mortality will be.

The residual effects of treatment carryover from test to test was evaluated by combining the data from 3 tests and calculating an analysis of variance on the randomized block design. These data show that there were no significant effects on the results caused by residue in succeeding tests because of a change in rank of means and lack of consistency of treatment effects in the different tests.

Duncan's multiple range test (Duncan 1955) was used to determine the statistical significance between the treatment means According to the criterion

Table 6.—Average number of mosquito larvae in plots treated with selected insecticides at 0.05 and 0.5 lb/acre.

Insecticides	Lb/acre	Treatment means[a]
Abate	0.5	0 a
Fenthion	.5	1.0 a
Dursban	.05	15.4 ab
Malathion T	.05	38.8 bc
Naled	.05	39.2 bc
Diazinon with spreader	.05	39.8 bc
Furadan	.05	47.0 bcd
Malathion EC	.05	48.0 cd
Diazinon EC	.05	62.2 de
Bromophos	.05	75.8 e
Check		90.2 e

[a] Means not followed by the same letter are significantly different from each other at the 0.01 level of probability.

used, Abate gave the best control in all tests (Tables 5 and 6). Fenthion and Dursban at 0.5 and 0.05 lb/acre, respectively, were not significantly different from Abate at 0.5 lb/acre.

The total amount of Abate and fenthion applied to the plots was the equivalent of 0.605 lb/acre. No Abate and fenthion residues were detected in rice grain at 0.5 and 0.01 ppm, respectively.

REFERENCES CITED

American Cyanamid. 1967. Colorimetric procedure for the determination of CL 52,160 residues in rice grain and plants. American Cyanamid Rep. C-73: 5-9.

Asnes, S. M. 1939. Resultats des observations sur la peuplement par la Gambusia des riziers du Kolkhoz "Asovris" Districe de Mariupol, Region de Stalino, 1938. Med. Parasitol. 8 (3): 364-5.

Barney, R. L., and B. J. Anson. 1921. Abundance of mosquito fish in relation to male frequency. Ecology 2 (1): 53-69.

Bowling, C. C., and H. R. Hudgins. 1964. Compatibility of insecticides with the herbicide propanil as spray applications on rice. Texas Agr. Exp. Sta. Progr. Rep. 2302: 1-3.

1966. The effects of insecticides on the selectivity of propanil on rice. Weeds. 14 (1): 94-5.

Cialone, J. C., G. Bayer, and D. W. Davis. 1963. A small plot logarithmic sprayer: some modifications. Proc. 17th Ann. NE Weed Contr. Conf.: 71-2.

Duncan, D. B. 1955. Multiple range and multiple F tests. Biometrics 11: 1-42.

Everett, T. R. 1966. Arthropod pests of rice fields in the United States. U.S. Delegation to the 11th Session of the Working Party on Rice Production and Protection. International Rice Commission, FAO. Contribution under Agenda Item no. 10. 19 p.

Gahan, J. B. 1957. Further studies with water-soluble insecticides for the control of mosquito larvae in irrigation water. Mosquito News. 17 (3): 198-201.

Geiger, J. C., and W. C. Purdy. 1919. Experimental mosquito control in rice fields. J. Amer. Med. Ass. 72 (11): 774-9.

Hess, A. D., and C. M. Tarzwell. 1941. The feeding habits of *Gambusia affinis affinis* with special reference to the malaria mosquito, *Anopheles quadrimaculatus*. Amer. J. Hyg. 35: 142-51.

Hildebrand, S. F. 1925. A study of the top minnow *Gambusia holbrooki*, in its relation to mosquito control. USPHS Bull. 153: 136 p.

Horsfall, W. R. 1942. Biology and control of mosquitoes in the rice area. Arkansas Agr. Exp. Sta. Bull. 427. 46 p.

Lancaster, J. L., Jr. 1965. Control of mosquitoes in rice fields. Arkansas Farm Res. 14 (5): 12.

Mathis, W., V. B. Pickett, and W. O. Miller. 1954. Chemical control of rice field mosquitoes in Mississippi. USPHS Reprint 69 (9): 803-7.

Olson, T. J. 1967. Determination of residues of fenthion in rice grain by thermionic emission gas chromatography. Chemagro Corp. Rep. 20417. 10 p.

Rice Millers Association. 1967. Rice acreage in the U.S., 1967. Rice Millers Acreage Rep., 1967: 1.

Russell, P. F. 1941. Naturalistic methods of malaria control. AAAS Publ. 15: 478-83.

Schwardt, H. H. 1939. Biologies of Arkansas rice field mosquitoes. Arkansas Agr. Exp. Sta. Bull. 377. 21 p.

Smith, R. J., Jr., and W. T. Fox. 1965. New developments in weed control in rice. Rice J. 68 (2): 36-39.

Whitehead, F. E. 1951. Rice field mosquito control by pellet borne insecticides. Arkansas Agr. Exp. Sta. Bull. 511. 30 p.

1952. A large scale experiment in rice field mosquito control. Arkansas Agr. Exp. Sta. Rep. Ser. 32 p.

Wills, V. C. 1965. New applicator aids mosquito control. Rice J. 68 (9): 31.

Wisecup, C. B., W. C. Brothers, and P. M. Eide. 1945. Airplane spraying of rice fields with DDT to kill mosquito larvae. J. Econ. Entomol. 38 (6): 686-8.

Population Trends of Insect Predators of the Elm Leaf Beetle[1]

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ABSTRACT

Pyrrhalta luteola (Muller) is one of the more injurious insects attacking Siberian elm trees, *Ulmus pumila* L., in Oklahoma. The damage is due to the frequent defoliation of trees by *P. luteola* larvae and adults. Twelve species of insects were found to be predaceous on *P. luteola*. The 3 most abundant predators were *Brochymena quadripustulata* (F.), *B. cariosa* Stål, and *Chrysopa carnea* Stephens. Predator populations were highest during June in 1966 and 1967. *Brochymena* spp. tended to remain on the elm trees and survive during relatively low infestations of *P. luteola*.

Several species of elms have been planted as shade and ornamental trees in Oklahoma. The ability of the Siberian elm, *Ulmus pumila* L., to survive and grow under Oklahoma environmental conditions resulted in large numbers of this species being planted throughout the State, and the fact that this tree was relatively free from destructive insects in Oklahoma several years ago encouraged home owners to plant more of them. The large number of Siberian elm trees now present provides an abundance of susceptible host material for the elm leaf beetle, *Pyrrhalta luteola* (Muller). It was first recorded in Oklahoma at Shawnee in 1955 (Davis,[3] 1965), and since then it has been reported as a serious defoliator of *U. pumila* and other species of elm in numerous instances for the past 9 years (Lamdin 1967).

While considerable literature is available on chemical control of *P. luteola*, very little work has been conducted and reported on natural control by predators. Predators of the leaf beetle have been listed as toads, birds, and several kinds of insects (USDA 1960).

While the biology of *P. leutola* in Oklahoma was being studied, observations showed that all its stages were attacked by several insect predators.

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[2] Associate Professor and Graduate Assistant, respectively.

[3] L. H. Davis. 1965. Plant Pest Control Division, Agr. Res. Serv., USDA, Hyattsville, Maryland. Personal communication.

1968 Craven, B. R., and C. D. Steelman
Relative Susceptibility Of Psorophora Confinnis (Lynch-Arribalzaga) Larvae In The Rice Producing Area Of Southern Louisiana To Selected Insecticides.
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RELATIVE SUSCEPTIBILITY OF *PSOROPHORA CONFINNIS* (LYNCH-ARRIBALZAGA) LARVAE IN THE RICE PRODUCING AREA OF SOUTHERN LOUISIANA TO SELECTED INSECTICIDES[1]

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Studies conducted in 1965 revealed that populations of *Psorophora confinnis* (Lynch-Arribalzaga) ranging from 2 to 6 million larvae per acre were produced from rice fields in the southern rice-producing area of Louisana. These massive populations were observed during the months of May and June and corresponded to the flooding of the rice fields.

Since no dosage-mortality regression lines for different insecticides were available on *P. confinnis* it was deemed desirable to obtain this information for future reference.

MATERIALS AND METHODS. Test mosquitoes used in the insecticide toxicity tests were collected at six locations in the rice producing area of Southwest Louisiana: Louisiana State University Rice Experiment Station, Crowley; North Central Acadia Parish; West Central Lafayette Parish; Northwest Vermillion Parish; South Central Evangeline Parish; and East Central Jefferson Davis Parish.

Adult female *P. confinnis* were collected and transported to the laboratory at Louisiana State University in Baton Rouge where they were fed on an adult male chicken. The fed mosquitoes were retained individually in 2.5 x 10.0 cm. glass shell vials containing 2 cm. of cellucotton saturated with water from the area where the females were collected. Each female was provided one pre-soaked raisin for a source of carbohydrate and held in a rearing room which was maintained at 27± 3° C. and a 14-hour photoperiod provided by a 100 watt incandescent light bulb.

The cellucotton on which the eggs had been deposited was placed in a 30 ml. plastic cup. The cup was sealed with a cardboard top and stored at 27±3° C. until larvae were needed for testing.

Eggs were stimulated to hatch by flooding with a suspension prepared by placing loose oat straw in a gallon jar containing 5 g. of brewer's yeast and the jar filled to capacity with distilled water. After 24 hours the solution was ready for use.

The plastic cups containing eggs were filled with the hatching suspension and after 24 hours the larvae were transferred to 7 x 40 x 20 cm. enamel pans filled with distilled water. A maximum of 600 larvae were placed in each pan. A compressor with a 1/6 hp. motor operating at 1,725 r.p.m. was used to aerate the water. Rubber tubing 5 mm. in diameter with an adjustable shut-off valve extended from the compressor to the pans. The valve was adjusted so that air was pumped into a corner of each pan at the rate of 15 bubbles/min.

Commercially available rabbit feed in the form of pellets was ground with a mortar and pestle and 2–4 g. were added to each pan per day to provide food for the larvae. The larvae were held in the pans until late third and early fourth instars at which time they were randomly removed for testing.

In addition to the F_1 generation larvae that were used for testing purposes, second and third instar larvae were also collected with an aquatic insect net from rain puddles and intermittently flowing ditches and placed in lots of 200–350 in 1 qt. polyethelene bags. The bags were filled with equal amounts of water and air and sealed. An ice chest containing water

[1] A portion of a thesis presented by the senior author in partial fulfillment of the requirements of the degree of Master of Science.

cooled to 5–10° C. was used to transport the larvae to the laboratory. The larvae were placed in enamel pans, aerated, and fed as previously described. They were held at 27±3° C. for 24 hours prior to testing to eliminate those injured by collection and transportation techniques.

The mortality of *P. confinnis* to the test insecticides was determined by the procedure described by the World Health Organization (1963). The WHO test kit composed of preformulated DDT, lindane, dieldrin, malathion, diazinon and fenthion was used. In addition, emulsifiable concentrates of the following insecticides were used: Dursban® (*O,O*-diethyl *O*-(3,5,6-trichloro-2-pyridyl) phosphorothioate), Abate® (*O,O,O′,O′*-tetramethyl *O,O′*-thiodi-*p*-phenylene phosphorothioate), Dasanit® (*O,O*-diethyl *O*- *p*-(methylsulfinyl) phenyl phosphorothioate), Furadan® (2,2-dihydro-2,2- dimethyl-7-benzofuranyl methylcarbamate), EL-400 (*O*-(4 Bromo-2,5-dichlorophenyl) *O,O*-dimethyl phosphorothioate), and naled. Desired concentrations were obtained by serial dilutions of the emulsifiable concentrates with distilled water.

RESULTS AND DISCUSSION. Table 1 lists the LC_{50}'s, LC_{90}'s and slopes of the dosage-mortality regression lines (ld-p) for the insecticides used in the base-line study. Fenthion, Dasanit, Furdan, and lindane mortality lines for *P. confinnis* larvae were plotted on log-probit paper and the resulting dosage-mortality regression lines were eye-fitted. Sufficient data were not collected to use a computer program (Daum and Killcreas, 1966) for the latter four compounds as was done on the other insecticides.

TABLE 1.—Relative susceptibility of *Psorophora confinnis* larvae to selected insecticides.

Insecticide	p.p.m. LC_{50}	p.p.m. LC_{90}	Slope of Line
Abate	.0014	.0113	1.42
fenthion	.0025	.0045	*
Dursban	.0027	.0234	1.37
EL-400	.0093	.0531	1.70
diazinon	.0095	.0207	3.76
Dasanit	.011	.074	*
malathion	.0257	.0482	4.69
Furadan	.035	.056	*
naled	.0365	.1373	2.23
dieldrin	.0534	.3632	1.54
DDT	.1222	1.0252	1.38
lindane	.16	.36	*

* Eye fitted curves.

Literature Cited

DAUM, R. J., and KILLCREAS, W. 1966. Two computer programs for probit analysis. Bull. Entomol Soc. Amer. 12(4):365–369.

WORLD HEALTH ORGANIZATION. 1963. Instructions for determining the susceptibility or resistance of mosquito larvae to insecticides. WHO Rep. Ser. No. 265. p. 55–61.

1968 Harden, F. W., and B. J. Ethridge
Unique Problems In Insect And Pest Control Of NASA's Mississippi Test Facility
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PAPERS AND PROCEEDINGS OF THE 24TH ANNUAL MEETING

of the

AMERICAN MOSQUITO CONTROL ASSOCIATION

and the

10TH ANNUAL MEETING

of the

LOUISIANA MOSQUITO CONTROL ASSOCIATION

New Orleans, Louisiana, March 31–April 3, 1968

Part I

UNIQUE PROBLEMS IN INSECT AND PEST CONTROL OF NASA'S MISSISSIPPI TEST FACILITY

FREDERICK W. HARDEN AND BEVERLY J. ETHRIDGE [1]

The mosquito control program at the National Aeronautics and Space Administration's Mississippi Test Facility is unique among organized mosquito control programs. The area under control has no permanent residents, only transient employees of NASA and its contractors, many of whom have never lived in an area with a serious mosquito annoyance problem. The test complex is located in a remote area of south coastal Mississippi. The central Fee area, or government-owned land, encompasses over 13,000 acres and the surrounding uninhabited, acoustical buffer zone another 128,000 acres in size.

The insect and pest control program is under the supervision of a non-governmental agency, the General Electric Company, NASA's operational and service contractor at the Mississippi Test Facility. The technical personnel are General Electric employees; the field inspection, maintenance, repair and custodial work is done by four unionized subcontractors to General Electric. Operational management is, to say the least, not typical of that of a local county mosquito control program.

During the severe 1963 mosquito outbreak, *Aedes sollicitans* and *Aedes taeniorhynchus* were found in astronomical numbers, reaching 100+ per minute landing rate counts throughout the area. This created a situation which was almost intolerable, causing many construction crews to leave their jobs. It was estimated there was a loss of work efficiency of at least 25 percent. Since there was no organized program at the time, the Air Force Special Spray Flight was brought in to treat approximately 150,000 acres with malathion in oil; this gave satisfactory control for several weeks.

The present control program began about one year after the initiation of construction. There were few roads available, and those that were were usually occupied by heavy construction equipment day and night. It was not unusual to use a construction road one week as a fog road and have it obliterated by a canal the following week. As a result, to provide adequate coverage, a system of small fog roads was constructed entirely separate from the existing road system.

[1] General Electric Company, Mississippi Test Support Department, Bay Saint Louis, Mississippi.

To provide control in the salt marsh south of our control area but outside our jurisdiction, MTF has a cooperative agreement with the Gulf Coast Mosquito Control Commission to provide insecticide for adulticiding, paris green for larval control and helicopter flying time for inspection at a total cost of approximately $36,000.00 In addition, a three-quarter yard dragline has been supplied for permanent mosquito control in Hancock County salt marshes immediately south and southeast of the test site.

As one would expect, the principal area of control is the test complex, where there are three test stands, one over 400 feet in height. This entire area is extremely well lighted and borders a large swamp beyond the fog area. hence it is subject to rapid mosquito reinfestation from areas outside our jurisdiction.

Personnel work in the test area continuously 24 hours a day, 7 days per week. Until the problem of liquid oxygen (LOX) compatibility came to our attention, the standard fogging chemicals with a #2 diesel oil base were used. However, when any hydrocarbon, whether it be an insecticide or not, is brought into the presence of LOX in sufficient quantity, a catastrophic explosion may occur. Consequently, last spring our fog trucks were banned from the test area during the handling of LOX, which, during tests, may be a period of several days to a week. As a result, lab personnel at MTF began a crash program testing insecticides to determine the hydrocarbon level of the various field formulations. This was done by infra red determination expressed as cetane, a typical hydrocarbon, which is a standard in LOX work. These data were then converted to acreage deposit amounts assuming that all particles were deposited within the first 300 feet, even though our standard swath is 600 plus feet.

Two insecticides—Dibrom and Baygon —were found to fall within the approved range of two milligrams of hydrocarbon per square foot. A non-thermal fog machine (cold fogger) is used in these areas, applying Dibrom 8 at the rate of 1.75 ounce technical per gallon at 40 gallons per hour. As soon as satisfactory ground equipment for the application of ultra low volume insecticide is developed this operation will be converted to ultra low volume.

Since diesel oil formulations can still be used in the balance of the Fee area, the non-thermal applications have provided satisfactory control in the test area on most occasions. However. mosquitoes and certain midges have apparently not read the references which state they do not usually go above the second floor of buildings. Mosquitoes at MTF so far have become annoying in the test stands up to the tenth floor. This created a control problem which has not yet been solved.

Mosquito control is only a portion of the work listed in the unit's work scope; for example, structural pest control (roaches, ants and termites) and rodent control is carried on in some 119 buildings, encompassing approximately 1-¼ million square feet, ranging in size from the smallest skid house to a 19-story test stand. Additional responsibilities are weed and brush control, encephalitis surveillance, removal of small animals such as snakes, skunks and squirrels, and control of turf, horticultural and forest insects and diseases. The diversified work creates a number of problems usually not encountered. For example: One unusual problem has been the annual fall migration of *Polistes* wasps by the tens of thousands from the surrounding pine woods into all levels of test stands and high bay areas accumulating largely on the tops of the high boom rigs. They are apparently attracted by the grease on the cables and in the sheaves, as well as a warmer location. The Booster Storage building, with a 123-foot ceiling, has presented quite a pest control problem especially since the large access doors remain open most of the time. Microsol misters are used, treating from the upper levels of the building.

During one period of high density, an S-II rocket engine stage (weighing approximately 86,000 pounds) was being lifted into its stand by a high boom. At this critical moment, several wasps entered the cab of the crane operator. Since there was a chance the operator might be stung and cause the "Bird" to be dropped, the entire operation was stopped until the pest control unit could supply personnel to treat the test stand for wasps.

Dog flies and deer flies constitute another problem throughout the summer. Satisfactory control has been obtained using the Florida State Board of Health's dog fly control recommendation of Dibrom 14 at 3.5 ounces of technical material per gallon at 40 gallons per hour. However, during high density of deer flies the output has to be increased to 80 gallons per hour.

Since General Electric is a contractor to the government, our operation is subjectively graded each month by NASA as to efficiency. Our contract is of the CPAF (Cost Plus Award Fee) type. The areas covered include cost performance, manpower, utilization, quality of work, management performance and timing, safety and material utilization.

Since the inception of the pest control program in 1964, there has not been any loss of work efficiency due to mosquitoes.

LABORATORY STUDIES ON THE SEASONAL HATCHABILITY OF EGG BATCHES OF *AEDES SOLLICITANS*, *A. TAENIORHYNCHUS*, AND *PSOROPHORA CONFINNIS*

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INTRODUCTION. Most multivoltine floodwater species of the genera *Aedes* and *Psorophora* are inactive from November to March in southwestern Louisiana. Exceptions are *Aedes sollicitans* which breeds throughout the year and *Aedes vexans* which, in this area, is inactive during the warmer months but abundant from fall to spring. The eggs of these species that are inactive during the cooler months were said by Clements (1963) to be in a state of facultative diapause, and he concluded that facultative diapause occurs only in eggs laid in late summer or autumn. However, Moore and Bickley (1966), in a study of colonized *Aedes taeniorhynchus*, found that less than 10 percent of the females produced batches of eggs that were nearly all in a state of deep diapause. These eggs, they said, plus a few from nearly all egg batches, were responsible for "installment hatching" as defined by Mallack *et al.* (1964) and Breeland and Pickard (1967).

In the present study, we have examined the variability of hatching of consecutively laid egg batches produced by spring and fall broods of the multivoltine species, *Aedes sollicitans*, *A. taeniorhynchus* and *Psorophora confinnis*. We hoped to relate the presence of batches that were in a less hatchable state to the season and to individual females.

METHODS AND MATERIALS. The aquatic stages of *P. confinnis and A. taeniorhynchus* are normally absent from local breeding areas from November to March because their eggs are in a state of facultative diapause. We therefore collected newly emerged females from the first and last major broods of the three species in the field in late May and mid-September of 1966 and in mid-April and mid-September

[1] In cooperation with McNeese State College, Lake Charles, Louisiana.

1968 Knapp, F. W., and C. E. Rogers
Low Volume Aerial Insecticide Application For The Control Of Aedes Sollicitans Walker
Mosquito News 28: 535-540 (Amvac Ref. #1354)

LOW VOLUME AERIAL INSECTICIDE APPLICATION FOR THE CONTROL OF *AEDES SOLLICITANS* WALKER [1]

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Because of the continued success of ultra-low volume (ULV) application of insecticide against *Aedes sollicitans* Walker in Kentucky, (Knapp and Roberts 1965, Knapp and Pass 1966a, 1966b, Knapp 1967, and Knapp and Gayle 1968), investigations on the application and effectiveness of different insecticides were continued during the spring of 1966.

Materials and Methods. A Piper Super Cub airplane modified for low-volume spraying was equipped with two modified Fischer EA–12 electro atomizers.[3] One atomizer was secured to each side of the plane by brackets attached to the plane's spray boom (Figs. 1, 3). The atomizers consisted of a 12-volt series-wound motor driving a stainless steel rotating screen. In normal practice the insecticide is fed into a molded polypropylene manifold and through orifices directed toward the rotating screen. The speed at which the screen rotates determines the particle size; however, in these tests the screen was rotated at the maximum speed of 6,400 r.p.m. A model AD–240A 12-volt Stewart Warner electric fuel pump containing Telfon® gaskets and diaphram was used to pump the insecticide from a stainless steel tank to the atomizer. The pump and the tank were mounted in the luggage compartment of the plane (Fig. 2). A coiled 2/8" copper recirculating line ran from the pump to the tank. This line was insulated with plastic tubing and served to warm the insecticide on cool mornings to insure an even flow through the atomizer. A 12-volt solenoid valve was placed in the recirculating line and in the line leading to the atomizer. The latter line was of 2/8" polyethylene. When spraying was desired, one switch located on the instrument panel in the cockpit turned the recirculating solenoid valve off and the spray line solenoid valve on. The pump was on a separate switch. Another suction line attached to a two-way valve on the pump was used to clean the system with solvents. The inner walls of the tank were washed by the solvent being recirculated and forced through small jets inside the tank. A valve was mounted at the lower end of the bottom of the tank for draining.

Because the fuel pump was only capable of producing 8 lbs. psi, the atomizer was modified in such a way that the 2/8" tubing fed the insecticide directly into the center of the rotating screen (Fig. 2). A needle valve was inserted into this line to regulate the flow rate. In this manner the insecticide flowed onto a stainless steel splash plate that held the screen in place. By centrifugal force insecticide was thus thrown through the screen and was dispersed into a fine droplet spray.

Depending upon the insecticide and the dosage rate, 1 or 2 of these electric atomizers were used.

Insecticides tested were: naled, 14 lbs. per gallon; fenthion, 8 lbs. per gallon; Baygon® (O-isopropoxyphenyl methyl carbamate), 2 lbs. per gallon; trichlorfon, 4 lbs. per gallon; malathion, 10.2 lbs. per gallon and dichlorvos, 93 percent active (approximately 11.6 lbs. per gallon). The

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[1] The investigation reported in this paper No. 68–7–30 is in connection with a project of the Kentucky Agricultural Experiment Station supported partially by Chemagro Corporation, Kansas City, Missouri, and the Chevron Chemical Company, Atlanta, Georgia, and is published with the approval of the Director.

[2] Associate Professor of Entomology and Graduate Assistant, respectively.

[3] Fischer Associates, Inc. Royal Oak, Maryland 21662.

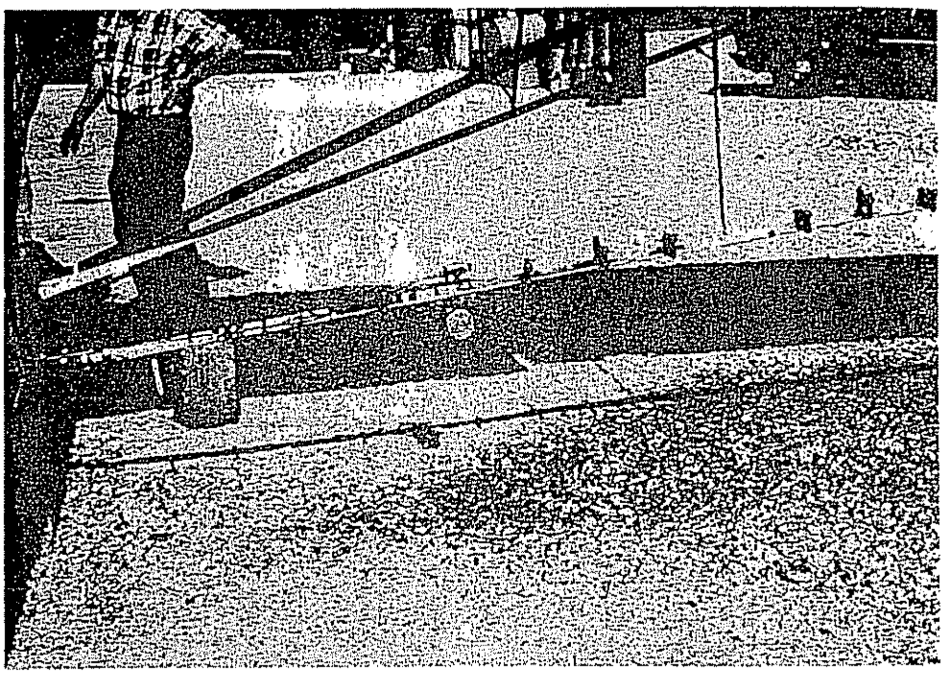

FIG. 1.—Position of atomizer on right boom of plane.

latter two were combined in a 5:1 weight ratio.

Applications of insecticides requiring a higher dosage rate than the fuel pump could produce were applied by use of the plane's own spraying system as described by Knapp and Pass (1966).

All treatments were applied between 7 to 8 p.m. and 5:30 to 7:30 a.m. Central Daylight Time. The airplane was flown at an altitude of 75 to 100 feet and at an air speed of 80 m.p.h. An effective swath width of 100 feet was used for calculating the dosage per acre. The areas used in these tests ranged from 200 to 300 acres. Pre-spray and post-spray adult mosquito counts were taken by counting the number of mosquitoes on and in the immediate vicinity of the person within 30 seconds as described by Knapp and Pass (1966). This was repeated in five locations within each test area. The test sites were sparsely populated consisting mainly of swamps bounded by densely wooded areas.

The weather was good, with wind speeds from 0 to 4 m.p.h. and temperatures varying from 65 to 80° F.

Two different rates of naled, 0.05 lb. (0.5 fluid oz.) and 0.10 lb. (1 fluid oz.), were applied with one electric atomizer. Two tests at 0.05 lb. per acre and 1 at 0.1 lb. per acre were applied in the evening whereas one of each was applied during the morning hours.

Baygon ULV was compared to Baygon in water at the rate of 0.05 lb per acre. The Baygon ULV was applied at 3.2 fluid oz., whereas the Baygon in water was applied at the rate of 64 oz. per acre. Two electric atomizers were used for applying Baygon ULV, and the plane's own spray system was used to apply the Baygon in water. In the latter application, 17 Spraying Systems Company Tee-Jet® nozzles No. 730385 were used. Eight of these nozzles were placed on the left boom and nine on the right. A boom pressure of 40 psi was used on this test. Both ap-

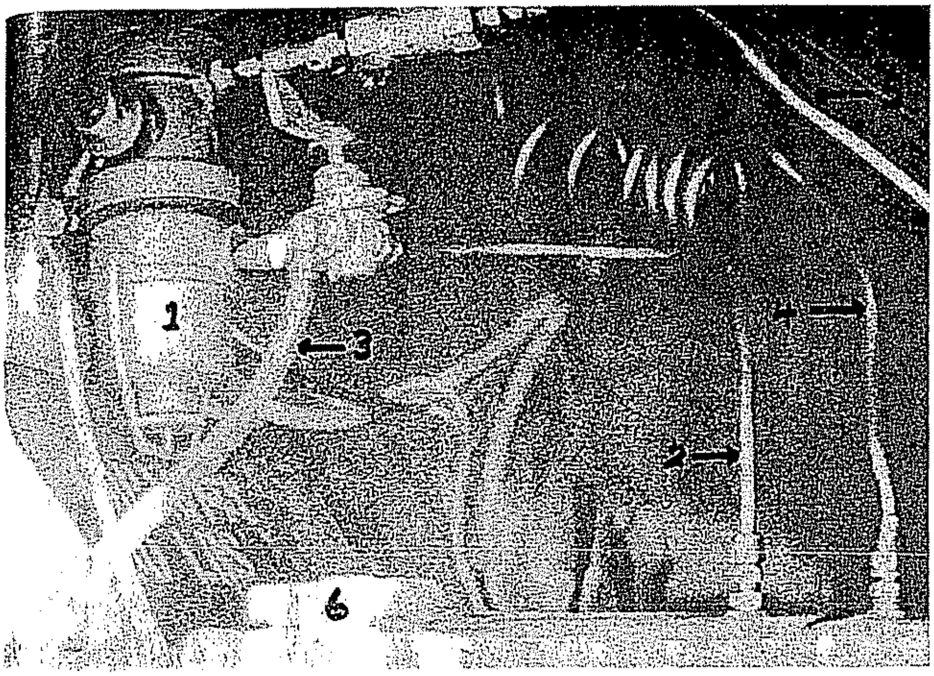

FIG. 2.—Fuel pump (1), suction line from tank (2), suction line for cleaning pump and tank (3), insulated recirculating line (4), insulated outlet line to atomizer (5) and tank (6).

plications were made during the evening hours. Baygon and fenthion combination was applied with two electric atomizers at the rate of 0.04 lb. per acre respectively (3.2 fluid oz.). Malathion was mixed with dichlorvos at the ratio of 5 to 1 and applied during the evening hours at the rate of 0.15 lb. of malathion to 0.03 lb. of dichlorvos (2.4 fluid oz.) per acre. Two treatments of trichlorfon was applied at the rate of 0.3 lb. (9.7 fluid oz.) per acre. Trichlorfon treatments were applied using the plane's spray unit. Four 800e Tee-Jet nozzles, two mounted on each side of the plane was used in this test.

The type of foliage cover that each test was applied over is shown in Table 1.

RESULTS AND DISCUSSION. The results of the various treatments are shown in Table 1. The density of the foliage cover had some influence upon the percentage reduction of adult mosquitoes. This can especially be seen in comparing the two evening applications of naled at 0.05 lb. per acre. In areas having a medium-to-heavy foliage a 44 percent reduction of adult mosquitoes was seen at 2 hours after the application as compared with approximately 99 percent reduction of mosquitoes for the area having light-to-no-foliage cover. The same dosage rate applied during the morning hours at a temperature of 68° F. showed that the mosquitoes were adequately reduced within 1 to 1½ hours, although the control started to decline after 6 hours. This decline may have been because the adult mosquitoes were not so active at the time of spraying, owing to the low temperature.

Naled applied at 0.1 lb. per acre over areas of little to no foliage showed little difference between the morning and evening application. However, again the morning application was not as effective as the evening application, whereas no

TABLE 1.—Effectiveness of various aerial applications of insecticides against *Aedes sollicitans* Walker adults.

Compound	Time application [a]	Temp. (°F.)	Fluid oz./ acre	Pound per acre	Type foliage [b]	Pretreatment no. adults 30 sec.	% Reduction—hours following treatment 0.5	1.0	1.5	2.0	6.0	10	24	36
naled	PM	80	0.5	0.05	1, 2	60	0	78 [c]	87	98.9	100	100	..	90
naled	PM	70	0.5	0.05	4, 5	15	..	..	..	44.0	100	100	100	86
naled	AM	68	0.5	0.05	5	38	43	83	96	..	97	66	..	..
naled	PM	80	1.0	0.10	1, 2	64	88 [d]	97	..	..	100	100	100	84
naled	AM	65	1.0	0.10	2	30	85	100	..	..	..	100	85	..
Baygon ®:water	PM	80	64.0	0.05	2	24	0	..	76	98.0	..	99	99	96
Baygon ®:	PM	81	3.2	0.05	2, 5	24	0	0	89	..	..	94	95	89
Baygon ®: fenthion (4:1)	AM	78	3.2	0.04: 0.04	3, 4	12	..	..	..	84.0	95	88	95	..
malathion: dichlorvos (5:1)	PM	80	2.4	0.15: 0.03	3, 5	24	..	..	92	..	88	80	83	..
trichlorfon	AM	64	9.7	0.30	4	40	88	..	..	..	68 [e]	46 [e]	..	..
trichlorfon	AM	64	9.7	0.30	4	14	91	..	..	..	96	65	..	..

[a] All treatments applied between 7 to 8 p.m. and 5:30 to 7:30 a.m., Central Daylight Saving Time.
[b] 1=4–6″ grass, 2=waist high grass, 3=light foliage—numerous open spaces, 4=medium foliage—few open spaces, 5=heavy foliage—very few open spaces.
[c] 47 percent at 45 minutes.
[d] 66 percent at 15 minutes.
[e] Adult emerging from pupae.

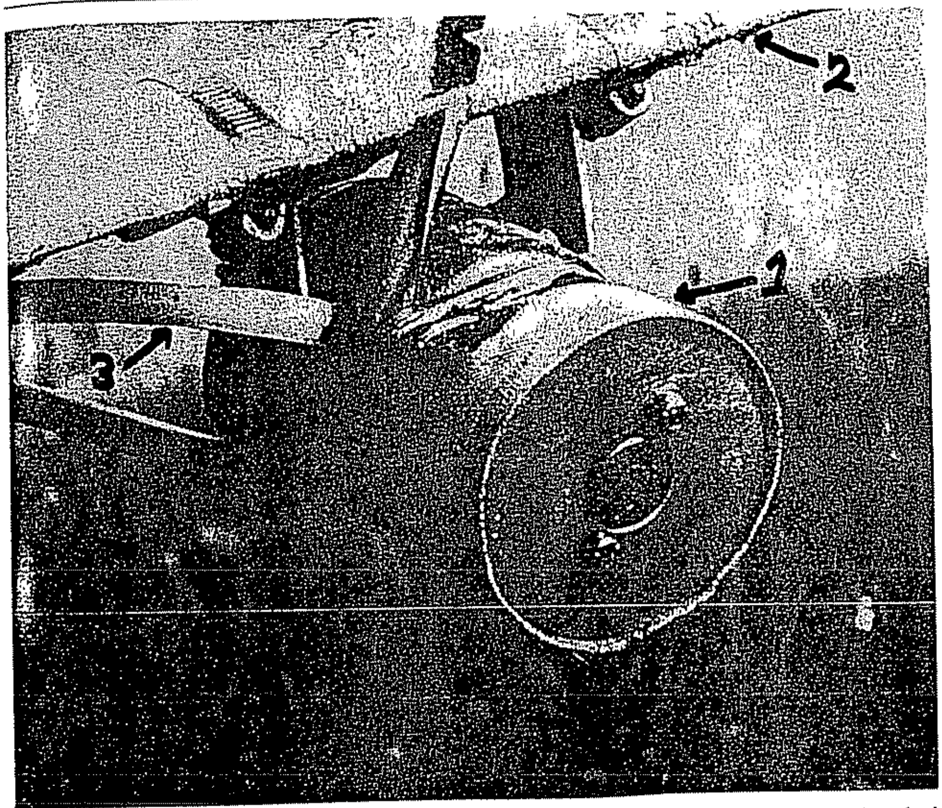

FIG. 3.—Close up of atomizer (1) attached to plane boom (2) and showing ⅛ inch tubing feed line (3).

reduction was found during the morning application in the same time period.

Very little difference in reduction of mosquitoes was seen between the Baygon in water and the Baygon ULV application, even though Baygon ULV application was applied over areas having a denser foliage than the area where the Baygon in water was applied. In general, the Baygon water application showed slightly better reduction. However, the gallonage of the solution needed for applying the same dosage rate as compared with the amount needed for the ULV is a disadvantage. Although the rapidity of knockdown of adult mosquitoes was not as great as it was with naled and trichorfon, adequate reduction occurred within 1½ to 2 hours after application. No advantage was seen in the reduction of adult mosquitoes by the use of Baygon and fenthion combination. The advantage of this combination has been reported by Knapp and Gayle (1968) in that Baygon was found ineffective as a larvicide but very effective as an adulticide, whereas fenthion was less effective as an adulticide but very effective as a larvicide.

The use of dichlorvos in malathion at the rate of 0.03 lb. of dichlorvos to 0.15 lb. of malathion per acre was advantageous in the knockdown of adult mosquitoes. However, 6 hours later adult mosquitoes began to increase. In previous tests, malathion applied at the same rate did not give any appreciable reduction of mosquitoes (Knapp and Roberts, 1965; Knapp and Pass, 1966). Knapp and Gayle

(1968) also found that when malathion was mixed with naled at the ratio of 0.154 to 0.017 lb. per acre a more rapid knockdown of adult mosquitoes occurred than with malathion alone. The two tests with trichlorfon at the dosage rate of 0.3 lb. per acre were not comparable because in one test the area treated had considerable numbers of pupae and the emergence of the pupae immediately after treating affected the percentage reduction of adults. However, in the test where pupae did not emerge until after the 6-hour count, 91 percent reduction of adults occurred at ½ hour and a 96 percent reduction at 6 hours after the application. Larvae of *Aedes sollicitans* placed in 32 oz. waxed cartons within the area treated with trichlorfon showed a 98 percent reduction of larvae 12 hours after treatment and a 100 percent reduction in 24 hours after treatment.

CONCLUSIONS. These tests show that insecticides are available, either alone or in combination, to give a rapid reduction of adult mosquitoes. The tests also show that the percentage reduction will vary owing to time of application and to the type of foliage cover in the area.

The use of Fischer EA electric atomizer served our purpose for a simple method of applying the insecticides. However, the insecticide used damaged the motor coverings and the electrical wire leading to the motor.

Literature Cited

KNAPP, F. W., and ROBERTS, W. W. 1965. Volume aerial application of technical malathion for adult mosquito control. Mosq. News 25(1):46–47.

KNAPP, F. W., and PASS, B. C. 1966a. Low-volume aerial sprays for mosquito control. Mosq. News 26(1):22–25.

KNAPP, F. W., and PASS, B. C. 1966b. Effectiveness of low-volume aerial sprays for mosquito control. Mosq. News 26(2):128–133.

KNAPP, F. W., and GAYLE C. H. 1967. ULV-aerial insecticide application for adult mosquito control in Kentucky. Mosq. News 27(4):478–482.

STERILE MALES FOR MOSQUITO CONTROL: A FIELD CAGE STUDY WITH *CULEX PIPIENS QUINQUEFASCIATUS*

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Ramakrishnan *et al.* (1962) were able to suppress populations of *Culex pipiens fatigans* Wiedemann (called *quinquefasciatus* Say in the United States) that were breeding in laboratory cages by introducing males sterilized by gamma irradiation; however, this technique was not successful in field tests. Krishnamurthy *et al.* (1962) could not reduce larval or adult populations of *Culex* in field tests when they released sterile males, even though the number of infertile egg rafts increased slightly.

LaBrecque (1961) and Weidhaas *et al.* (1961) reported the effectiveness of chemosterilants for the suppression of house flies, *Musca domestica* L., and mosquitoes, *Anopheles quadrimaculatus* Say and *Aedes aegypti* L., in the laboratory. Murray and Bickley (1964) conducted a series of basic studies of the effect of apholate on *Culex pipiens quinquefasciatus* and showed that sterile males exposed to 10–15 p.p.m. of apholate as fourth instar larvae were sexually more competitive than normal males. Mulla (1964) found that adult mosquitoes exposed continuously as fourth instar larvae to 10 p.p.m. apholate laid eggs which were 96 percent infertile; mosquitoes exposed to the same concentration of tepa and metepa laid eggs that were 16 and 5 percent infertile, respectively. Also, adult males and females fed for 24 hr. on a concentration of 0.01 per-

1968 Mount, G. A., C. S. Lofgren, N. W. Pierce and C. N. Husman.
Ultra-Low Volume Nonthermal Aerosols Of Malathion And Naled For Adult Mosquito Control.
Mosquito News 28: 99-103 (Amvac Ref. #1355)

(1355)

ULTRA-LOW VOLUME NONTHERMAL AEROSOLS OF MALATHION AND NALED FOR ADULT MOSQUITO CONTROL [1]

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Recently, investigators (Knapp and Roberts, 1965; Glancey *et al.*, 1965 and 1966; Knapp and Pass, 1966a and 1966b; Stevens and Stroud, 1966; Kilpatrick *et al.*, 1967; Mount and Lofgren, 1967) showed that ultra-low volume (ULV) aerial sprays of several insecticides will effectively control adult mosquitoes. However, adult mosquito control with ULV aerosols applied with ground equipment has not been reported. Such application would have several advantages: (1) it would eliminate or reduce to a minimum the need for carriers, solvents, and additives, (2) it would reduce the amount of spray solution or mixture that has to be carried and applied, (3) it would eliminate mixing and diluting insecticides, and (4) it would permit a reduction in the size of the equipment. The tests reported here were made: (1) to develop a means of producing aerosols from undiluted technical insecticide, (2) to correlate particle size of ULV aerosols with kill of adult mosquitoes, and (3) to compare the effectiveness of ULV nonthermal aerosols with that of high volume thermal aerosols on both caged and free-flying adult mosquitoes.

METHOD FOR PRODUCING ULV AEROSOLS. ULV insecticidal aerosols were produced by a nonthermal aerosol generator (Curtis Model 55,000) modified by replacing the standard 10-nozzle boom with a 3-nozzle boom or head (Figure 1) and replacing the insecticide pumping system with a CO_2 pressurized system. Also, a small needle valve was placed in the insecticide line between the tank and atomizing nozzles to permit precise calibrations of flow rates.

We do not want to imply this method of producing aerosols is the only means possible. Undoubtedly other apparatus could be used, and other modifications of the cold fogger are possible.

CORRELATION OF PARTICLE SIZE WITH MOSQUITO KILL. Different particle sizes could be obtained with the ULV aerosol generator by varying the volume of air and, to a lesser extent, by regulating the quantity of insecticide passing through the atomizing nozzles. Particles of malathion were then collected on silicone (General Electric SC-87 Dri-Film) treated glass microscope slides by waving the slides through the spray at a distance of 25 ft from the point of discharge. Mass median diameters (mmd) were determined according to the methods of Yeomans (1949); particle size was determined for four rates of air discharge and three doses, a total of 12 combinations. Rate of air discharge was measured on the manometer that is an integral part of the nonthermal aerosol generator and is reported as inches of differential height of mercury in the two columns of the manometer. Each inch of mercury differential represents ½ p.s.i.

Effect of particle size on mosquito kill was evaluated with caged female *Aedes taeniorhynchus* (Wiedmann) from the laboratory colony. The females were exposed to the aerosols by placing cages 5 ft above the ground on stakes 150, 300, and 600 ft downwind of the path of the aerosol generator. From 2 to 3 replications of three cages of 25 mosquitoes each were tested with each combination, and percentage mortality was determined 18 hours posttreatment.

[1] Mention of a proprietary product does not necessarily imply endorsement of this product by the USDA.

[2] Present address: Screwworm Eradication Program, Animal Health Division, P.O. Box 696, Mission, Texas 78572.

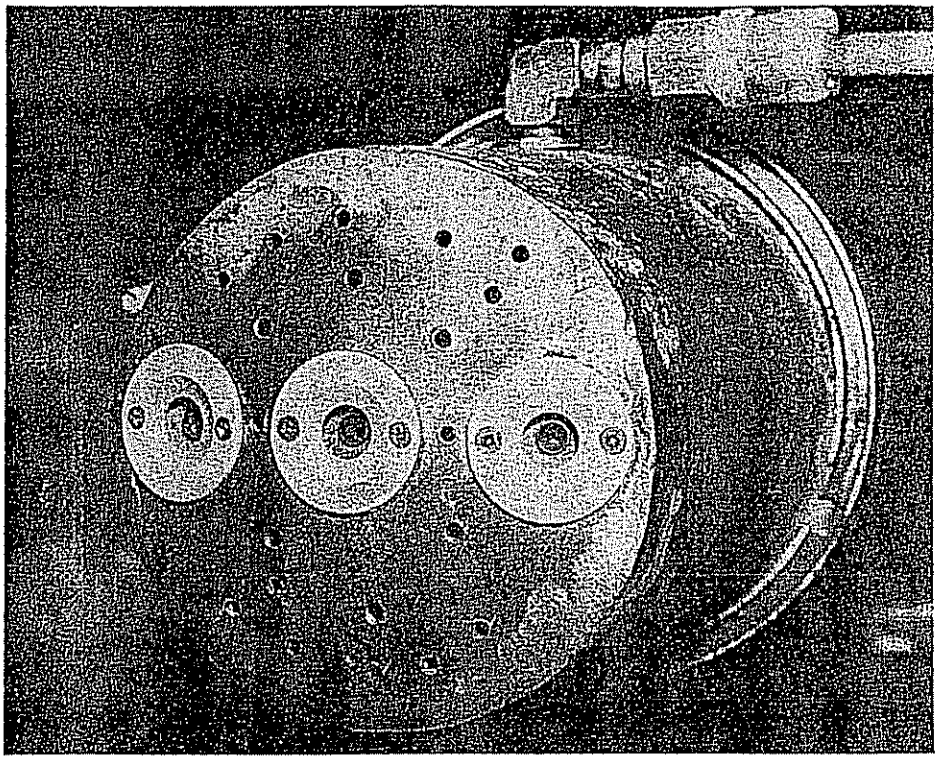

FIG. 1.—Three-nozzle head used to disperse aerosols of undiluted malathion and naled. Small holes drilled in face bleed off excess air volume.

Table 1 shows that with malathion the average mmd produced by the nonthermal generator ranged from 6 to 22.4 microns, depending on the rate of flow and air discharge. In general, the percentage mortality of mosquitoes increased when the mmd decreased at a given dose. For example, at a dose of 0.009 lb of malathion per acre, a mmd of 17.4 microns gave 71 percent average kill compared with 97 percent kill when the mmd was only 6.4 microns. These results probably reflect a tendency of the smaller particles to drift farther and thus to cause greater kill, especially at a distance of 600 ft.

COMPARISON OF ULV AND HIGH VOLUME AEROSOLS. The toxicity of ULV nonthermal and high volume thermal aerosols of malathion or naled (Dibrom 14) to caged and free-flying mosquitoes was compared. A Leco Model 120 calibrated to deliver 40 gal of fluid per hour and operated at a burner temperature of 850° F was used to disperse the thermal aerosols. The nonthermal aerosol generator (Curtis 55,000) was operated at a differential of 8 and 12 inches of mercury in the tests with malathion and naled, respectively.

Malathion was tested during the spring of 1967 against caged mosquitoes; naled was tested the following summer against both caged and free-flying mosquitoes. The procedures for the tests with caged mosquitoes were the same as those used in the tests of particle size.

The tests with malathion (Table 2) showed a slight difference in kill for the ULV and the high volume aerosols: the LD_{90} was 0.012 lb. of malathion per acre for the ULV aerosol and 0.018 lb. per acre for the high volume aerosol.

The data obtained with naled against

TABLE 1.—Effect of particle size on efficiency of kill of caged female *Aedes taeniorhynchus* (Wiedemann) with ultra-low volume nonthermal aerosols of undiluted malathion (95 percent).

Dose* (lb/acre)	Flow rate (gal/hr)	Air discharge (differential in in. Hg.)	Mass median diameter (microns)	Percent mortality after 18 hr at indicated distance (ft)			Average percentage mortality
				150	300	600	
0.0045	0.17	3.2	13.4	34	18	8	20
		5.2	11.6	34	38	18	30
		8	8.3	56	38	28	41
		12	6.0	50	38	38	42
.009	.34	3.2	17.4	90	52	70	71
		5.2	12.3	98	98	32	76
		8	9.7	100	100	88	96
		12	6.4	92	100	98	97
.018	.68	3.2	22.4	100	84	76	88
		5.2	14	100	100	100	100
		8	10.8	100	100	96	99
		12	7.6	100	100	100	100

* Based on a 600 ft swath and a truck speed of 5 m.p.h.

TABLE 2.—Comparison of ultra-low volume nonthermal and high volume thermal aerosols of malathion against caged female *Aedes taeniorhynchus* (Wiedemann).

Dose* (lb/acre)	Concentration (%)	Flow rate (gal/hr)	Percent mortality after 18 hr at indicated distance (ft)			Average percentage mortality
			150	300	600	
		ULV (95 percent malathion, undiluted)				
0.0045	95	0.17	68	48	40	52
.009	95	.68	100	89	61	83
.018	95	.68	99	97	99	98
.036	95	1.36	100	100	90	97
		High Volume (malathion diluted in No. 2 fuel oil)				
.0045	0.5	40	52	52	16	40
.009	1	40	89	87	81	86
.018	2	40	88	97	87	91
.036	4	40	96	100	90	95

* Based on a 600 ft swath and a truck speed of 5 m.p.h. except for the ULV dose of 0.009 lb/acre which was dispersed at 10 m.p.h.

caged mosquitoes (Table 3) indicated that the ULV aerosol was definitely more effective. For example, at a dose of 0.009 lb. of naled per acre, ULV aerosols gave 87 percent kill compared to 47 percent kill for the high volume aerosols. During these tests, the high volume applications of naled layered out at 10 ft. or more above ground; the ULV aerosols appeared to remain closer to the ground, which probably accounts for the greater kill with this type of application. (The results with malathion and naled should not be compared because the two compounds were not evaluated at the same time and the weather conditions were noticeably less favorable in the tests with naled.)

The tests with naled against free-flying mosquitoes (predominantly *A. taeniorhynchus*) were conducted in citrus groves near Titusville, Florida in a plot of about 6 acres. The landing rate of mosquitoes was counted at six locations, two each 100, 200, and 300 ft. from the path of the aero-

Table 3.—Comparison of ultra-low volume nonthermal and high volume thermal aerosols of naled against caged female *Aedes taeniorhynchus* (Wiedemann).

Dose[a] (lb/acre)	Concentration (%)	Flow rate (gal/hr)	Percent mortality after 18 hr at indicated distance (ft) 150	300	600	Average percentage mortality
		ULV (Naled, undiluted)				
0.0045	85	0.12	76	58	24	53
.009	85	.24	100	100	60	87
.018	85	.48	100	98	66	88
		High Volume (Naled, diluted in No. 2 fuel oil)				
.0045	0.5	40	32	8	2	14
.009	1	40	64	52	24	47
.018	2	40	70	92	80	81

[a] Based on a 600 ft swath and a truck speed of 5 m.p.h.

sol generators, just before the application (<1 hr.) and ½ and 12 hrs. after application. Doses of 0.018 and 0.036 lb. per acre were applied with the ULV nonthermal aerosol generator, and 0.036 lb. per acre was applied with the Leco fogger between 7:30 and 8 p.m. The formulation used in the Leco consisted of 2 percent naled in No. 2 fuel oil containing 0.5 percent Ortho additive (mixed amide-amine oleate from modified fatty acids and polyamines). The results are shown in Table 4. At a dose of 0.036 lb. per acre, the ULV aerosol gave 95 percent control in ½ hr. compared with 74 percent control for the high volume aerosol; the ULV aerosols containing 0.018 lb. per acre gave 85 percent control in ½ hr. Reinfestation occurred after 12 hrs. (overnight) with all treatments.

Summary. A nonthermal aerosol generator (Curtis Model 55,000) was modified to disperse ultra-low volume (ULV) aerosols of malathion and naled, and tests were conducted against both caged and natural populations of *Aedes taeniorhynchus* (Wiedemann). 1. At all doses tested, particles of malathion having mmd's of 6 to 10 microns were more effective than particles of 11 to 22 microns. 2. ULV nonthermal aerosols of malathion were at least as effective as high volume thermal aerosols against caged mosquitoes. 3. ULV aerosols of naled were more effective than high volume aerosols against caged and free-flying mosquitoes.

Table 4.—Comparison of ultra-low volume nonthermal and high volume thermal aerosols of naled against natural populations of salt-marsh mosquitoes, predominantly *Aedes taeniorhynchus* (Wiedemann).

Type of aerosol[a]	Dose (lb/acre)[b]	Concentration (%)	Flow rate (gal/hr)	Percentage control at indicated interval after treatment ½ hr	12 hr
Thermal, high volume	0.036	2	40	74	20
Nonthermal, ULV	.036	85	0.48	95	24
Nonthermal, ULV	.018	85	.24	85	0

[a] Naled was diluted in No. 2 fuel oil for high volume treatments and was undiluted for ultra-low volume treatments.

[b] Based on a 300 ft. swath and a truck speed of 5 m.p.h.

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Literature Cited

GLANCEY, B. M., LOFGREN, C. S., SALMELA, J., and DAVIS, A. N. 1965. Low volume aerial spraying of malathion for control of adult salt-marsh mosquitoes. Mosq. News 25(2):135–137.

GLANCEY, B. M., WHITE, A. C., HUSMAN, C. N., and SALMELA, J. 1966. Low volume applications of insecticides for the control of adult mosquitoes. Mosq. News 26(3):356–359.

KILPATRICK, J. W., JACOB, W. L., and ADAMS, C. T. 1967. Ultra-low volume application of malathion in Dallas, Texas to arrest an epidemic of encephalitis. Mosq. News (In press).

KNAPP, F. W., and PASS, B. C. 1966a. Low-volume aerial sprays for mosquito control. Mosq. News 26(1):22–25.

———. 1966b. Effectiveness of low-volume aerial sprays for mosquito control. Mosq. News 26(2):128–132.

KNAPP, F. W., and ROBERTS, W. W. 1965. Low volume aerial application of technical malathion for adult mosquito control. Mosq. News 25(1):46–47.

MOUNT, G. A., and LOFGREN, C. S. 1967. Ultra-low volume and conventional aerial sprays for control of adult salt-marsh mosquitoes, *Aedes sollicitans* (Walker) and *Aedes taeniorhynchus* (Wiedemann), in Florida. Mosq. News 27(4): 473–477.

STEVENS, L. F., and STROUD, R. F. 1966. Control of mosquito adults and larvae with ultra-low volume aerial applications of Baytex and Baytex-Baygon mixture. Mosq. News 26(2):124–128.

YEOMANS, A. H. 1949. Directions for determining particle size of aerosols and fine sprays. USDA Bur. Entomol. Pl. Quarantine ET-267.

PRELIMINARY HOST PREFERENCE STUDIES ON VIRGINIA *CULICOIDES* (DIPTERA:CERATOPOGONIDAE) [1]

JAKIE ALEXANDER HAIR [2] AND E. CRAIG TURNER, JR.[3]

Female *Culicoides* have available a great diversity of sources of blood meals, and the potential of these biting flies to act as vectors of a disease depends greatly on their source of blood. Kettle (10) believed that each species had a range of hosts on which it would feed, but generally preferred one. In addition to birds and mammals, *Culicoides* have been collected on turtles, lizards and recently engorged mosquitoes (4, 12, and 3). The most commonly reported mammalian host of *Culicoides* has been man. Jamnback (9) reported that 17 of the 37 species found in New York had been reported feeding on man. Numerous other reports are listed for species not found in the Eastern United States.

The works of Fallis and Wood (8), Fallis (5), Bennett and Fallis (2) and Fallis and Bennett (6) on host preferences of ornithophilic species of *Culicoides* have been the most extensive studies on host preferences for this group of blood-sucking flies. These workers used only a few hosts and all were fowl. Because of the almost complete lack of data on host preferences, the present study, utilizing as many as 14 different hosts, was undertaken. Failures in disease transmission studies of avian infectious synovitis by Turner *et al.*, (13) and of eastern viral encephalitis and vesicular stomatitis by Lee (11) can possibly be attributed to the utilization of improper species as potential vectors. Lee (11) stated that possible guides as to species to consider as disease vectors should result from further knowledge of host preferences for species of this group.

HOSTS AND SITES USED IN THIS STUDY. Due to inadequate knowledge as to the

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1356

EVALUATION OF THERMAL AND NONTHERMAL FOGS AGAINST FOUR SPECIES OF MOSQUITOES[1]

ROBERT T. TAYLOR AND H. F. SCHOOF

INTRODUCTION. Space spray evaluation of malathion, Dursban, naled and Baygon as thermal aerosols was conducted in Savannah, Georgia, in 1966. In addition, the studies included comparison of the relative effectiveness of thermal and nonthermal fogs and of oil and emulsion formulations.

METHODS AND MATERIALS. The test area used was described by Jakob (1966) and Schoof *et al.* (1962). Except for an increase in the density of the vegetation, none of the physical aspects of the area had changed.

The equipment[2] consisted of a Leco 120 thermal fog generator mounted on a ¾-ton truck and a Curtis "Cold Fogger" mounted on a trailer. In all evaluations malathion was formulated at a rate of 6 oz./gal. of finished spray, and naled, Dursban® (*O,O*-diethyl *O*-[3,5,6-trichloro-2-pyridyl phosphorothioate]) and Baygon® (*O*-isopropoxyphenyl methylcarbamate) at 2 oz./gal. The solvent was No. 2 fuel oil except when emulsions were under test. An auxiliary solvent, Ortho additive, was incorporated in the naled sprays at 0.4 percent by volume.

Oil formulations of malathion, naled, and Baygon were prepared from 95 percent technical malathion, 14 lb./gal. naled concentrate, and 1.5 lb./gal. Baygon concentrate, respectively. Emulsions of malathion and Dursban were formulated from concentrates containing 8 and 4 lb./gal. of the toxicants, respectively.

Tests were conducted at night between 7:00 and 11:00 p.m., using *Aedes aegypti*,[3] *Anopheles albimanus*,[4] and *Culex quinquefasciatus*[4] as the primary test insects, with *Aedes taeniorhynchus*[4] included on a limited basis. Approximately 100 females of each species after knock down by CO_2 were transferred into 3¼-inch diameter by 6-inch screen-wire cages. Caged specimens were prepared for exposure at sites at 150 and 300 feet on each of three streets and for each of four possible test runs per night; thus each test distance and species were replicated three times per run. The cages were hung 6 feet above the ground at the exposure stations, which were located along three streets 270 feet apart (Fig. 1). Malathion and naled also were tested at 75 feet. The length of the application run was 1,300 feet; the travel time at about 5 m.p.h. was 3 minutes. At a discharge rate of 40 gal./hr., 2 gallons of the formulation were discharged during each run. Runs were conducted only when wind velocities permitted a drift of the fog over the test area.

Each night's testing began with the malathion nonthermal fog and was followed by the test material. Malathion was then run as a thermal fog followed by the same test material. Approximately 15 minutes after each test run the cages were removed to the laboratory and the insects transferred to holding cages, given food, and held for 24-hour female mortality counts. Check insects were transported to the test site prior to each test and then returned to the laboratory grounds where they were suspended outdoors in the same manner as the treated specimens. Subsequent handling was the same as that for the treated mosquitoes.

RESULTS. Thermal and nonthermal fog tests with malathion at 6 oz./gal. and

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[1] From the Biology Section, Technical Development Laboratories, Aedes aegypti Eradication Program, National Communicable Disease Center, Bureau of Disease Prevention and Environmental Control, Public Health Service, U. S. Department of Health, Education, and Welfare, Savannah, Ga. 31402.

[2] The use of trade names is for identification purposes only and does not constitute product endorsement by the Public Health Service.

[3] DDT-dieldrin resistant strain.

[4] Susceptible strain.

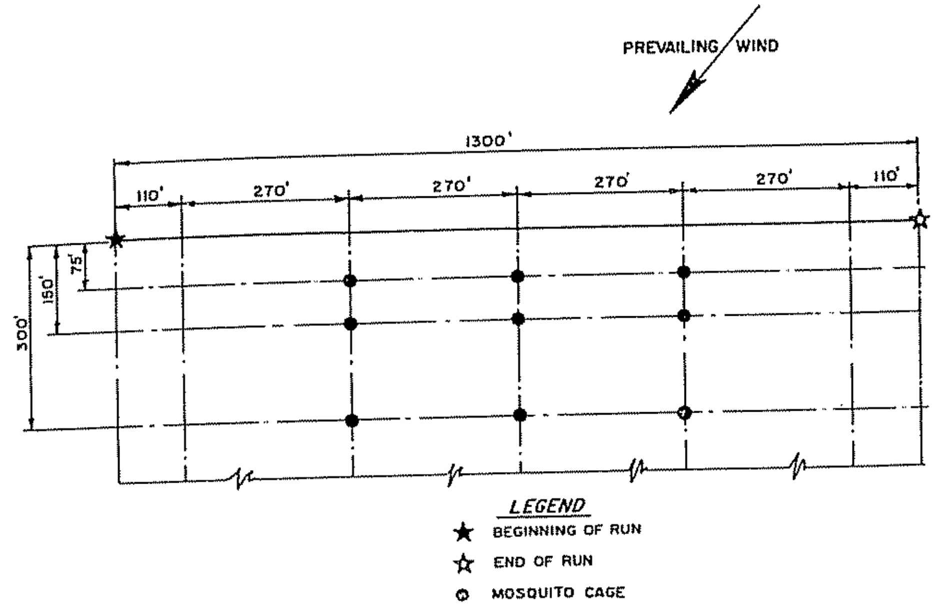

FIG. 1.—Location of caged mosquitoes in space spray studies, Savannah, Georgia, 1966.

Dursban, naled and Baygon at 2 oz./gal. showed malathion to be superior against *Ae. aegypti*, *C. quinquefasciatus*, *A. albimanus* and *Ae. taeniorhynchus* at distances up to 300 feet from the point of discharge of the fogs (Tables 1, 2 and 3). Of the compounds tested at the 2 oz./gal. dosage, Dursban was the most effective, Baygon the least effective. Naled gave unsatisfactory results with kills of about 70 to 75 percent of *Ae. aegypti* and *C. quinquefasciatus* at 150 feet. Against *A. albimanus* it was more effective with kills of 84–92 percent at 150 feet.

TABLE 1.—Percent kill of adult female mosquitoes 150 and 300 feet from the point of discharge of thermal fogs.

Insecticide	Test Runs	*Ae. aegypti* 150'	*Ae. aegypti* 300'	*An. albimanus* 150'	*An. albimanus* 300'	*Cu. quinque.* 150'	*Cu. quinque.* 300'
Malathion	12	94	83	94	84	94	82
Dursban	5	91	72	93	73	95	70
Naled	10	69	24	84	49	71	28
Baygon	3	20	14	91	42	43	22

TABLE 2.—Percent kill of adult female mosquitoes 150 and 300 feet from the point of discharge of nonthermal fogs

Insecticide	Test Runs	*Ae. aegypti* 150'	*Ae. aegypti* 300'	*An. albimanus* 150'	*An. albimanus* 300'	*Cu. quinque.* 150'	*Cu. quinque.* 300'
Malathion	12	97	89	98	95	86	79
Dursban [1]	6	90	75	90	75	91	80
Naled	12	74	24	92	51	75	31
Baygon	3	39	10	85	83	61	22

[1] Dursban was formulated as an emulsion; malathion, naled and Baygon as oil solutions.

TABLE 3.—Percent kill of adult female *Aedes taeniorhynchus* with malathion and naled fogs.

Insecticide (type fog)	Test runs	150′	300′
Malathion (thermal)	4	97	87
Malathion (nonthermal)	5	100	98
Naled (thermal)	2	59	27
Naled (nonthermal)	2	62	8

Thermal fogs of malathion appeared to be equally effective against all of the test species. Nonthermal fogs, however, were somewhat less effective against *C. quinquefasciatus*. The most susceptible mosquito appeared to be *A. albimanus* as indicated in tests with naled and Baygon.

Tests with specimens exposed at 75 feet showed that malathion and naled produced similar high levels of effectiveness against *Ae. aegypti* and *A. albimanus* but against *C. quinquefasciatus* malathion produced higher kills. At 150 feet the kills with naled were considerably less than those with malathion (Table 4).

Comparison of thermal fogs and nonthermal fogs formulated as oil solutions and emulsions showed little difference in effectivity against the test species (Table 5).

Temperatures ranged from 72° to 82° F. during the 7:00 and 11:00 p.m. test period; the average relative humidity was from 85 to 100 percent. Wind conditions varied from 0 to 500 feet per minute (0–6 m.p.h.); however, over 90 percent of the time the wind velocity was less than 1 m.p.h.

DISCUSSION. Against the four species involved, malathion gave the best results

TABLE 4.—Percent kill of adult female mosquitoes by malathion and naled 75 and 150 feet from the point of discharge of thermal fogs.[1]

	Malathion		Naled	
Species	75′	150′	75′	150′
Aedes aegypti	99	94	98	69
An. albimanus	98	94	97	84
Cu. quinque	98	94	82	71

[1] Four test runs each at 75 feet. 12 test runs of malathion and 10 test runs of naled at 150 feet

at the standard strength of 6 oz./gal., but Dursban at one-third the strength was almost as effective as a thermal fog. All of the compounds were effective against *A. albimanus* at 150 feet.

The fact that naled performed well at 75 feet confirms laboratory data that it is highly toxic to these mosquitoes but its dispersal beyond that distance appears to be much more affected by local conditions than is true of the other materials. Tests in previous years by Jakob (1966) produced much the same results.

There was no demonstrable difference between the biological effectiveness of thermal and nonthermal fogs of malathion, as was also found in tests by Mount *et al.* (1966). Neither was there any difference in effectiveness between oil and emulsion formulations as cold fogs. Emulsions were cleaner materials to work with in formulation and in equipment maintenance than were the fuel oil preparations.

SUMMARY. Baygon, Dursban and naled were tested in the field at Savannah, Georgia, against caged *A. albimanus, C. quinquefasciatus, Ae. aegypti* and *Ae.*

TABLE 5.—Percent kill of adult female mosquitoes with various fog formulations of malathion.

	Thermal Fogs		Nonthermal Fogs			
	(oil solutions)[1]		(oil solutions)[1]		(emulsions)[2]	
Species	150′	300′	150′	300′	150′	300′
Ae. aegypti	94	83	97	89	99	98
An. albimanus	94	84	98	99	99	90
Cu. quinque	94	82	96	86	96	86

[1] Twelve test runs.
[2] Three test runs.

taeniorhynchus. Baygon and naled were inferior to Dursban at 2 oz./gal. and only the latter approached malathion (6 oz./gal.) in efficacy. *C. quinquefasciatus* and *Ae. aegypti* were far more difficult to kill than *A. albimanus* with either Baygon or naled. Tests with malathion and naled at 75 feet produced similar results; at 150 and 300 feet, however, malathion was superior. No differences in effectiveness were detected between thermal and nonthermal fogs or between oil solutions and water emulsions.

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References

JAKOB, W. L. 1966. Thermal fog tests against *Aedes aegypti* (L.) and *Anopheles albimanus* (Wied.). Mosq. News 26(2):118–121.

MOUNT, G. A., LOFGREN, C. S., GAHAN, J. B., and PIERCE, N. W. 1966. Comparisons of thermal and nonthermal aerosols of malathion, fenthion, and naled for control of stable flies and salt-marsh mosquitoes. Mosq. News 26(2):132–138.

SCHOOF, H. F., ELMORE, C. M. JR., and DUFFY, J. P. 1962. Effectiveness of fog, dust and mist applications of several organophosphorus compounds against *Aedes taeniorhynchus*. Mosq. News 22(4):329–332.

SIMULATED FIELD EVALUATION OF PROMISING INSECTICIDES FOR USE AGAINST *AEDES AEGYPTI*[1]

ROBERT T. TAYLOR

INTRODUCTION. Simulated field studies along the lines of those of Brooks and his coworkers in 1965 (Brooks *et al.*, 1967) were continued during 1966 at Savannah, Georgia. Suspensions of the test compounds were evaluated as larvicides and adulticides for use in treatment of junk or trash-pile harborages of *Aedes aegypti*. Several of the insecticides were also compared as suspensions and emulsions under weathering conditions.

METHODS AND MATERIALS. In the larvicide tests, quarter sections of rubber tires and rusty No. 10 size tin cans were treated in triplicate with 1.25 and 2.5 percent suspensions of Abate,[2] Bayer 69047, bromophos, Dursban, fenitrothion, malathion, OMS-868, OMS-958, Schering 34615 and SD-8447 ("Gardona"). Dursban also was sprayed as a 0.625 percent suspension. A 2-gallon compressed air sprayer with an 8002 teejet nozzle and a pressure of 40 psi was used to apply the target dosages of 0.5, 1.0 and 2.0 g/m^2. The tires and tin cans were treated in place in an open field where they were subject to full weathering (Fig. 1).

In a second series, bromophos, Dursban, fenitrothion, Schering 34615 and Gardona treatments were applied to tire sections

[1] From the Biology Section, Technical Development Laboratories, Aedes aegypti Eradication Program, National Communicable Disease Center, Bureau of Disease Prevention and Environmental Control, Public Health Service, U. S. Department of Health, Education, and Welfare, Savannah, Ga. 31402.

[2] References to commercial materials, equipment, and processes are for identification purposes only and do not constitute endorsement by the Public Health Service.

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Selected Plastic Formulations for Use as Mosquito Larvicides[1,2]

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ABSTRACT

Laboratory evaluations were conducted of Abate® (*O,O*-dimethyl phosphorothioate *O,O*-diester with 4,4' thiodiphenol), Dursban® (*O,O*-diethyl *O*-3,5,6-trichloro-2- pyridyl phosphorothioate), naled, and malathion as mosquito larvicides formulated at selected concentrations into plastic pellets composed of polyvinyl chloride, polyurethane foam, and polyamide. Southern house mosquitos, *Culex pipiens quinquefasciatus* Say, were bioassayed with repeated use of single pellets, and mortality was recorded at the end of 24 hours. All nonfoam formulations except naled and malathion at 0.5 and 1.0% concentrations have given more than 90% mortality to date.

Pellet weight varied from 10 to 20 mg depending upon the plastic or mold used. Polyurethane foam pellets gave effective control for only 2 tests at all levels for each insecticide. Polyamide and polyvinyl chloride appear to show promise for slow larvicide release when applied at the same rate presently used in emulsion and granular applications. Naled-plastic formulations extend the longevity of this insecticide considerably and overcome its corrosive properties.

Until the advent of low-volume and ultra low volume (ULV) applications of insecticide, it was standard practice to use carrier formulations such as dusts and granules as mosquito larvicides. Advantages of carriers have been the increased penetration of insecticidal material through vegetative cover and the sustained release of insecticide, allowing effective long-term control.

Various synthetic and organic materials have been used as carriers. Elliott (1955) reported that briquettes formed of sand and cement, mixed with 50% dieldrin WP, controlled larvae of the yellow fever mosquito, *Aedes aegypti* (L.), in water jars for up to 1 year. Similarly, Evans and Fink (1960) used dieldrin-impregnated cement briquettes for control of *A. aegypti* in fire barrels. Barnes et al. (1967) reported that laboratory tests with charcoal briquettes and briquettes of a casting plaster-tap water mixture (2:1) impregnated with Abate® (*O,O*-dimethyl phosphorothioate *O,O*-diester with 4,4'thiodiphenol), and malathion gave excellent control of larvae of the southern house mosquito, *Culex pipiens quinquefasciatus* Say.

Use of plastic carriers in conjunction with mosquito larvicides has been limited, although plastic has been used for control of adult insects. Several years ago dichlorvos (DDVP) was impregnated into a resinous polyvinyl chloride (PVC) strip for control of various winged insects. Bultman et al.[4] (1966) incorporated polyvinyl chloride plastic with insecticides and tests in the Panamanian jungle indicated that this formulation may prove effective in reducing termite damage. More recently, Sanders and Knoke (1967) reported using 2 liquid plastic adjuvants (Plyac® and Estab®) as residual extenders with endosulfan, endrin, lindane, and malathion placed on the stems of seedlings of young cacao, *Theobroma cacao* L.

There is a wide range of plastics, rubbers, and related synthetic materials currently on the market which can compete both on an economical and physical basis with many of the carriers currently used in mosquito larvicide formulations. Laboratory screening of candidate materials was initiated at the U.S. Army Environmental Hygiene Agency in 1967 to investigate the potential of these organic substrates. Consultations with polymer chemists resulted in the selection of 3 plastics for initial testing; PVC, polyurethane foam, and polyamides.

This paper reports the findings of these laboratory tests. Field tests of promising formulations are planned for the spring and summer of 1968.

METHODS AND MATERIALS.—Technical grades of Abate, Dursban® (*O,O*-diethyl *O*-3,5,6-trichloro-2-pyridyl phosphorothioate), naled, and malathion were incorporated into 1 or all of the aforementioned synthetic materials.

Dosage-mortality tests were conducted with each insecticide as a prelude to these investigations. Ap-

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[2] The use of trade names is for identification purposes only and does not imply endorsement by the U.S. Army.

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[4] J. D. Bultman, J. M. Leonard, and C. R. Southwell. 1966. Termite Resistance of Polyvinyl Chloride plastics. Memorandum Report 1704, U.S. Naval Research Laboratory, Washington, D. C. (5 p.)

Table 1.—Toxicity of 4 insecticides (in ppm) to southern house mosquito larvae.[a]

Insecticide	LC_{50}	LC_{95}
Abate	0.00037	0.00060
Naled	.038	.044
Dursban	.00041	.00070
Malathion	.098	.21

[a] Avg of 3 tests with duplicate pint jars; 20 late-2nd- or early-3rd-instar larvae/jar; 250 ml of demineralized water/jar.

propriate acetone solutions of each insecticide were added to 250 ml of water in pint jars to obtain the desired concentrations. Twenty laboratory-reared southern house mosquito larvae were placed in each jar. Mortality readings were made after 24 hr and log-dosage-probit lines were constructed. Table 1 shows the estimated LC_{50} and LC_{95} values. Laboratory studies using PVC are complete; however, new formulations will be studied as available. Preliminary studies using polyurethane foam and polyamides are currently underway.

Polyvinyl Chloride.—Four insecticides; Abate, naled, Dursban, and malathion were mixed with PVC to give 0.5, 1.0, 5.0, 10.0, and 20.0% (w/w) mixtures. The resulting material was poured into a 3/8-in.-thick aluminum mold plate containing round depressions 1/4 or 3/8 inch in diam. The plastic was set by heating the mold at 150° C for 20 min, then cooled by immersing in cold water. The resulting pellets were removed and bioassayed by placing 1 pellet of each insecticide concentration into a glass jar containing 250 ml of demineralized water and 20 larvae. Triplicate tests were conducted at each concentration along with untreated controls. Mortality was recorded after 24 hr. The pellets were then removed, placed into a clean jar containing 250 ml of fresh water and 20 larvae, and the test was continued. Naled, Dursban, and Abate pellets weighed an average of 70 mg; malathion pellets averaged 210 mg.

Polyamide.—Pellets have been prepared from Elvamide®[5] 8061, 8062, and 8063 at 0.5, 1.0, 5.0, 10.0, and 20.0% (w/w) of Abate, naled, Dursban, and malathion. Elvamide nylon resin was weighed and sufficient absolute methyl alcohol was added to dissolve the nylon when heated and agitated. The desired weight of insecticide was added and mixed for 20 min when the solution reached the viscosity of molasses. The material was poured into either a mold or a pan to allow excess alcohol to evaporate. The resulting sheets were cut into pellets with a no. 2 cork borer. The pellets, each weighing 60 mg, appeared hard and white upon drying, and with higher concentrations of insecticide were slightly oily to the touch. Upon drying, the pellets were bioassayed in the same manner as that used for polyvinyl chloride pellets.

Polyurethane Foam.—Technical grades of Dursban, naled, Abate, and malathion were combined with the polyurethane foam component W of Isofoam PE-12®[6] to give a 0.5, 1.0, 5.0, 10.0, and 20.0% (w/w) mixture at the completion of the foaming reaction. The solution was mixed with Isofoam PE-12 component A at a ratio of 75 parts W to 100 parts A. The resulting reaction produced a foam weighing 12 lb/ft³. Isofoams in other densities are available to formulate lighter or heavier foams as required. The insecticidal foam was evaluated in 2 ways; in pellets and in granulated foam. A no. 3 cork borer was used to bore out foam pellets weighing 20 mg each. A pellet was placed into a glass mason jar containing 250 ml of demineralized water and 20 southern house mosquito larvae. Mortality readings were made after 24 hr. The pellets were removed from jars where 100% mortality occurred and were placed into new jars containing fresh water and live mosquito larvae. Where 100% mortality did not occur, the pellet remained in the jar until 100% mortality was achieved. Larvae were fed rabbit chow throughout the test.

In another series of tests, the insecticidal foam was cut into small chunks, placed into a Waring blender, and chopped to a fine consistency. Ten mg of the resulting ground foam was placed into glass jars and bioassayed as in previous tests.

RESULTS AND DISCUSSION.—Table 2 shows results using polyvinyl chloride pellets. Pellets containing 50% Abate gave effective control for 142 tests. For purposes of this paper, effective control is defined as 90–100% mortality. It was noted that from the 3rd to the 9th test there was a breakdown of effective control with the 25% pellet, mortality dropping to as low as 30%. It appears that after initial release of insecticide situated on the periphery of the pellet, the toxicant deeper within the pellet did not diffuse into the water at the same rate as did the peripheral toxicant. However, after the 9th day, 90–100% control was obtained for more then 133 additional tests. Abate at 0.5, 1, 5, 10, and 20% gave effective control for the entire testing period (37 tests).

Pellets containing Dursban, naled, and malathion have not been evaluated over the same time frame as

Table 2.—Effectiveness of control of several insecticides incorporated into polyvinyl chloride.

Insecticide	% concn (w/w)	No. tests	No. tests with 90–100% mortality
Abate	0.5	37	37
	1.0	37	37
	5.0	37	37
	10.0	37	37
	20.0	37	37
	25.0	142	136
	50	142	142
Dursban	.5	40	40
	1	40	40
	5	40	40
	10	40	40
	20	40	40
Malathion	.5	37	31
	1	37	33
	5	37	37
	10	37	27
	20	37	37
Naled	.5	37	17
	1	37	23
	5	37	33
	10	37	33
	20	37	34

[5] Elvamide available from E. I. Dupont de Nemours & Company, Wilmington, Del. 19898.
[6] Available from Isocyanate Products, Inc., 700 Wilmington Road, New Castle, Del.

Table 3.—Effectiveness of control of several insecticides incorporated into polyamide.

	% concn (w/w)	No. tests	No. tests with 90–100% mortality
Abate	0.5	24	24
	1	24	24
	5	24	24
	10	142	131
	10	24	24
	20	24	24
Dursban	5	43	38
	1	43	43
	5	43	43
	10	43	43
	20	43	43
Malathion	5	24	5
	1	24	5
	5	24	12
	10	24	21
	20	24	24
Naled	5	24	3
	1	24	5
	5	24	8
	10	24	9
	20	24	16

have Abate pellets. However, it was found that Dursban gave 95–100% control at all concentrations for 40 tests. Pellets containing 0.5 and 1.0% malathion gave inconsistent mortalities, with a loss of effective control from test 16 to test 21. The inconsistency found with these pellets was not interpreted as a breakdown of the insecticide remaining in the pellet but rather a lack of uniformity in the diffusion of the insecticide from the pellet.

Pellets containing 0.5% naled began to lose their effectiveness after 17 tests, 1.0% pellets after 23 tests, and 5.0% after 33 tests. Effective control was obtained with 10 and 20% pellets for 34 tests. When low 24-hr mortality occurred with the 0.5 and 1.0% pellets, they were kept in the jars for an additional 38 hr. After that time, the 0.5% pellets were still ineffective. However, 100% mortality was obtained with 1.0% pellets. As would be expected, the smaller amounts of insecticide remaining in the 0.5 and 1.0% pellets took longer to diffuse into the water.

In the past, naled has not been used as a larvicide because of its rapid decomposition in water. When incorporated into plastic, it appears that decomposition is not so rapid and the naled remains effective for a longer period.

As mentioned previously, the use of polyurethane foam and polyamides is still under investigation. Polyurethane pellets containing Dursban and naled gave complete kill at all concentrations when they were initially placed into water. Only the higher concentrations gave effective control after 2 or more tests; with Abate, only 5.0, 10.0, and 20.0% pellets gave effective control in 24 hr, while only the 20.0% malathion pellets were effective. In all probability, most of the insecticide found near the surface of the foam is released into the water. Since the physical composition of the foam is one of discontinuous cells, the insecticide, in diffusing from the middle of the foam granule to the periphery, would essentially have to traverse the surfaces of adjoining spheres and thereby would have a considerably greater distance to travel than, e.g., the radial distance of a solid spherical granule.

The polyurethane ground to a fine dust in the blender gave effective control in the few tests which were conducted. Evaluation of long-term residual effects of the ground foam has not been possible because of the difficulty of recovering the small pieces of floating material.

The tests using Dursban, malathion, naled, and Abate in nylon (polyamide) have also looked promising (Table 3). Effective control has been obtained with separate 10% Abate pellets in more than 131 tests. After 43 tests there has been effective control with Dursban pellets at 1.0, 5.0, 10.0, and 20.0% concentrations, while 0.5% lasted for 38 tests. Abate gave complete mortality at all concentrations for 24 tests. Naled and malathion were less effective, with only the 20% concentration of malathion lasting the entire testing period (24 tests).

The main requirement for larviciding for mosquito control has been mortality 24 hr after insecticide application. When a prehatching treatment is applied, even under ideal conditions the larvicide has a minimum of 4–5 days to cause mortality to the developing larvae. It was noted by Barnes and Webb (1968) that in treated pools where insecticide levels in the water were not lethal to the mosquito larvae there was a retardation in larval development. It may be that the sublethal amounts of insecticide being released into the water by various plastic formations would inhibit the normal development of the larvae until a lethal concentration was obtained. Observations on effects of sublethal concentrations were not made in our laboratory tests, since most tests were terminated in 24 hr.

A problem often encountered with larvicides is the breakdown of the toxicant by various physical and chemical means. It appears that another advantage of plastics is that while there is a slow release of the insecticide from the pellet into the water, water does not appear to penetrate the deep layers of the plastic. Therefore, the toxicant remaining in the pellet could be protected from these breakdown forces.

This paper has dealt with the use of plastic formulations as mosquito larvicides. There is a possibility that use of other agricultural pesticides and plant additives with plastics would permit longer intervals between applications. The principle of slow release from a material has been widely used in pharmaceuticals, and in view of increasing labor costs, should be given consideration for use in agriculture. One can envision a herbicide that is applied every 5th year, a growth stimulant applied every 10th year, fungicides every second year, and household insects controlled by polymer-pesticide-impregnated building materials.

In summary, laboratory tests with various synthetic plastic materials were conducted to determine the feasibility of their use as a carrier for mosquito larvicides. Thus far, insecticides incorporated into PVC and polyamide have given very promising results. The plastic allows a slow diffusion of the insecticide, thereby producing long-term residual control. Extensive field tests in 1968 should give more critical data on the future of plastic–insecticide formulations in mosquito abatement.

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REFERENCES CITED

Barnes, W. W., and A. B. Webb. 1968. A field evaluation of Abate briquettes in woodland pools. Mosquito News (In press.)

Barnes, W. W., A. B. Webb, and L. B. Savage. 1967. Laboratory evaluation of Abate and malathion insecticidal briquettes. Mosquito News 27(4): 488–90.

Elliott, R. 1955. Larvicidal control of peridomestic mosquitoes. Roy. Soc. Trop. Med. Hyg. Trans. 49(6): 528–42.

Evans, R., and E. J. Fink. 1960. Dieldrin cement briquettes in controlling *Aedes aegypti* in fire barrels. Mosquito News 20(4): 388–9.

Sanders, J. L., and J. K. Knoke. 1967. Persistence of endosulfan, endrin, lindane, and malathion on cacao seedlings when formulated with Plyac® and Estab® liquid plastic adjuvants. J. Econ. Entomol. 60(2): 588–9.

Field-Cage Releases of *Chrysopa carnea*[1] for Suppression of Populations of the Bollworm[2] and the Tobacco Budworm[2] on Cotton[3,4]

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ABSTRACT

When inundative releases of larvae and eggs of a green lacewing, *Chrysopa carnea* Stephens, were tested in field cages to determine effects on the bollworm, *Heliothis zea* (Boddie), and the tobacco budworm, *H. virescens* (F.), the predator reduced larval populations from 73.8 to 99.5% (a minimum of 266 larvae/acre). The differences in percentage reduction were probably caused by the differences in numbers of lacewings released, the amount of alternate prey available, and the population of *Heliothis* spp. present.

When eggs and larvae of the predator were released in the presence of abundant prey, 23.5 and 25.0%, respectively, were recovered as pupae or adults. Escapes and inefficient collecting were probably responsible for only partial recovery of the pupae and adults. Different sized populations of *C. carnea* were established by releasing different numbers.

Natural predators and parasites often play a substantial role in regulating populations of the bollworm, *Heliothis zea* (Boddie), and the tobacco budworm, *H. virescens* (F.), in cotton fields (Quaintance and Brues 1905, Fletcher and Thomas 1943, Ewing and Ivy 1943, Wille 1951, Whitcomb and Bell 1964, Ridgway et al. 1967). However, they frequently do not prevent the populations of *Heliothis* spp. from reaching economically important levels. Therefore, it would be desirable to augment the natural levels of predators and parasites by liberating mass-reared insects. These releases could be made periodically as a control measure, or they might be integrated with other methods of control as part of a total population-suppression program (Knipling 1966).

Numerous predators and parasites are known to attack bollworms and tobacco budworms on cotton, but available information indicated that green lacewings, *Chrysopa* spp., might be particularly effective. For instance, Quaintance and Brues (1905) mentioned the larvae of lacewings among the more important predators of the bollworms, Whitcomb and Bell (1964) stated that few insects were as efficient predators, Reed (1965) stated that a *Chrysopa* sp. was the main predator of *H. armigera* (Hübner) in Western Tanganyika, and van den Bosch and Hagen (1966) reported that green lacewings are among the most important beneficial insects in California cotton fields. Also, Fleschner (1950), though his laboratory studies were not specifically related to cotton, indicated that *C. carnea* Stephens was a particularly efficient predator. More recently, laboratory and field-cage studies made by Lingren et al. (1968) demonstrated that larvae of *Chrysopa* spp. could reduce a population of caged tobacco budworms by 96.5%.

Chrysopa spp. have another advantage over other predators. They are tolerant to many insecticides (Bartlett 1964, Lingren and Ridgway, 1967). Also, the larvae are apparently not killed by systemic insecticides that are injurious to other predators (Ahmed et al. 1954, Ahmed 1955, Ridgway et al. 1967). Thus, they could be well integrated into a program of control that included certain conventional or systemic insecticides.

At least 7 species of *Chrysopa* occur in cotton fields in the United States. Of these, *C. carnea* is among the most abundant (Burke and Martin 1956, Whitcomb and Bell 1964, van den Bosch and Hagen 1966) and probably the most widely distributed (Braum and Bickley 1963). Our collection of 198 adult *Chrysopa* spp. from 2 central Texas cotton fields during June and July 1966 included 62, 34, and 4% of *C. carnea*, *C. rufilabris* Burmeister, and *C. oculata* Say, respectively. Therefore, *C. carnea* was chosen for our present study because of its general distribution and commercial availability. (Eggs and larvae were purchased from Vitova Company, Inc., Rialto, Calif.)

GENERAL METHODS AND MATERIALS.—During the summer of 1966, 3 experiments were conducted on

[1] Neuroptera: Chrysopidae.
[2] Lepidoptera: Noctuidae.
[3] In cooperation with the Texas Agricultural Experiment Station, Texas A&M University, College Station. Accepted for publication March 20, 1968.
[4] Mention of a proprietary product does not necessarily imply its endorsement by the USDA.
[5] The technical assistance of L. J. Gorzycki of this Division, and J. R. Cate, J. W. Shane, and J. L. Baldwin of Texas A&M University is gratefully acknowledged

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(1346)

NEW INSECTICIDES AS NONTHERMAL AEROSOLS FOR CONTROL OF ADULT MOSQUITOES[1]

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The continual development of resistance to insecticides by various species of mosquitoes emphasizes the need to search constantly for new compounds for their control. Such a search for adulticides has been carried on by this laboratory through many years. Essentially, it now consists of: (1) wind tunnel tests in the laboratory to select promising compounds; (2) preliminary field evaluations in which caged mosquitoes are exposed to thermal or nonthermal aerosols; and (3) aerial spraying and fogging against natural populations of mosquitoes. The present paper presents results of recent tests made during the second phase of these investigations.

Eight insecticides were compared with three standard insecticides as nonthermal aerosols against three species of mosquitoes, *Aedes taeniorhynchus* (Wiedemann), *Culex pipiens quinquefasciatus* Say, and *Anopheles quadrimaculatus* Say. Although these data were obtained with nonthermal aerosols, they indicate the results that could be expected from thermal aerosols since Mount *et al.* (1966) demonstrated that nonthermal and thermal aerosols are equal in effectiveness.

METHODS AND MATERIALS. The tests were conducted in an open field near Gainesville, Florida from April to October 1966. Most tests were performed between 6 and 9:00 p.m.; however, several tests in October were conducted between 4:30 and 6:00 p.m. Atmospheric conditions were favorable for all tests. Temperatures 5 feet above the ground ranged from 72 to 85° F and averaged about 80° F. Wind speeds ranged from <2–12 m.p.h. and averaged about 4 m.p.h.

The insecticides tested were as follows:

- Sumithion® (*o,o*-dimethyl *o*-4-nitro-*m*-tolyl phosphorothioate)
- Bay 39007 (*o*-isopropoxyphenyl methylcarbamate)
- Schering 34615 (*m*-cym-5-yl methylcarbamate)
- Dursban® (*o,o*-diethyl *o*-3,5,6-trichloro-2-pyridyl phosphorothioate)
- Shell SD-8211 (2-chloro-1-(2,5-dichlorophenyl) vinyl dimethyl phosphate)
- Barthrin
- Abate® (*o,o*-dimethyl phosphorothioate *o,o*-diester with 4,4′-thiodiphenol)
- Shell SD-8447 (2-chloro-1-(2,4,5-trichlorophenyl) vinyl dimethyl phosphate)

Fenthion, naled, and malathion were included as standards.

Commercial emulsifiable concentrates were used with all compounds except barthrin and Schering 34615. The concentrations of the commercial preparations in lb./gal. were: Sumithion (4.75), Bay 39007 (1.5), Dursban (4), Shell SD-8211 (2), Abate (4), Shell SD-8447 (2), fenthion (4), naled (8), and malathion (5). The emulsifiable concentrate of barthrin was prepared by dissolving 2 pounds of technical barthrin in a gallon of a mixture of xylene and Triton X-100 emulsifier (9:1 ratio). The emulsifiable concentrate of Schering 34615 was prepared by mixing equal parts of a 25 percent emulsifiable concentrate with a solution of xylene and Triton X-100 emulsifier (9:1 ratio), since the commercial preparation of Schering 34615, 25 percent E.C., did not form a stable emulsion at the concentrations needed.

The nonthermal aerosol generator used to disperse the formulations was a truck-mounted Curtis Model 55,000 calibrated to deliver 40 gallons of liquid per hour. The generator was moved at 5 m.p.h. Adult

[1] Mention of a proprietary product does not necessarily imply endorsement by the U. S. Department of Agriculture.

female mosquitoes, 2–7 days old, were exposed in 16-mesh screen wire cages (25 per cage) which were suspended 5 feet above ground from stakes 150 and 300 feet downwind and in a row perpendicular to the line of travel of the generator. Three cages (one containing mosquitoes of each species) were hung on each stake, a total of six cages of mosquitoes for each replication. From 2–6 replications were conducted with each concentration of each insecticide. After the passage of the aerosol generator, the mosquitoes were transferred to plastic tubes lined with clean paper. Except during exposure to the aerosols, the mosquitoes were held in insulated chests containing ice in cans. Absorbent cotton pads dipped in 10 percent sugar-water solution were placed on the holding tubes when they were returned

TABLE 1.—Mortality of adult females of three species of mosquitoes 18 hours after exposure to nonthermal aerosols of various insecticides formulated as water emulsions.

Insecticide	Concentration (%)	Percentage mortality of indicated species[a]: *Aedes taeniorhynchus*	*Culex pipiens quinquefasciatus*	*Anopheles quadrimaculatus*	Average for 3 species
		New Insecticides			
Sumithion	0.5	18	46	21	28
	1	86	87	87	87
	2	92	99	100	97
	4	98	100	100	99
Bay 39007	.5	58	30	81	56
	1	75	44	89	69
	2	100	96	100	99
	4	100	93	100	98
Schering 34615	.5	20	44	9	24
	1	73	86	86	82
	2	63	99	70	77
	4	96	100	100	99
Dursban	0.5	13	42	1	20
	1	54	70	65	63
	2	76	98	87	87
	4	96	98	84	93
Shell SD-8211	1	45	53	34	44
	2	83	90	49	74
	4	97	100	87	95
Barthrin	2	23	18	61	34
	4	70	75	99	81
Abate	2	21	31	4	19
	4	74	88	49	70
Shell SD-8447	4	76	38	8	41
		Standards			
Fenthion	0.5	57	65	53	58
	1	93	83	84	87
	2	100	94	94	96
	4	100	99	99	99
Naled	.5	85	42	57	61
	1	80	54	68	67
	2	99	84	99	94
	4	100	99	96	98
Malathion	1	47	32	51	43
	2	83	80	85	83
	4	95	84	90	90
None (check)		5	3	4	4

[a] Average mortality at 150 and 300 feet.

to the laboratory. Mortality counts were made 18 hours after exposure to the aerosols.

RESULTS AND DISCUSSION. The mortality data obtained for all three species of mosquitoes are presented in Table 1; the respective estimated LC_{90}'s are shown in Table 2. On the basis of the combined average LC_{90}'s for the three species, Sumithion, with an LC_{90} of 1.3 percent, was about equal to the fenthion standard (1.2 percent) and slightly more effective than the naled standard (1.9 percent). Bay 39007 and Schering 34615, with LC_{90}'s of 1.6 percent and 2.1 percent, respectively, were about equal to naled and were twice as toxic as malathion. Previously Mount *et al.* (1967) reported that Sumithion and Bay 39007 were highly effective as nonthermal aerosols against caged female *A. taeniorhynchus*, and Lofgren *et al.* (1966) obtained good results with Bay 39007 and Bay 41831 (Sumithion) as nonthermal aerosols against *Culex tritaeniorhynchus* Giles and *C. p. quinquefasciatus*.

As shown in Table 2, Dursban and Shell SD-8211, with average LC_{90}'s of 2.5 percent and 3.2 percent, were less effective than fenthion and naled, but were more effective than the malathion standard (4 percent). In other tests with nonthermal aerosols, Mount *et al.* (1967) showed that Dursban was highly effective against *A. taeniorhynchus*, and Lofgren *et al.* found Shell SD-8211 to be effective against *C. tritaeniorhynchus* and *C. p. quinquefasciatus*. Shell SD-8211 was also demonstrated to be 1.3 times more toxic than malathion in laboratory wind-tunnel tests by Glancey *et al.* (1966). As shown in Table 2, barthrin, Abate, and Shell SD-8447 were generally less effective than malathion, but barthrin was more effective against *A. quadrimaculatus*.

In general, the results obtained with the 3 species of mosquitoes were about the same; however, Bay 39007 was less effective against *C. p. quinquefasciatus* than against the other species, whereas, Shell SD-8211 was least effective, and barthrin was most effective against *A. quadrimaculatus*.

TABLE 2.—LC_{90} values for adult females of three species of mosquitoes exposed to nonthermal aerosols of various insecticides formulated as water emulsions.

Insecticide	LC_{90} (%) for indicated species			
	Aedes taeniorhynchus	*Culex pipiens quinquefasciatus*	*Anopheles quadrimaculatus*	Average for 3 species
	New Insecticides			
Sumithion	1.6	1.1	1.1	1.3
Bay 39007	1.7	2.2	1.0	1.6
Schering 34615	2.7	1.1	2.4	2.1
Dursban	2.9	1.6	2.9	2.5
Shell SD-8211	2.7	1.9	>4	3.2
Barthrin	>4	>4	2.8	>4
Abate	>4	>4	>4	>4
Shell SD-8447	>4	>4	>4	>4
	Standards			
Fenthion	1.0	1.2	1.3	1.2
Naled	1.2	2.6	1.8	1.9
Malathion	2.7	>4	3.8	4

SUMMARY. Nonthermal aerosols of eight new insecticides and three standards (malathion, naled, and fenthion) were evaluated against caged female *Aedes taeniorhynchus* (Wiedemann), *Culex pipiens quinquefasciatus* Say, and *Anopheles quadrimaculatus* Say. Sumithion (*O,O*-dimethyl *O*-4-nitro-*m*-tolyl phosphorothioate) was about equal to fenthion and slightly more effective than naled. Bay

39007 (*o*-isopropoxyphenyl methylcarbamate) and Schering 34615 (*m*-cym-5-yl methylcarbamate) were about equal to naled and twice as effective as malathion. Dursban (*O,O*-diethyl *O*-3,5,6-trichloro-2-pyridyl phosphorothioate) and Shell SD-8211 (2-chloro-1-(2,5-dichlorophenyl)= vinyl dimethyl phosphate) were less effective than fenthion or naled but were more effective than malathion. Barthrin, Abate (*O,O*-dimethyl phosphorothioate *O,O*-diester with 4,4'-thiodiphenol), and Shell SD-8447 (2-chloro-1-(2,4,5-trichlorophenyl) vinyl dimethyl phosphate) were generally less effective than malathion, but barthrin was more effective against *A. quadrimaculatus*.

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Literature Cited

GLANCEY, B. M., SAVAGE, K. E., and LOFGREN, C. S. 1966. Laboratory evaluation of promising insecticides against adult salt-marsh mosquitoes, *Aedes taeniorhynchus* (Wied.). Mosq. News 26(3):397–399.

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ULTRA-LOW VOLUME AND CONVENTIONAL AERIAL SPRAYS FOR CONTROL OF ADULT SALT-MARSH MOSQUITOES, *AEDES SOLLICITANS* (WALKER) AND *AEDES TAENIORHYNCHUS* (WIEDEMANN), IN FLORIDA [1]

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The past few years the concept of low volume spraying, that is, the use of undiluted or concentrated insecticide, for area control of insects has captured the imagination of many engaged in insect control. In large-scale insect control programs, the savings in cost, time, and labor that this technique offers are enormous. Credit for the modern-day interest in this method goes to the Methods Improvement Section of the Plant Pest Control Division (PPCD), ARS, USDA. The first experiments with this method (in grasshopper control) were reported by Messenger (1963, 1964).

Before proceeding, it is necessary to clarify terminology in this field. It is quickly obvious in talking to people involved in other aspects of insect control that the term "low volume" is not very descriptive. Researchers on cotton insects consider as "low volume" applications of technical or concentrated insecticide between ½ to 15 gallons per acre. One-half gallon or less is called "ultra-low volume." From this definition it is apparent that ultra-low and low volume sprays have been used for mosquito control for many years. In fact over 15 years ago Blanton *et al.* (1950) reported on tests in Alaska where

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(1347)

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Literature Cited

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ULTRA-LOW VOLUME AND CONVENTIONAL AERIAL SPRAYS FOR CONTROL OF ADULT SALT-MARSH MOSQUITOES, *AEDES SOLLICITANS* (WALKER) AND *AEDES TAENIORHYNCHUS* (WIEDEMANN), IN FLORIDA[1]

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The past few years the concept of low volume spraying, that is, the use of undiluted or concentrated insecticide, for area control of insects has captured the imagination of many engaged in insect control. In large-scale insect control programs, the savings in cost, time, and labor that this technique offers are enormous. Credit for the modern-day interest in this method goes to the Methods Improvement Section of the Plant Pest Control Division (PPCD), ARS, USDA. The first experiments with this method (in grasshopper control) were reported by Messenger (1963, 1964).

Before proceeding, it is necessary to clarify terminology in this field. It is quickly obvious in talking to people involved in other aspects of insect control that the term "low volume" is not very descriptive. Researchers on cotton insects consider as "low volume" applications of technical or concentrated insecticide between ½ to 15 gallons per acre. One-half gallon or less is called "ultra-low volume." From this definition it is apparent that ultra-low and low volume sprays have been used for mosquito control for many years. In fact over 15 years ago Blanton *et al.* (1950) reported on tests in Alaska where

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application rates of DDT in oil as low as ¼ pint or 4 fl. oz. were evaluated against mosquitoes.

To avoid confusion in this paper, "ultra-low volume" will be used to designate any spray in which total volume applied is less than ½ gallon per acre. This will also be done when referring to the work of other authors even though they used different terminology. Applications greater than ½ gallon will be referred to as "conventional" sprays.

At the Gainesville laboratory, we became interested in ultra-low volume spraying through our contacts with PPCD, and in 1964, we obtained the Mini-Spin ® nozzles recommended by them. In late summer and fall of that year, the first tests were made in Florida (Glancey *et al.*, 1965). The results showed clearly that rates of application of technical malathion as low as 2 fl. oz. per acre could give good control of salt-marsh mosquitoes, *Aedes sollicitans* (Walker) and *A. taeniorhynchus* (Wiedemann) (over 90 percent in 24 hours). Also, Knapp and Roberts (1965) reported good control of *A. sollicitans* in preliminary tests in Kentucky with ultra-low volume applications of malathion.

Further tests in 1966 (Glancey *et al.*, 1966a) showed that ultra-low volume applications could be used successfully with other insecticides; they obtained excellent control with naled and various combinations of naled and malathion. Fenthion was also tested. Although the doses applied (0.016–0.03 lb. per acre) were below the rates required for optimum control, the results again appeared promising. For these tests, they used a self-contained spraying system which circumvented the conventional system. It consisted essentially of a small stainless-steel spray tank pressurized by CO_2 gas from a cylinder located in the baggage compartment behind the pilot. A Tygon ® insecticide line extended from the baggage compartment through the pilot's compartment, where a control valve was located, and out along the standard spray boom. The insecticide was dispersed through two or four Mini-Spin nozzles attached to the metal boom and the Tygon tubing. This system eliminated the continual problem of blockages of lines and nozzles of the conventional system so volumes of liquid as low as ¼ fl. oz. per acre could be used.

In all the tests at the Gainesville laboratory, and in all those of other investigators, no direct comparison has been made of the effectiveness of ultra-low volume sprays with conventional sprays. Obviously, such information is necessary before judgments can be made of the true effectiveness of ultra-low volume treatments. In Florida, the conventional spray rate recommended by the State Board of Health is 1 to 6 quarts per acre, and 3 quarts per acre has been our standard rate of application in tests for many years. This paper presents results of tests conducted this past year in which the effectiveness of ultra-low and conventional sprays (3 quarts per acre) of malathion, naled, and fenthion was compared against mixed populations of the two salt-marsh mosquitoes, *A. taeniorhynchus* and *A. sollicitans*.

METHODS AND MATERIALS. The tests were conducted between July and September 1966 in 10- to 40-acre citrus groves adjacent to salt marshes on the north end of Merritt Island near Titusville, Florida. Large numbers of the two species of salt-marsh mosquitoes were in the citrus groves throughout the tests; pretreatment counts for the individual plots ranged from 7 to 741 per man per 30 seconds, and the average for all tests was 72 mosquitoes per man per 30 seconds.

The sprays were applied from a Stearman airplane owned and operated by the Brevard Mosquito Control District, Merritt Island, Florida. In all the tests, the airplane was flown at a speed of 85 m.p.h., at an altitude of 50 to 75 feet, and at 100-foot swath intervals.

A self-contained system similar to that described by Glancey *et al.* (1966b) was mounted on the plane and used for all ultra-low volume treatments. Differences were the three-eighths inch polyethylene tubing used throughout the unit to compensate for the high degree of solvency of some components of the formulations and the four flat fan Tee Jet® nozzles (Spraying Systems Co.) used instead of Mini-Spin nozzles. These nozzles were spaced 6 and 12 feet from each side of the fuselage and under the lower wings of the airplane. The desired rate of application of each formulation was obtained by varying the nozzle size (No. 800067 to No. 8003) and line pressure (24 to 42 p.s.i.). The volume of spray applied per acre ranged from 1.6 to 6.4 fl. oz., depending on the dose desired and the concentration of insecticide in the formulation.

Conventional spraying was done with a typical metal spray boom equipped with 17 flat fan Tee Jet (#6510) nozzles operated at a pressure of 20 p.s.i. In all tests the orifices of the nozzles were oriented straight downward at a 90° angle to the wings of the airplane.

The insecticides tested were naled, fenthion, and malathion. Although we wished to apply undiluted insecticides for all the ultra-low volume tests, such a procedure was impossible for some rates of application with the nozzle sizes we had available. Therefore, it was necessary to dilute the insecticides to obtain some of the desired flow rates. The 0.05 and 0.1 lb. per acre applications of naled and fenthion and the 0.1 and 0.2 lb. per acre applications of malathion were achieved by making a 4 lb. per gallon solution of the insecticide in methylene chloride; this solvent was chosen because of its high solvency and low flammability. Naled and fenthion (0.2 lb. per acre) and malathion (0.4 lb. per acre) were applied as undiluted concentrates (naled, 14 lb. per gallon; fenthion, 8 lb. per gallon; malathion, 95 percent technical).

Conventional spraying was done with water emulsions formulated from the following emulsifiable concentrates: naled (8 lb. per gallon), fenthion (4 lb. per gallon), and malathion (5 lb. per gallon).

Counts of mosquitoes were made the day before and 6, 24, and 48 hours after treatment to evaluate the effectiveness of the treatments. Counts were made at 10 locations by two observers after standing side by side and facing opposite directions for 30 seconds. Counting stations were about 50 feet apart and were arranged in one, two, or three rows (depending on the width of the grove) near the center of each plot at 90° angles to the flight swaths.

The tests were conducted on 10 different mornings at times ranging from 5:30 to 10:30 a.m. Wind speeds during the applications never exceeded 10 m.p.h. and were usually less than 5 m.p.h. From 2 to 10 replications were made with each treatment.

RESULTS AND DISCUSSION. Data for the ultra-low volume spray tests are presented in Table 1. Naled was the most effective compound after 6 hours; it produced 88 and 94 percent reductions at rates of 0.1 and 0.2 lb. per acre, respectively; however, the degree of control decreased appreciably after 24 hours. Fenthion, which gave only fair control after 6 hours at all three doses, gave better control after 24 to 48 hours at the two higher doses (75 and 89 percent). Malathion gave poor control, regardless of doses or interval after treatment; this result reflects the resistance to this insecticide that is developing in Florida. Recent tests have indicated a 15-fold tolerance to malathion in mosquitoes collected from this area compared with that of our standard laboratory colony. Recent papers by Glancey *et al.* (1966b) and Gahan *et al.* (1966) discuss this problem further.

In the conventional spray tests (Table 2), fenthion gave good immediate control (95 to 98 percent in 6 hours) at all three test doses. At the highest rate, good control was maintained for 48 hours, but only fair control was obtained at 24 and 48 hours at the two lower rates. Naled was less effective than fenthion at the two lower rates of application. Control at a rate of 0.2 lb. per acre was excellent after 6 hours but declined considerably after 24 hours. Again, malathion was less effective; however, at 0.2 lb. per acre, it maintained from 74 to 88 percent control

TABLE 1.—Control of adult salt-marsh mosquitoes with ultra-low volume aerial sprays of various insecticides.

Insecticide	Lb./acre	Oz. of spray per acre	Nozzle size	p.s.i.[a]	No. of replics.	Pretreatment count (mosq./man/1/2 min.)	Percentage reduction at indicated hour after treatment[b] 6	24	48
Naled	0.05	1.6	800067	42	10	46	65	17	..
	.1	3.2	80015	38	6	69	88	36	..
	.2	1.8	8001	28	5	169	94	78	33
Fenthion	.05	1.6	800067	34	6	49	79	60	..
	.1	3.2	80015	34	6	50	72	75	84
	.2	3.2	730116	42	5	53	75	89	77
Malathion	.1	3.2	80015	34	4	127	54	30	..
	.2	6.4	8003	42	6	81	63	53	53
	.4	5.3	8002	38	5	233	46	66	55
None (untreated)	..	..	..	..	19	56	+10	4	+10

[a] Pressure between insecticide tank and nozzles while system was operating.
[b] + indicates percentage increase.

throughout the 48-hour test. Both naled and malathion were less effective than reported by Davis *et al.* (1960). As indicated previously, the poor results with malathion are attributable to resistance; however, cross-resistance to naled could not be demonstrated in preliminary laboratory tests, and the poorer results are therefore unexplained.

A comparison of the results obtained with the ultra-low volume and conventional sprays indicates that naled was the only compound that gave essentially the same control with both methods of application. Fenthion produced about 20 per-cent less control at 6 hours when it was used as an ultra-low volume than as a conventional spray, but both methods gave about the same control at 24 and 48 hours. Ultra-low volume spraying with malathion was slightly less effective than conventional spraying, regardless of the time after treatment.

Thus differences do exist in the effectiveness of an insecticide applied by the two methods. The comparable results obtained by the two methods with naled may have been caused by its fumigating effect which could nullify differences in effectiveness caused by particle size and

TABLE 2.—Control of adult salt-marsh mosquitoes with conventional (3 quarts per acre) aerial sprays of various insecticides.

Insecticide	Lb./acre	No. of replications	Pretreatment count (mosq./man/1/2 min.)	Percentage reduction at indicated hour after treatment[a] 6	24	48
Naled	0.05	4	18	79	24	..
	.1	2	25	82	44	..
	2	2	381	99	73	..
Fenthion	.05	2	26	97	57	..
	.1	2	33	98	64	74
	.2	2	38	95	96	80
Malathion	.2	2	35	74	88	77
	.4	2	187	84	70	..
None (untreated)	..	10	56	+18	4	34

[a] + indicates percentage increase.

distribution. Those differences obtained with fenthion or malathion might be attributable to particle size or distribution. Investigations into the effects these factors might have on mosquito control would certainly be worthwhile.

SUMMARY. A comparison of the effectiveness of ultra-low volume and conventional sprays of malathion, naled, and fenthion were made with adult salt-marsh mosquitoes, *A. taeniorhynchus* and *A. sollicitans*. Naled gave essentially the same control with both methods of application: a dose of 0.2 lb. per acre was necessary to obtain over 90 percent control within 6 hours and no application gave good residual control. Fenthion gave excellent control as a conventional spray (95 to 98 percent) at doses of 0.05 to 0.2 lb. per acre for 6 hours, but only the higher rate gave residual control (80 percent after 48 hours). The ultra-low volume treatments that gave only fair control (72 to 79 percent) at the same doses at 6 hours gave as good or better control after 24 to 48 hours at the two higher rates (75 to 89 percent). Malathion gave poor control regardless of dose, undoubtedly because of resistance; however, slightly better control was obtained with conventional spray applications.

ACKNOWLEDGMENTS. The authors wish to express their appreciation to Jack Salmela, Director of the Brevard Mosquito Control District, Merritt Island, Fla., for his cooperation in conducting these tests. Appreciation is also expressed for the assistance of pilots John Sullivan and Dick Blakeway of the Brevard Mosquito Control District, and Ned Pierce, Paul Bishop, Kenneth Baldwin, and Hugh Ford of the Gainesville, Fla., laboratory.

References Cited

BLANTON, F. S., TRAVIS, B. V., SMITH, NELSON, and HUSMAN, C. N. 1950. Control of adult mosquitoes in Alaska with aerial sprays. J. Econ. Entomol. 43(3):347–350.

DAVIS, A. NELSON, SALMELA, J., and SPENCER, C. B., JR. 1960. Aerial spray tests against adult salt-marsh mosquitoes in Florida. Proc. New Jersey Mosquito Extermin. Assoc. 47:92–94.

GAHAN, J. B., SMITH, C. N., and GLANCEY, B. M. 1966. Resistance in Florida and countermeasures involving chemicals. Mosq. News 26 (3):330–337.

GLANCEY, B. M., LOFGREN, C. S., SALMELA, J., and DAVIS, A. N. 1965. Low volume aerial spraying of malathion for control of adult salt-marsh mosquitoes. Mosq. News 25(2):135–137.

———, WHITE, A. C., HUSMAN, C. N., and SALMELA, J. 1966a. Low volume applications of insecticides for control of adult mosquitoes. Mosq. News 26(3):356–359.

———, LOFGREN, C. S., and MILLER, T. WAYNE. 1966b. Malathion resistance in the black salt-marsh mosquito, *Aedes taeniorhynchus* (Wiedemann) in Florida. Mosq. News 26(3): 439.

KNAPP, F. W., and ROBERTS, W. W. 1965. Low volume aerial application of technical malathion for adult mosquito control. Mosq. News 25(1):46–47.

MESSENGER, K. 1963. Low volume aerial spraying will be a boon to applicator. Agr. Chem. 18(12):63–66.

———. 1964. Low volume aerial spraying. Agr. Chem. 19(9):61–64.

1967 Knapp, F. W., and C. H. Gayle
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(1345)

ULV AERIAL INSECTICIDE APPLICATION FOR ADULT MOSQUITO CONTROL IN KENTUCKY[1]

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Ultra-low volume (ULV) aerial application of insecticides for mosquito control was first used in Kentucky on June 25, 1964 (Knapp and Roberts, 1965). Because of the success of these tests using malathion other tests were applied during the spring and fall of 1965 (Knapp and Pass, 1966a, 1966b). The majority of the tests were conducted in the western part of the state where the salt-marsh mosquito, *Aedes sollicitans* (Walker) is the major pest mosquito. The origin of this species in Kentucky is unknown, but it is well-adapted to the highly acid swamp areas associated with sulfuretic waste from coal strip mines.

Since information was needed on the effectiveness of insecticides on adult mosquitoes when applied by the ULV method, additional tests were conducted during the fall of 1966 in Western Kentucky against this mosquito.

MATERIALS AND METHODS. A Piper Super Cub airplane converted for ULV aerial spraying (Knapp and Pass, 1966) was used in these tests. An additional spray system consisting of either a 1- or 2-gallon stainless steel B & G sprayer was secured within the baggage compartment of the plane. A small carbon dioxide cylinder as described by Glancey *et al.*, (1966) provided the pressure. A 12-volt solenoid valve was placed on the outlet line of the spray tank and a quick-coupling valve connected the carbon dioxide line to the spray tank (Fig. 1). Copper tubing was used for the boom lines. The boom was secured to the plane's original spray boom and had 3 nozzles, 24 inches apart, on each side of the plane (Fig. 2). The small ULV unit and its

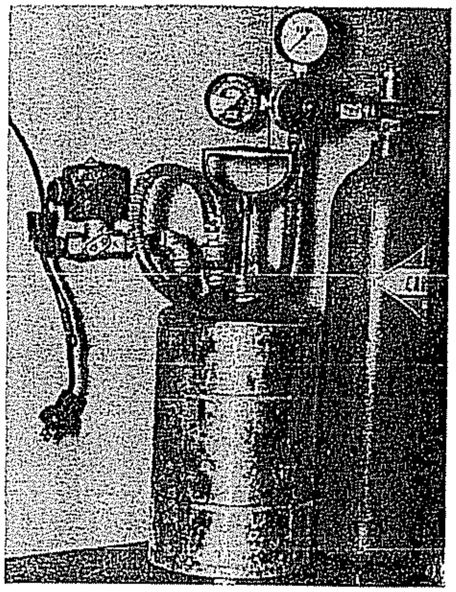

FIG. 1.—Carbon dioxide cylinder, regulator, 1 gallon sprayer, and 12-volt solenoid used for ULV aerial application of insecticides.

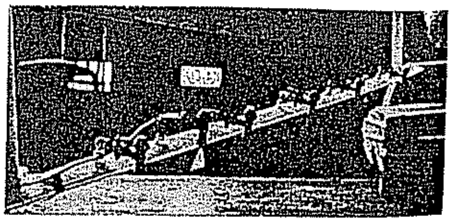

FIG. 2.—Position of spray nozzles attached to conventional spray boom.

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boom were so arranged that the pilot was able to utilize both spray systems independently of each other. A pressure gauge and a control switch for the solenoid valve was mounted on the instrument panel of the plane. The solenoid valve acted as a safety device in the event a spray line ruptured during the application, i.e. the pilot could avoid losing a full tank of insecticide or avoid any contamination to himself by closing the solenoid valve on the tank. Two spray tanks were utilized in the tests so that while one was being used the other was always in preparation for the next test.

Insecticides tested were: naled, 14 pounds per gallon; fenthion, 8 pounds per gallon; Baygon® (o-isopropoxyphenyl methyl carbamate), 4 pounds per gallon; malathion, 10.2 pounds per gallon, and a mixture of malathion-naled (10:1 ratio).

All applications were made within a 4-day period, either between 6:30 a.m. and 8:00 a.m. or between 5:00 p.m. and 7:00 p.m. The airplane was flown at an altitude of 65 to 85 feet at an air speed of 80 m.p.h. An effective swath width of 100 feet was used for calculating the dosage per acre. Boom pressure was kept as close to 40 psi as possible, but varied as needed to obtain the correct rate of the insecticide. Spraying Systems Tee-Jet® nozzles were used to apply the various insecticides. The area used in the tests ranged from 250 to 400 acres. Treatments were not replicated, but pre-spray and post-spray adult mosquito counts were taken by counting the number of mosquitoes on and in the immediate vicinity of a person within 30 seconds as described by Knapp and Pass (1966). This was repeated in five locations within each test area. Mosquito larvae were not sufficiently numerous for larviciding tests to be conducted. The test sites were sparsely populated, consisting mainly of swamps bounded by densely wooded areas varying from light to heavy canopy cover.[3]

The weather was considered good, with wind speed from 0 to 4 mph and temperatures varying from 72° F. during the morning to 82° F. during the evening. Pilot studies indicated that temperature affected the flow rate of the insecticides; therefore, the equipment was calibrated for each insecticide as it was used. Calibration was done with one nozzle; then the nozzles needed for the required dosage rate were opened so that the correct CO_2 pressure could be set.

When several dosage rates of the same compound were to be tested, the higher rates were applied first. The pilot then closed the appropriate number of nozzles by pulling a cord attached to the nozzle valve to obtain the next lower dosage rate. This method, plus the use of two separate spray systems, proved to be a time saver. This was because on some evenings less than an hour of good flying weather was available for the application.

When an odd number of nozzles was used in any application, for example, 1 or 3 nozzles, the odd number was placed on the right side of the plane to minimize the effect of the prop wash.

Two rates of Baygon, 0.0375 lb. (1.2 fluid oz.) and 0.075 lb. (2.4 fluid oz.) per acre were applied with one and two 8001 nozzles, respectively. A third rate of 0.033 lb. (1.06 fluid oz.) per acre was applied with one 80015 nozzle. It was intended for the latter dosage to be between the first two but due to a loss in pressure the correct dosage was not applied. The area where the 0.033 lb./acre was applied had a light canopy cover whereas the other two had a medium to heavy cover. Applications of the two higher rates were made in the evening while the lower rate was applied during the morning.

Application of 0.15 lb. (2 fluid oz.) and 0.30 lb. (4 fluid oz.) of malathion was made with 2 and 4-80015 nozzles, respectively. The two treatment areas were of similar terrain and had a medium canopy cover. Both applications were made during the morning. A malathion-naled mix-

[3] Light canopy=sparsely wooded area with low growing vegetation.
Medium canopy=dense wooded areas with numerous open spaces.
Heavy canopy=dense wooded areas with very few open spaces.

ture (10:1 fluid ratio) was applied over a similar area at a dosage of 0.145 lb. of malathion and 0.017 lb. of naled. This treatment was applied during the morning.

Two rates of naled, 0.049 lb. (0.5 fluid oz.), and 0.098 lb. (1.0 fluid oz.) per acre were applied with 1 and 2–8001 nozzles, respectively. The lower dosage was applied at dusk over an area varying from no canopy to a medium canopy. The higher dosage was applied the following morning over an area having a heavy canopy.

RESULTS AND DISCUSSION. The results of the various treatments are shown in Table 1. No difference was found between the two higher rates of Baygon, and good reduction of mosquitoes was achieved within 2 hours after treatment. Although there was only 0.0045 lb. per acre difference between the two lower rates, the lower of the two did not give adequate reduction of mosquitoes. It is possible that the dosage was not adequate for sufficient control; however, it is more probable to assume, since the treatment area had a heavier foliage canopy, that good penetration of Baygon was not achieved. This treatment was also applied during the morning when the mosquitoes were less active. The temperature was 5 to 8 degrees lower during the morning tests which may also have affected the results as the action of Baygon decreases at lower temperatures (Stevens and Stroud, 1966).

A more rapid knock-down of adults was achieved with the lower rate of Baygon-fenthion mixture than with the higher rate or with Baygon alone. From 2 to 24 hours after treatment very little difference was found between the Baygon-fenthion mixture and Baygon alone, except for the lower rate of the latter. The advantage of the combination, if any, would be in a more rapid knock-down. Knapp (1966) found that in a Baygon-fenthion mixture there was a synergistic effect on the house fly, *Musca domestica* L.[4] It may be possible that this mixture has the same effect on mosquitoes.

The performance of malathion was similar to that in previous tests (Knapp and Roberts, 1965; Knapp and Pass, 1966). It did not cause any appreciable reduction of mosquitoes until 6 hours after treatment. The lower dosage of 0.15 lb. per acre was not sufficient for adequate reduction of mosquitoes in areas of medium-to-heavy foliage. The malathion-naled mixture (0.145:0.017 lb./acre) resulted in a more rapid reduction of mosquitoes than did the higher dosage of malathion alone (2 hours vs. 6 hours) and exceeded the high dosage of malathion in its effectiveness at 6 and 24 hours after treatment. It is not known if naled at the rate of 0.017 lb. per acre alone would have achieved the same results. Naled at rates of 0.049 and 0.098 lb. per acre, however, gave a very rapid reduction of adults, although the lower rate exceeded the higher rate in effectiveness. The latter rate was applied over a heavy canopy area and during the morning when the mosquitoes were less active.

From these tests a relationship is seen between the time of application and the effectiveness of all compounds tested. All the evening applications were superior to those made during the morning, especially in the initial knock-down of adults.

A small spray tank pressurized by CO_2 worked exceedingly well when the temperature was constant. However, it was necessary to calibrate the unit with each insecticide just prior to application. A decrease in temperature resulted in a lower flow rate of the insecticide thus requiring an increase in CO_2 pressure to obtain the desired dosage. When the correct pressure was obtained on the ground, ther was a pressure loss in flight. The temperature difference between the ground and altitude of applications may have been a factor in this case. The loss in pressure was corrected by increasing the CO_2 pressure by 5 lb.

CONCLUSION. Baygon and a Baygon-fenthion mixture were equally effective in the reduction of adult mosquitoes although

[4] Unpublished data. University of Kentucky Agricultural Experiment Station, Lexington.

TABLE 1.—Effect of ULV aerial application of insecticides for control of *Aedes sollicitans* adults.

Compound	Time of Application	Fluid Oz. Per Acre	Pre-treatment Avg. Mosquitoes Per Person/30 Sec.	Percent Reduction—Hours After Treatment					
				0.5	1	2	6	10	24
Baygon	a.m.	1.06	49.3	....	62.7	51.6	51.6	....	69.6
	p.m.	1.20	23.6	....	....	97.1	....	....	99.6
	p.m.	2.40	17.0	....	47.1	95.3	....	....	98.3
Baygon-fenthion[a]	p.m.	1.20	9.3	94.7	....	....	93.6	....	95.7
	a.m.	2.40	18.7	....	84.0	96.8	....	96.3	98.4
Malathion	a.m.	2.00	12.7	....	....	0	57.1	32.1	76.9
	a.m.	4.00	17.7	....	....	0	82.0	88.2	92.7
Malathion-naled[b]	a.m.	2.00	5.7	....	....	85.7	96.9	....	100
Naled	p.m.	0.5[c]	21.5	97.7	100	100	100	....	100
	a.m.	1.0[d]	15.0	90.7	72.7	96.0	100	....	82.7

[a] Fluid ratio of 2 Baygon to 1 fenthion.
[b] Fluid ratio of 10 malathion to 1 naled.
[c] No to medium canopy.
[d] Heavy canopy.

the combination showed a slight advantage in the time required for effective knock-down. Dosages of less than 0.3 lb. per acre of malathion were found to be inadequate in areas containing medium-to-heavy foliage cover. The addition of a small amount of naled (0.017 lb./acre) to the low rate of malathion (0.145 lb./acre) improved the effectiveness of that rate of malathion and the results exceeded those of the higher rate of malathion (0.3 lb./acre) alone. Naled was the most effective compound tested, and it resulted in a very rapid knock-down of adult mosquitoes.

References Cited

GLANCEY, B. M., WHITE, A. C., HUSMAN, C. N., and SALMELA, J. 1966. Low volume application of insecticides for control of adult mosquitoes. Mosq. News 26(3):356–359.

KNAPP, F. W., and ROBERTS, W. W. 1965. Low volume aerial application of technical malathion for adult mosquito control. Mosq. News 25(1):46–47.

KNAPP, F. W., and PASS, B. C. 1966a. Low volume aerial sprays for mosquito control. Mosq. News 26(1):22–25.

KNAPP, F. W., and PASS, B. C. 1966b. Effectiveness of low volume aerial sprays for mosquito control. Mosq. News 26(2):128–132.

STEVENS, L. F., and STROUD, RICHARD F. 1966. Personal communication. Chemagro Corporation. Kansas City, Mo.

CONTROL OF MOSQUITO ADULTS AND LARVAE WITH ULTRA-LOW VOLUME AERIAL APPLICATIONS OF Baygon® AND Baygon-Baytex® MIXTURE

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In 1965 the authors conducted tests with Baytex (*O,O*-diethyl *O*-[4-(methylthio)-m-tolyl] phosphorothioate) and Baygon-Baytex mixtures applied in undiluted form by airplane to control adults and larvae of *Aedes stimulans* (Walker). These tests indicated that the Baygon-Baytex mixture was superior to Baytex alone because the addition of Baygon (*o*-isopropylphenyl methylcarbamate) contributed to rapid knockdown of adult mosquitoes (Stevens and Stroud, 1965). Similar results were obtained in tests conducted on adult *Aedes sollicitans* (Walker) by Knapp *et al.*, (1965) and *Aedes taeniorhynchus* (Wiedemann) by Glancey *et al.*, (1966). A question left unanswered was whether or not Baygon without the addition of Baytex would give satisfactory control of adult mosquitoes. To answer this question, a second series of tests was conducted in the vicinity of Gobles, Michigan during the month of June 1966. The prevalent mosquito species at that time was *Aedes stimulans* (Walker), as it was in 1965. However, the larvae referred to in these tests were all *Culex restuans* (Theob.).

The first in a series of two comparisons was made on June 16 and 17. On June 16 at 8:00 p.m. an application of Baygon 4 lb./gal. ultra-low volume concentrate was applied undiluted by airplane at the rate of 1.6 fluid ounces per acre (0.8 ounce of active ingredient per acre) to an area of approximately 400 acres.

This is a typical Michigan resort area in which there is a lake, Brandywine Lake, surrounded by dense woods. On June 17 at 9:30 a.m. an application of Baygon with the addition of Baytex was made to approximately 200 acres. This area, Mill Lake, was similar to the area to which Baygon was applied alone. For this treatment Baygon 4 lb./gal. ultra-low volume concentrate was mixed with Baytex 8 lb./

1967 Rathburn, Jr., C. B. and A. H. Boike, Jr.
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tive control of adult insects in these situations, provided the basic characteristics of the method are understood by the operator.

Finally, the data show that naled is effective against adults of the stable fly when effective dosage and operations are used.

Literature Cited

RATHBURN, CARLISLE B., JR., and ROGERS, ANDREW J. 1959. Field tests of mists and dusts against caged adults of *Aedes taeniorhynchus* (Wied.). Proc. N. J. Mosq. Exterm. Assoc. 46: 200–205.

YEOMANS, A. H. 1960. Directions for applying windborne aerosols for insect control out of doors. Agric. Res. Serv. Bull. No. 33-57, p. 5.

STUDIES OF INSECTICIDE RESISTANCE IN FLORIDA MOSQUITOES

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The first instance of mosquito resistance to insecticides in Florida was DDT resistance in the salt-marsh mosquitoes *Aedes taeniorhynchus* and *A. sollicitans* reported by Deonier and Gilbert in 1950 (Deonier and Gilbert, 1950). Resistance to DDT was soon followed by resistance to BHC and then to dieldrin (Keller and McDuffie, 1952, and Keller and Chapman, 1953). As a result, satisfactory control of these species could not be obtained in some areas of the state from about 1950 to 1956. In 1955 malathion was first introduced as a mosquito adulticide (Gahan *et al.*, 1956) and by 1957 it was widely used throughout Florida.

It was at this time that the Florida State Board of Health, fearing resistance to malathion, developed a policy of limiting the use of malathion to adulticiding in non-breeding areas. It was felt that frequent treatment of large populations of larvae and adults in breeding areas would result in the rapid selection of resistant individuals with the subsequent development of a high degree of malathion resistance. As a result of the policy, malathion has found only very limited use as a larvicide in the state, but has been used extensively and with good results as an adulticide for 10 years. Since mosquitoes have been shown to develop resistance to malathion after a period of only 2 years of extensive use as a larvicide (Gjullin and Isaac, 1957), it appears that this policy has greatly prolonged the effectiveness of malathion in Florida.

In 1964 the Florida State Board of Health, realizing the necessity of obtaining reliable information on the current status of insecticides used in the State, began to obtain baseline data for various insecticides on susceptible mosquito species (Rogers and Rathburn, 1964). In the summer of 1965 came reports of poor mosquito control with malathion adulticides in Lee County. These reports were investigated concurrently and resistance confirmed by this laboratory and the U. S. Department of Agriculture (Gahan *et al.*, 1966).

Although the more important pest species in the state over the years have been *Aedes taeniorhynchus* and *A. sollicitans*, recent research on arboviruses has pointed to the importance of many other species, namely, *Culex nigripalpus*, *C. quinquefasciatus* and *Aedes infirmatus*. This study has attempted to obtain data on several species of mosquitoes from several areas of the state and with all of the insecticides presently used. It is hoped that this research will be expanded in the future to include more species from more areas so that a reduction in susceptibility to any insecticide can be determined before widespread resistance is prevalent, thereby providing time to develop new tools to combat resistant species.

MOSQUITO COLLECTION AND TRANSPORTATION. Mosquitoes were collected in Bay and Walton Counties in western Florida; Marion and Polk Counties in central Florida; Pinellas, Hillsborough, Sarasota and Lee Counties on the west coast; and Volusia, Brevard and Indian River Counties on the east coast of the State.

Adult mosquitoes were collected by means of light and bait traps, and when numerous, by sweeping with insect nets. They were transported to the Laboratory in cages made from pint ice cream cartons. The cages, each containing up to 200 adults, were shipped in styrofoam ice chests. The mosquitoes were fed a sugar solution by means of cotton pads placed on the screened top portion of the cage and kept cool in transit by means of "canned" ice. They were shipped by means of airplane, bus or automobile.

MOSQUITO REARING. Upon arrival, the mosquitoes were placed in 12 x 9 x 8 inch screened cages, supplied with a sugar solution and blood-fed on anesthetized chickens. *Aedes* species were identified and separated prior to egg collection. Eggs of these species were collected on damp cotton balls wrapped with cheesecloth. The eggs were removed by washing in ice water to prevent hatching, placed in a thin layer on 1 x 1 inch organdy squares and held in petri dishes at room temperature for five to seven days prior to hatching. Eggs to be held longer than one week were stored in a refrigerator and removed 5 to 7 days prior to hatching. Nitrogen was bubbled through the water as a stimulant for hatching.

Eggs of the *Culex* species were collected from small bowls containing hay-infusion water placed in the cages the preceding day. *Culex* species were identified as larvae, one egg raft being reared per pan. Both *Aedes* and *Culex* species were reared in 15 x 10 inch enamel pans containing about 1000 ml. of water and fed a water solution of powdered liver and brewer's yeast.

TESTING METHOD. Larval tests were conducted with minor modifications according to procedures outlined by the World Health Organization (World Health Organization, 1960). One millimeter of the appropriate insecticide soltuion was pipetted under the surface of 200 ml. of water contained in each 600 ml. test beaker. Alcohol (95 percent) was used as the diluent for malathion, Baytex and DDT solutions. The solutions of Dibrom were prepared in acetone. Twenty-five third instar larvae, previously placed in 50 ml. of water in 50 ml. beakers, were then added to each test beaker. Each replication consisted of a series of five insecticide dosages plus a check of alcohol or acetone. Because of variations in the number of available larvae for testing, from one to four replications were conducted at a time. In order to reduce variations in susceptibility caused by rearing and testing, it was desired to have at least 16 replications obtained in at least four different tests for each species, area and insecticide used. However, due to variations in the number of larvae obtained for testing, this was not always possible.

Tap water was used in testing all *Culex* species since it was also used in rearing these species. Salt water of the same salinity as the rearing water was used in testing the *Aedes* species. The temperature of the water during testing was between 22° and 28° C. Larval mortality was determined at 24 hours. Larvae incapable of rising to or submerging from the surface upon probing were considered dead. Tests with control mortality above 10 percent or in which more than 5 percent of the larvae pupated during the experiment were discarded. The percent mortalities obtained for the treatments in each test were corrected for the amount of control mortality by means of Abbott's formula. The control mortality for all

TABLE 1.—Susceptibility of five species of mosquitoes from different areas of Florida to malathion 1965–66.

		Lethal concentrations in p.p.m.					
		1965			1966		
County	Area	LC50	LC90	Reps.	LC50	LC90	Reps.
Aedes taeniorhynchus (Wied.)							
Lab. Colony		.029	.062	15	.025	.050	14
Hillsborough	MacDill AFB	.470	1.750	8	...	...	...
	Ruskin	.056	.290	3	...	...	...
	Big Bend	...	...	...	.044	.118	12
Sarasota	Siesta Key	.590	3.900	16	...	...	...
	Longboat Key	.420	2.800	10	...	...	...
	Casey Key	.160	.760	3	...	...	...
Lee	Sanibel Island	.343	2.200	19	.220	2.600	8
	Captiva Island	.570	4.600	19	...	...	...
	Ft. Myers	.140	.670	8	...	...	...
	Iona[1]	.114	.350	20	...	...	...
	Bonita Beach	.275	1.500	7	.105	1.050	5
Volusia	Turtle Mound	.044	.170	3	...	...	
	Oak Hill	.078	.370	3	...	...	...
Brevard	Mims	.100	.780	3	...	...	...
	Merritt Island	.180	.460	4	...	...	...
	South Brevard	...	...	...	.080	.150	16
Indian River	Vero Beach	.082	.490	15	...	...	...
Aedes sollicitans (Walk.)							
Brevard	Allenhurst	...	...	...	.042	.086	16
	Titusville Beach	...	...	...	.075	.124	16
Culex nigripalpus Theob.							
Lab Colony		...	...	...	.045	.074	18
Bay	State Park	...	...	...	.038	.070	13
Marion	Orange Springs	...	...	...	.034	.044	21
Polk	Bartow	...	...	...	.082	.110	3
Pinnellas	Lake Maggiore	...	...	...	.038	.058	22
	Largo	...	...	...	.036	.059	24
Hillsborough	Temple Terrace	.044	.062	19	...	...	...
Lee	Sanibel	...	...	...	.050	.082	6
	Ft. Myers	...	...	...	.054	.084	5
	Orange River	...	...	...	.053	.084	6
Volusia	New Smyrna Beach	...	...	...	.044	.066	16
Culex salinarius Coq.							
Walton	Santa Rosa	...	...	...	.048	.060	8
Pinellas	Lake Maggiore	...	...	...	.067	.121	12
Culex quinquefasciatus Say							
Lab. Colony		...	...	...	.130	.215	28

[1] Average of tests of larvae collected in field and larvae reared from eggs of field collected adults.

tests averaged only 2 percent. Testing vessels were washed with detergent and rinsed in clear water and then acetone after each test.

RESULTS. The results of tests with malathion are shown in Table 1. These tests indicate an advanced degree of resistance of *Aedes taeniorhynchus* in the offshore islands of Sarasota and Lee Counties and in the peninsula of Hillsborough County occupied by MacDill Air Force Base. Tests conducted with malathion on *A. taeniorhynchus* larvae in 1966 indicate an increase in susceptibility in the two areas of Lee County that were sampled. This increase in susceptibility may possibly represent a reversion since malathion was not used in this area in 1966.

TABLE 2.—Susceptibility of five species of mosquitoes from different areas of Florida to Dibrom, Baytex and DDT, 1966.

		Lethal concentrations in p.p.m.								
		Dibrom			Baytex			DDT		
County	Area	LC50	LC90	Reps.	LC50	LC90	Reps.	LC50	LC90	Reps.
Aedes taeniorhynchus (Wied.)										
Lab. Colony	....	.103	.185	20	.0005	.0017	4	.0094	.056	14
Walton	Santa Rosa [1]	...	...	..	...	...	..	.0047	.019	14
Brevard	South Brevard	.103	.141	12	...	...	..	...	...	..
Aedes sollicitans (Walk.)										
Walton	Santa Rosa	...	...	..	...	...	..	.0043	.019	4
Brevard	Allenhurst	.117	.180	4	...	...	..	...	...	..
	Titusville Beach	.090	.130	16	.0015	(2)	8	...	...	..
Culex nigripalpus Theob.										
Lab Colony	....	.051	.067	12	.0032	.0051	4	.040	.097	6
Bay	State Park	...	...	..	...	...	..	.028	.070	6
Marion	Orange Springs	.067	.082	24	...	...	..	.014	.043	12
Pinellas	Lake Maggiore	.068	.090	16	.0028	.0044	12	...	...	..
	Largo	.054	.078	4	...	...	..	...	...	..
Volusia	New Smyrna Beach	.078	.098	12	...	...	..	...	...	..
Culex salinarius Coq.										
Bay	State Park	.060	.082	4	...	...	..	...	...	..
Walton	Santa Rosa	...	...	..	...	...	..	.014	.033	8
Pinellas	Lake Maggiore	.103	.169	4	...	...	..	...	...	..
Culex quinquefasciatus Say										
Lab. Colony	....	.102	.121	12	.0032	.0050	8	.049	.103	4

[1] Larvae hatched from sod collected in field, 50% *Ae. sollicitans*.
[2] Insufficient data to accurately determine.

The only other areas in which there were indications of a reduction in susceptibility of *A. taeniorhynchus* to malathion in 1965 were in Brevard County and the mainland portions of Lee County. *A. sollicitans* obtained from Brevard County appear to exhibit the same degree of susceptibility to malathion as *A. taeniorhynchus* from this area. Previous research with adulticides has also demonstrated no significant difference in insecticide susceptibility between these two species (Rogers and Rathburn, 1958). From the data presented it appears that there is no resistance of *C. nigripalpus* or *C. salinarius* to malathion in any of the sampled areas. The reason for the high LC_{50} obtained with the colony *C. quinquefasciatus* when tested with malathion is not known. These mosquitoes were colonized in 1966 from specimens obtained from various parts of Bay County. Since none of the other species of mosquitoes collected from this area exhibit any reduction in susceptibility, it can only be assumed that this difference may be due to species variation.

Shown in Table 2 are the results of tests with Dibrom, Baytex and DDT. Although only limited data have been obtained with Dibrom and Baytex, there appears to be no resistance by any of the species tested from any of the areas to these chemicals. The colony of *A. taeniorhynchus* was established from a colony maintained since 1957 at the Entomological Research Center at Vero Beach. Although the colonized mosquitoes were collected in an area in which DDT resistance has been previously demonstrated, it appears that much of the original resistance to DDT may have been lost after the 10-year period of colonization.

The degree of DDT resistance is difficult to ascertain due to the lack of a susceptible strain. However, based upon the commonly accepted LC_{50} for DDT susceptible larvae of .002 to .004 p.p.m., the mosquitoes collected from certain areas of northwestern Florida may still be susceptible to DDT. Although larval data are lacking for many areas of the state, research with adulticides has shown that a high degree of resistance to DDT is prevalent throughout most of the state (Rogers and Rathburn, 1958; and Rogers and Rathburn, 1964). The *C. nigripalpus* collected in Marion County are from an area in which no mosquito control has been practiced and therefore may represent a DDT susceptible population. However, in the absence of baseline data with this species, no definite conclusions can be made. The colony *Culex nigripalpus* used in these tests were obtained from a colony originally established at the Entomological Research Center in 1964. Therefore this colony was established after the extensive use both of DDT and malathion in that area and represents a population with possibly some reduction in susceptibility to these insecticides.

Discussion. This research did not encompass the entire state; the susceptibility of mosquitoes in many areas still remains to be determined. From present data, however, malathion resistance is limited to the *Aedes taeniorhynchus* populations of the offshore islands of Lee and Sarasota Counties and in peninsular Hillsborough County. These areas represent somewhat isolated and concentrated populations of mosquitoes which in most instances are the subject of intensive control operations. As was mentioned earlier, it is believed that these are the conditions which favor development of resistance, and therefore may account for the resistance in these areas.

It is well known that differences in temperature and availability and type of food cause differences in the susceptibility of mosquito larvae to insecticides. Because of this and other factors, larvae are naturally more difficult to kill in some areas than others. This natural variation or what is commonly referred to as "vigor tolerance" may result in a lethal concentration of an insecticide for a particular mosquito species that may be considerably higher in one area than another or at one time of year than another. One of the benefits of a continuing study of this type is to establish these differences. However, by testing larvae reared under controlled conditions of food, temperature, larval density, type of water, etc., it was hoped to reduce these field variations to a minimum, thereby making the results obtained more comparable. The many unknown causes of variations in larval susceptibility were further reduced by the use of a considerable number of replications obtained over a relatively long period of time.

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References Cited

DEONIER, C. C., and GILBERT, I. H. 1950. Resistance of salt-marsh mosquitoes to DDT and other insecticides. Mosq. News 10(3):138–43.

GAHAN, J. B., BERTHOLF, J. H., DAVIS, A. N., JR., and SMITH, C. N. 1956. Field tests with two phosphorothioates against resistant salt-marsh mosquitoes. Mosq. News 16(2):91–93.

———, SMITH, C. N., and GLANCY, B. M. 1966. Resistance in Florida and countermeasures involving chemicals. Mosq. News 26(3):330–337.

GJULLIN, C. M., and ISAAC, L. W. 1957. Present status of mosquito resistance to insecticides in the San Joaquin Valley in California. Mosq. News 17(2):67–70.

KELLER, J. C., and CHAPMAN, H. C. 1953. Tests of selected insecticides against resistant salt-marsh mosquito larvae. Jour. Econ. Ent. 46(6):1004–1006.

———, and MCDUFFIE, W. C. 1952. Resistance of salt-marsh mosquitoes to insecticides in Florida. Proc. 38th Ann. Mtg. N.M. Mosq. Exterm. Assn. pp. 54–56.

ROGERS, A. J., and RATHBURN, C. B., JR. 1958. Aerosol tests with DDT and malathion comparing five species of mosquitoes and comparing salt-marsh *Aedes* from eight localities in Florida and Georgia. Mosq. News 18(2):74–80.

———. 1964. Present status of insecticides for mosquito control in Florida. Mosq. News 24(3):286–291.

WORLD HEALTH ORGANIZATION. 1960. Instructions for determining the susceptibility or resistance of mosquito larvae to insecticides. Reprinted from W.H.O.: Technical Report Series. No. 191, 1960.

MALE PHEROMONES OF *CULEX QUINQUEFASCIATUS*, *C. TARSALIS* AND *C. PIPIENS* THAT ATTRACT FEMALES OF THESE SPECIES

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Chemicals released by the females of many species of insects have been shown to attract males of the same species. Also males have been shown to produce chemicals that sexually excite females of the same species. Jacobson (1965), in a recent review, lists over 200 species which produce odors that promote mating.

Observations on the male behavior of *Opifex fuscus* by Kirk (1923), *Deinocerites cancer* Theobald by Haeger and Phinezee (1959) and *Culiseta inornata* Williston by Rees and Onishe (1951) suggest that sex attractants may be produced by the female of these species. Kliewer *et al.*, (1966) demonstrated that a sex attractant is produced in the female *C. inornata*.

The purpose of the present paper is to report the presence of male pheromones in *Culex pipiens quinquefasciatus* Say, *C. tarsalis* Coquillett, and *C. pipiens pipiens*.

MATERIALS AND METHODS. Tests for

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LABORATORY AND FIELD STUDIES ON MOSQUITO CONTROL IN WASTE DISPOSAL LAGOONS IN LOUISIANA

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The mosquito breeding potential of waste disposal lagoons has been reported by Eads and Mengies (1956), Beadle and Harmston (1958), Rapp (1960), Beadle and Rowe (1960), Rapp (1961), Myklebust and Harmston (1962), and Rapp and Emil (1965). Baseline susceptibility tests by Mulla *et al.*, (1960), Mulla (1961), Mulla *et al.* (1961), Mulla *et al.* (1962), Mulla *et al.*, (1964) and Keppler *et al.*, (1965) showed LD_{50} and LD_{90} data for susceptible laboratory strains of *Culex pipiens quinquefasciatus* (Say) to selected insecticides. Dosage mortality data on field-collected larvae of this species were obtained by Burton (1964) and Lofgren *et al.*, (1966). Wray (1959), reported that two applications of 8 percent DDT in fuel oil at a rate of 1 lb. per acre reduced larval populations as high as 90 percent in sludge lagoons. Steelman *et al.* (1966) showed that larvicide concentrations must be held to 1 ppm. or less in order to protect the bacterial flora necessary to the proper functional processes of the lagoon.

An increase in the number of stabilization lagoons used in connection with various types of livestock operations in Louisiana, along with recent reports of encephalitis have demonstrated the urgent need for mosquito control procedures. The southern house mosquito, *Culex pipiens quinquefasciatus* (Say), an important vector of the St. Louis strain of encephalitis, has reached larval populations as high as 1500 larvae per dipper in waste disposal lagoons in Louisiana.

MATERIALS AND METHODS. Larval *Culex pipiens quinquefasciatus* from an untreated swine lagoon were tested in the laboratory to determine baseline susceptibilities to eight insecticides. To reduce mortality, larvae were collected 24 hours prior to testing and held in groups of 500 in 16 x 10 x 2.5 inch enamel pans containing 2,500 ml. of glass distilled water at 27° C. The larvae in each pan were fed 1 gm. of pulverized rabbit feed, and only healthy larvae were used for testing purposes at the end of the holding period. All larvae were transferred with 96 mesh wire and eye droppers.

Technical grades of DDT, dieldrin, Dursban®, Baygon®, naled, fenthion, Abate®, and malathion were serially diluted with 95 percent ethanol such that 1 ml. added to 250 ml. of water would give the desired test concentration. Solid technical materials were dissolved with small amounts of acetone. The testing procedure and data processing were in accordance with the WHO insecticide susceptibility determination instructions (World Health Organization, 1960).

All materials listed above, with the exception of DDT and dieldrin, were tested as emulsifiable concentrates under field conditions by treating the lagoons with insecticide materials at a rate which would provide a 1 ppm. concentration of the insecticide in the total volume of lagoon water.

The amount of test material required for each lagoon was calculated as follows:

1. Length x width x depth = no. $ft.^3$ of water in lagoon
2. No. $ft.^3$ water in lagoon x no. gal. water/$ft.^3$ (7.5)
3. No. gal. water in lagoon was then used in standard insecticide spray formula to calculate the amount of emulsifiable material required to produce a .0001 percent (1 p.p.m.) concentration in total water volume of the lagoon.

Three methods of application were used to treat the lagoons. Two methods involved the use of a 50-gallon pressure

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sprayer applying the materials at 150 psi. to the lagoons. The amount of insecticide material required to produce 1 ppm. concentration in the lagoon was added to 50 gallons of water to facilitate more uniform distribution. In method one the material was pumped to the bottom of the lagoon and the pressure hose moved about at random on the bottom until the material was dispersed. In the second method using the 50-gallon sprayer the insecticide was sprayed over the surface of the lagoon with a standard livestock spray gun.

The third method of application involved the use of a 3-gallon hand pump sprayer equipped with a fan-type nozzle. The amount of insecticide material required to give a 1 ppm. concentration in the lagoon was poured into the sprayer and the sprayer subsequently filled to capacity with water. The material was applied by uniformly spraying the surface margins of the lagoon to a distance of 3 feet out from the bank.

Larval population samples were made with an enamel dipper 4.5 in. in diameter and 450 ml. capacity. One dip was made along the margin of the lagoon at 10-yard intervals with the average number of larvae per dipper being calculated and used as a population index.

Total bacterial population counts were made pre- and post-treatment to determine the effect of these materials on the bacterial flora under field conditions. Bacteriological techniques utilized were identical with those described by the Society of American Bacteriologists, (1957).

RESULTS AND DISCUSSION. Results of the baseline susceptibility tests are shown in Table 1. The most toxic materials tested were Dursban (LD_{50}=0.000135, LD_{90}=0.00068) and Abate (LD_{50}=.00054, LD_{90}=.0012). Dieldrin and Baygon appeared to be the least toxic.

Results of the field tests using 1 p.p.m. concentrations of selected emulsifiable concentrate insecticide materials are shown in Table 2. Dursban provided 144 days of 100 percent larval control while no apparent difference was demonstrated among Abate, fenthion, naled, and Baygon. Malathion gave only two days of 100 percent control.

No differences in effective mosquito control were observed between the three methods of application evaluated. However, due to ease of application, the method utilizing the hand-pump 3-gallon sprayer appeared to be the most desirable method for treating the lagoons.

No bacterial mortality occurred as a result of treating the lagoons with 1 p.p.m. concentrations of the materials tested.

The baseline and field test data suggest that residual chemical action retained in lagoons treated with 1 p.p.m. concentrations is sufficient to provide continued mosquito control until the chemical is broken down or diluted below the required lethal level. The length of time that effective mosquito control continues will vary depending on the insecticide material selected and the rate of dilution of the chemical.

TABLE 1.—Susceptibility of *Culex pipiens quinquefasciatus* to selected insecticide materials.

	p.p.m. Concentration	
Material	LD_{50}	LD_{90}
Abate	.00054	.0012
Baygon	.2	7
Dursban	.000135	.00068
naled	.05	.063
fenthion	.051	.093
malathion	.049	.121
Dieldrin	.135	.67
DDT	.064	.205

TABLE 2.—Control of larval *Culex pipiens quinquefasciatus* in waste disposal lagoons.

Material *	Number days 100 % control
malathion	2
fenthion	18
naled	19
Baygon	20
Abate	20
Dursban	144

* Each emulsifiable concentrate formulation used at 1 p.p.m. concentration in the total volume of lagoon water.

Literature Cited

BEADLE, L. D., and HARMSTON, F. C. 1958. Mosquitoes in sewage stabilization ponds in the Dakotas. Mosq. News 18:293.

BEADLE, L. D., and ROWE, J. A. 1960. Sewage lagoons and mosquito problems. Proc. Symposium on Waste Stabilization Lagoons. U. S. Public Health Service, Kansas City, Mo.

BURTON, G. J. 1964. Results of insecticide resistance tests against larvae of *Culex pipiens quinquefasciatus* (Say) in British Guiana. Mosq. News 24(3):329–331.

EADS, R. B., and MENGIES, G. C. 1956. Texas mosquito problems from a species standpoint. Mosq. News 16(3):187.

KEPPLER, W. J., KLASSEN, W., and KITZMILLER, J. B. 1965. Laboratory evaluation of certain larvicides against *Culex pipiens* (L.), *Anopheles albimanus* (Wied.), and *Anopheles quadrimaculatus* (Say). Mosq. News 25(4):415–419.

LOFGREN, C. S., PENNINGTON, N., and YOUNG, W. 1966. Evaluation of insecticides against two species of *Culex* mosquitoes on Okinawa. Mosq. News 26(1):52–59.

MULLA, M. S. 1961. Susceptibility of various larval instars of *Culex quinquefasciatus* (Say) to insecticides. Mosq. News 21(4):320–323.

MULLA, M. S., AXELROD, H., and ISAAK, L. W. 1961. Effectiveness of new insecticides against mosquito larvae. Mosq. News 21(3):216–224.

MULLA, M. S., ISAAK, L. W., and AXELROD, H. 1960. Laboratory and field evaluation of new insecticides against mosquito larvae. Mosq. News 20(3):256–261.

MULLA, M. S., METCALF, R. L., and ISAAK, L. W. 1962. Some new and highly effective mosquito larvicides. Mosq. News 22(3):231–238.

MULLA, M. S., METCALF, R. L., and KATS, G. 1964. Evaluation of new mosquito larvicides with notes on resistant strains. Mosq. News 24(3):312–319.

MYKLEBUST, R. J., and HARMSTON, F. C. 1962. Mosquito production in stabilization ponds. Water Pollut. Cont. Fed. J. 34(3):302.

RAPP, W. F. JR. 1960. Sewage lagoon maintenance. Water Pollut. Cont. Fed. J. 32(6):660.

RAPP, W. F. JR. 1961. Mosquito production in sewage lagoons. Proc. No. Cent. Ent. Soc. Amer 16:105–107.

RAPP, W. F. JR., and EMIL, C. 1965. Mosquito production in a eutrophic sewage stabilization lagoon. Water Pollut. Cont. Fed. J. 37(6):867–870.

SOCIETY OF AMERICAN BACTERIOLOGISTS. 1957. Manual of Microbiological Methods. McGraw-Hill Book Co., Inc., New York.

STEELMAN, C. D., COLMER, A. R., CABES, L., BARR, H. T., and TOWER, B. A. (In press). Relative toxicity of selected insecticides to bacterial populations in waste disposal lagoons. J. Econ. Entomol. (Accepted for publication in 1966).

WORLD HEALTH ORGANIZATION. 1960. Insecticide resistance and vector control: tenth report of the expert committee on insecticide. WHO Tech. Rep. Series No. 191, pp. 25–29.

WRAY, F. C. 1959. Mosquito control in sludge lagoons. Mosq. News 19(2):81–3.

1966 Gahan, J. B., C. N. Smith and B. M. Glancey.
Resistance In Florida And Countermeasures Involving Chemicals.
Mosquito News 26: 330-337 (Amvac Ref. #1341)

ques, chemosterilants, negatively correlated compounds, biological control, genetic methods, hormone-like materials, photochemical substances, detergents, botanicals or synthetic botanicals, and oils. Each of these has factors limiting its general use—incomplete development, adverse effects on nontarget organisms, or extreme cost. Further research in these areas, however, may alter some of these conditions and make some of the above control methods more promising.

References Cited

BROWN, A. W. A., L. L. LEWALLEN, and P. A. GILLIES. 1963. Organophosphorus resistance in *Aedes nigromaculis* in California. Mosquito News 23:341-345.

GILLIES, P. A. 1964. Organophosphorus resistance in California mosquito larvae. C.M.C.A. Proc. & Papers 32:57-62.

GILLIES, P. A. and D. J. WOMELDORF. 1966. In preparation for publication in Mosquito News.

GJULLIN, C. M., and R. F. PETERS. 1952. Recent studies of mosquito resistance to insecticides in California. Mosquito News 12:1-7.

GJULLIN, C. M., and L. W. ISAAK. 1957. Present status of mosquito resistance to insecticides in the San Joaquin Valley in California. Mosquito News 17:67-70.

LEWALLEN, L. L. 1963. Chemical control investigations on economically important mosquitoes in California 1960-1961. Mosquito News 23:141-144.

LEWALLEN, L. L. and J. H. BRAWLEY. 1958. Parathion resistant *Aedes nigromaculis*. Calif. Vector Views 5:56.

LEWALLEN, L. L., and L. M. NICHOLSON. 1959. Parathion resistant *Aedes nigromaculis* in California. Mosquito News 19:12-14.

MULLA, M. S. 1964. Problems in the development of new mosquito larvicides. C.M.C.A. Proc. & Papers 32:45-47.

MULLA, M. S., R. L. METCALF, and G. KATZ. 1964. Evaluation of new mosquito larvicides with notes on resistant strains. Mosquito News 24:312-319.

WILDER, W. H. 1966. In preparation.

RESISTANCE IN FLORIDA AND COUNTERMEASURES INVOLVING CHEMICALS

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During the past 20 years a vast majority of the mosquito control projects in Florida have been directed against the two species most prevalent in salt marshes, *Aedes taeniorhynchus* (Wiedemann) and *Aedes sollicitans* (Walker). Although permanent control measures have been emphasized wherever practicable, large quantities of insecticides have been used to give inhabitants of heavily infested areas temporary relief while more permanent measures were being instituted.

DDT was used extensively between 1945 and 1949, with excellent results in most places. However, as early as 1947 and 1948, Bertholf (1950) and Cain (1950) were having difficulty obtaining good results in Broward and Brevard counties, and by the summer of 1949 other districts were reporting poor control with DDT. When Deonier and Gilbert (1950) compared the susceptibility of adults and larvae from treated and untreated areas, they found that resistance had developed both to DDT and TDE. Unfortunately the districts that had been the most conscientious in their efforts to kill mosquitoes were the ones with the worst problems. A direct relationship obviously existed between the percentage of mosquitoes killed and the rapidity with which resistance developed.

Good control was temporarily re-established by changing from DDT to benzene hexachloride. However, Keller and McDuffie (1952) soon found that larvae from the Cocoa Beach area were developing a tolerance for benzene hexachloride, and Keller and Chapman (1953) found that mosquitoes in the same area were becoming resistant to dieldrin. Nonetheless, benzene hexachloride continued to be the most widely used insecticide, and it produced satisfactory control in most places between 1950 and 1953–1954. Whenever resistance to benzene hexachloride became acute, dieldrin was substituted. By the summer of 1955, however, resistance had developed to such a degree in some of the intensely treated areas of Florida that satisfactory control could not be obtained with DDT, benzene hexachloride, or dieldrin (Beidler 1956, Bertholf 1956, Stutz 1956.)

By the spring of 1955, considerable uncertainty existed over a future course to follow in controlling salt-marsh mosquitoes with insecticides. Malathion was commercially available, and Gjullin and Peters (1956) had obtained satisfactory control of adults of *Aedes nigromaculis* Ludlow in California by applying aerial sprays of this insecticide at the rate of 0.5 pound per acre. However, there was some fear that the compound might be too toxic to use over inhabited areas. Because the salt-marsh mosquito problem was so acute in Broward County, J. H. Bertholf, director of the mosquito control district in that county, requested our laboratory to evaluate malathion in his area. In October 1955, Gahan *et al.* (1956) applied solutions of malathion plus cyclohexanone in fuel oil by airplane to areas heavily infested with adults of *Aedes taeniorhynchus* and *Aedes sollicitans* that were highly resistant to chlorinated hydrocarbon insecticides. Treatments at 0.5, 0.25, and 0.1 pounds of malathion per acre gave control of 95 to more than 99 percent. In 1956 Rogers *et al.* (1957) found that thermal aerosol formulations of malathion were highly effective against these two species when they were applied by ground equipment.

During the latter half of the 1950's and the early part of the 1960's malathion was the principal insecticide used to control salt-marsh mosquitoes in Florida. Rogers and Rathburn (1964) reported that in 1957 the Florida State Board of Health strongly recommended to the various mosquito control agencies in the State that they use organaphosphates only to control the adult mosquitoes. These control agencies were advised to conduct no large-scale campaigns with malathion in uninhabited areas. This restriction was suggested in order to maintain a large population of mosquitoes that had received no treatment which would breed with strains that had been sprayed with malathion. The only larvicides recommended were diesel oil and granular formulations containing paris green.

In 1956, Rogers and Rathburn (1964) obtained an average kill of 93 percent when they exposed DDT-resistant *Aedes taeniorhynchus* to a thermal aerosol containing 8 ounces of malathion per gallon of #2 fuel oil, applied at the rate of 40 gallons an hour from a vehicle moving at 5 mph. The same type of test was repeated in 1957, 1958, 1961, and 1963 with no appreciable reduction in kill or indication of resistance.

In 1956 and 1957 Davis *et al.* (1959) compared salt-marsh mosquito larvae collected in Florida with others collected as eggs from an area in Georgia where very little control work had been done. In the larvicide tests the Georgia strain was 8-10 times more susceptible to DDT, benzene hexachloride, and dieldrin than larvae collected in Florida, but there was no more than a 2-fold difference in susceptibility of the two strains to five organophosphorus insecticides. The Florida larvae were at least equally as susceptible to malathion as the Georgia larvae. In wind tunnel tests, adult mosquitoes from Florida were almost 8 times as resistant to DDT as those from Georgia but there was little difference in the susceptibility of the two strains to benzene hexachloride, and the adults from Florida were 2.4 times more susceptible to malathion than adults from Georgia.

It seems probable that the judicious use of malathion greatly prolonged the period of effectiveness of this insecticide in Florida, since Gjullin and Isaac (1957) reported that *Culex tarsalis* Coquillett developed resistance to malathion in California within 2½ years after it was first used on a large scale.

The first indications that salt-marsh mosquitoes in Florida might be developing resistance to malathion appeared during the summer of 1965. The Lee County mosquito abatement district had been using airplane applications of malathion successfully for several years. They found their treatments were not as effective in 1964 as they had been previously, and in 1965 the control obtained with this insecticide was poor. During the fall of 1965, laboratory tests were made by Glancey *et al.* (in press) to compare *Aedes taeniorhynchus* collected from this area with a strain of the same species that has been reared in the laboratory since 1958 without intentional exposure to insecticides. The results of these tests indicated that the strain from Lee County was definitely developing resistance to malathion: the quantity of insecticide required to produce similar kills in the wild strain was about 6 times higher at the LC_{50} and 14 times higher at the LC_{90} with larvae and 10 times higher at the LC_{50} and 13 times higher at the LC_{90} with adults than that required for the laboratory strains.

Our laboratory has begun a survey to determine the extent of resistance to malathion in Florida. Only six counties have been sampled to date so the present report is incomplete. Larvae from eggs of *Aedes taeniorhynchus* have been collected in the field from Brevard, Indian River, Dade, Pinellas, Broward, and St. Johns counties and brought to the laboratory. Some of these mosquitoes were used in larvicide tests, while others were reared to the adult stage and tested in a wind tunnel. Adults and larvae from the same laboratory colony of *Aedes taeniorhynchus* employed by Glancey *et al.* (in press) were used for comparison. Other similar studies were made on the same strains to determine whether cross resistance had also developed to some of the newer insecticides. Because of a shortage of mosquitoes, no larvicide tests were made with the strains collected in Broward County, and no adulticide tests were made on the strain from St. Johns County.

The larvicide tests were conducted by dissolving the chemicals in acetone and adding them to distilled water. The concentrations varied with the toxicity of the compounds, but with each larvicide at least four concentrations were used to produce a range in mortalities between 20 and 100 percent. The acetone solution of the insecticide was first introduced into 225 ml. of water in a 250-ml. beaker, then 25 larvae were counted into another 25 ml. of water, and the water containing the larvae was poured into the beakers containing the insecticide. Each concentration was tested against two batches of larvae, produced or collected on different days, and duplicate beakers of 25 larvae each were used in the tests with each batch, a total of 100 larvae. The mortality that occurred in 24 hours was recorded. The LC_{50} and LC_{90} were calculated from the mortalities obtained.

The wind-tunnel (adulticide) tests were conducted with insecticides dissolved in odorless kerosene. As in the larvicide studies, the concentrations varied with the insecticide. The wind tunnel consisted essentially of a cylindrical tube 4 inches in diameter through which a column of air was moved at 4 mph by a suction fan. A cage containing 25 female mosquitoes was placed in the center of the tube. One-fourth ml. of insecticide solution was atomized at a pressure of 1 psi into the mouth of the tunnel, and the mosquitoes were exposed to the spray momentarily as it was drawn through the cage. Duplicate tests were run at each concentration. After treatment, the mosquitoes were anesthetized with carbon dioxide, transferred to untreated screen holding cages, and held at a temperature of 29.5° C. and a relative humidity of about 70 percent. A cotton pad saturated with a 20 percent honey-water solution was placed on the top of each cage, and the mortality was recorded after 24 hours.

If we assume that the strain of *Aedes taeniorhynchus* reared in the laboratory was nonresistant, it is obvious from the results shown in Tables 1 and 2 that all the field strains showed considerable resistance to malathion. The tests with larvae show that the strains from Brevard and St. Johns counties have developed a high degree of resistance; these insects were more than 13 and 30 times as difficult to kill at the LC_{50} and about 170 and 40 times as difficult to kill at the LC_{90} as the laboratory-reared strain. The Lee and Pinellas strains were 13 to almost 17 times as resistant as the laboratory strain at the LC_{90}. The resistance of the Indian River and Dade strains were only 3-5 times higher than the laboratory strain at both the LC_{50} and LC_{90}.

TABLE 1.—Results of larvicide tests with malathion against *Aedes taeniorhynchus* from various sections of Florida and a laboratory colony.

Mosquito strain	Lethal concentration (in ppm.)	
	LC_{50}	LC_{90}
Brevard	0.634	17.4
Laboratory	.047	.102
Indian River	.17	.57
Laboratory	.053	.11
Pinellas	308	1.845
Laboratory	.05	.109
Dade	.096	.2
Laboratory	.02	.04
Lee	.326	1.144
Laboratory	.055	.087
St. Johns	.30	1.3
Laboratory	.01	.03

TABLE 2.—Results of wind-tunnel tests with malathion against adults of *Aedes taeniorhynchus* from various sections of Florida and a laboratory colony.

Mosquito strain	Lethal concentration (in percent)	
	LC_{50}	LC_{90}
Brevard	0.23	1.32
Laboratory	.019	.036
Indian River	.059	.32
Laboratory	.013	.021
Pinellas	.082	.557
Laboratory	.03	.05
Dade	.096	204
Laboratory	.02	.033
Broward	.06	.2
Laboratory	.02	.033
Lee	.09	.329
Laboratory	.009	.025

The Brevard strain of adults was also one of the most resistant in the wind-tunnel tests. It was about 12 times as resistant at the LC_{50} and over 36 times as resistant at the LC_{90} as the laboratory strain. The Lee strain, collected from the area that first reported difficulty in obtaining control with malathion, was less resistent than the Brevard strain and probably no more resistant than the Indian River or Pinellas strains at the LC_{90}. The Dade and Broward strains were 3-6 times more difficult to kill than the laboratory strain and were the least resistant of the group.

The Florida State Board of Health (unpublished data obtained during the same period) also reported that resistance to malathion is developing in *Aedes taeniorhynchus*.

It can be argued that these field collected insects may have received some exposure to insecticides before being used, because they were tested without being reared to the F_1 generation. However, no chemicals were applied to these breeding areas during the month before the collections were made. Since none of the larvicides in current use remain effective more than a few days in the presence of organic matter, it seems impossible that any effective residual deposits were present.

Field tests will be needed to determine whether other insecticides must be immediately substituted for malathion in the areas in question. However, the results obtained should forewarn those engaged in mosquito control operations in Florida that a change is occurring in the mosquito population and that control procedures may soon have to be revised again.

Fortunately, in 1966, more good insecticides with low toxicity to warm-blooded animals are available than there were in 1955. As early as 1959 Davis *et al.* (1960) and Davis and Gahan (1961) found that fenthion and naled were highly effective when they were applied by airplane to areas that were naturally infested with adults of *Aedes taeniorhynchus*. Fuel oil solutions applied from a Stearman airplane at the rate of 0.025 pound of naled or 0.05 pound of fenthion per acre caused reductions of 99 percent in the adult population. Fenthion gave 87 percent control at 0.025 pound per acre. Fenthion also was much more toxic than naled and malathion against larvae of this species in laboratory tests. Shortly thereafter Rathburn and Rogers (1961; 1963) found that naled and fenthion were effective against *Aedes taeniorhynchus* when they were used as thermal aerosols.

Naled was first sold to mosquito control districts in Florida during the summer of 1962. It has been used extensively since that time. Some fenthion has been applied during the past year, but so far this compound has not received general acceptance.

To determine whether or not the strains resistant to malathion showed cross-resistance to fenthion and naled, larvicide tests were run against the Brevard, Indian River, Pinellas, and St. Johns strains, and wind-tunnel tests were conducted against adults of the Pinellas strain to compare their susceptibility with that of the laboratory colony. As shown in Tables 3 and 4 there was no cross-resistance to either of these compounds. There seems little doubt that fenthion and naled could substitute for malathion in these areas.

Application by thermal aerosol generators is one of the preferred methods of dispersing insecticides in Florida to control adult mosquitoes. Mount *et al.* (in press) recently compared one of the popular thermal aerosol generators with a

TABLE 3.—Results of larvicide tests with fenthion and naled against *Aedes taeniorhynchus* from various sections of Florida and a laboratory colony.

Mosquito strain	Lethal concentration (in ppm)			
	Fenthion		Naled	
	LC_{50}	LC_{90}	LC_{50}	LC_{90}
Brevard	0.012	0.02	0.078	0.153
Laboratory	.011	.015	.059	.123
Indian River	.005	.008	.066	.133
Laboratory	.005	.008	.075	.148
Pinellas	.006	.014	.098	.17
Laboratory	.005	.008	.097	.173
St. Johns	.006	.01	.10	.18
Laboratory	.005	.009	.09	.17

TABLE 4.—Results of wind-tunnel tests with fenthion and naled against adults of *Aedes taeniorhynchus* from Pinellas County, Florida and a laboratory colony.

Mosquito strain	Lethal concentration (in percent)			
	Fenthion		Naled	
	LC_{50}	LC_{90}	LC_{50}	LC_{90}
Pinellas	0.007	0.014	0.004	0.008
Laboratory	.009	.013	.013	.023

nonthermal aerosol machine designed and developed by the U. S. Army Engineer Research and Development Laboratories, Fort Belvoir, Virginia (Morrill and Wesley, 1955 and Edmunds *et al.*, 1958), commonly called a "cold fogger." They found that both types of machines were about equally effective when malathion, fenthion, and naled were used as toxicants against caged adults of *Aedes taeniorhynchus*. They also found water equal to fuel oil as a diluent for insecticides dispersed as nonthermal aerosols. In other tests conducted against *Aedes taeniorhynchus* with the cold fogger by Mount *et al.* (in press), emulsions of fenthion, Bayer 41831 (*O,O*-dimethyl *O*-4-nitro-*m*-tolyl phosphorothioate), Baygon® (*o*-isopropoxyphenyl methyl carbamate), Dursban® (*O,O*-diethyl *O*-3,5,6-trichloro-2-pyridyl phosphorothioate) and Geigy GS-13005 (*O,O*-dimethyl phosphorodithioate *S*-ester with 4-(mercaptomethyl)-2-methoxy-Δ^2-1,3,4-thiadiazolin-5-one) were about equally effective.

Wind-tunnel tests conducted by Gahan and Davis (1964) showed that Baygon was slightly inferior to fenthion, about equal to naled, and superior to malathion against adults of the laboratory colony of *Aedes taeniorhynchus*. They also found that Bayer 41831 was slightly more toxic than malathion at the LC_{50} but less toxic at the LC_{90}. In another unpublished study, our laboratory found Shell SD–8211 (2-chloro-1-(2,5-dichlorophenyl) vinyl dimethyl phosphate) considerably more toxic than malathion and about equal to fenthion.

Tests have also been conducted in our laboratory with other materials that might be used as larvicides against *Aedes taeniorhynchus*. Fenthion, naled, malathion, DDT, and parathion were used as standards (Table 5). Dursban and Abate[(R)]

TABLE 5.—Results of larvicide tests with new compounds against *Aedes taeniorhynchus* reared in the laboratory.

Insecticide name or company designation	Lethal concentration (in ppm.) LC_{50}	LC_{90}
New Insecticides		
Dursban	0.00092	0.0012
Abate	.0015	.0025
Shell SD–7438	.004	.007
Bayer 41831	.018	.03
Shell SD–8211	.019	.031
Shell SD–8447	.036	.071
Standard Insecticides		
Parathion	.0032	.005
Fenthion	.0051	.0084
Malathion	.058	.092
Naled	.11	.2
DDT	.8	7.5

(*O,O*-dimethyl phosphorothioate *O,O*-diester with 4,4′-thiodiphenyl) were the outstanding materials; they show promise of being two of the most effective, if not the most effective, compounds ever tested by our laboratory against larvae of *Aedes taeniorhynchus*. Shell SD–7438 (*O,O*-dimethylphosphorodithioate *S,S*-diester with toluene-*alpha,alpha*-dithiol) was slightly inferior to parathion, the best of the standards, but was superior to all the other standards. Bayer 41831, Shell SD–8211, and Shell SD–8447 (2-chloro-1-(2,4,5-trichlorophenyl)vinyl dimethyl phosphate) were the least effective of the new materials, but they also should be considered promising larvicides because they were more toxic than malathion, naled, and DDT.

Of the new materials mentioned in this report, Abate, Baygon, Dursban, fenthion, and naled are commercially available. Based on the literature, on information received from manufacturers, or on the reports of the U. S. Food and Drug Administration, the oral LD_{50}s of these materials in mg./kg. of body weight in rats are at least 1,766 mg. for Abate, 95–104 mg. for Baygon, 135–163 mg. for Dursban, 215–245 mg. for fenthion and 430 mg. for naled. It appears that all should be safe enough to use. At the present time the three Shell compounds are not commercially available. However, Shell SD–8211 and Shell SD–8447 are extremely promising for field studies since they have oral LD_{50}s in rats of 3,680 and >2,500 mg./kg. of body weight, respectively, and appear to be both safe to warm-blooded animals and highly toxic to mosquitoes.

Little information is available on the resistance of other species of mosquitoes to insecticides. However, evidence collected by Evans *et al.* (1960) and Porter *et al.* (1961) showed that *Aedes aegypti* in the Miami area has developed some resistance to DDT. Abedi and Brown (1961) applied "selection pressure" with DDT to a strain of this species that was originally collected in Key West, Florida and found that the LC_{50} steadily increased. They concluded that larvae of *Aedes aegypti* from Key West, Florida are capable of developing high resistance to DDT. DDT has been used frequently to control larval *Aedes aegypti* in the southern part of Florida. Since a campaign to eradicate *Aedes aegypti* has recently been inaugurated in Florida, the problem of resistance to DDT assumes more importance than it has in the past.

Although resistance to insecticides continues to be a problem, we see no reason to be pessimistic about the future of chemicals in the control of mosquitoes. More than 50 years of research were required to find any toxicants that could be depended on to produce a high degree of control. Since statisticians tell us that scientific information is accumulating in a geometrical progression, it is not unreasonable to believe that a much shorter period of research will produce insecticides to which resistance cannot be developed.

SUMMARY. The two species of salt-marsh mosquitoes in Florida developed tolerance to the chlorinated hydrocarbons before 1955. At present, *Aedes taeniorhynchus* is becoming resistant to malathion also. However, the problem of finding suitable substitutes is not as acute as in 1955 because a larger number of effective materials are available that appear to be safe to use in inhabited areas. Commercially available insecticides that appear to be outstanding as both larvicides and adulticides are fenthion, naled, and Dursban® (*O,O*-diethyl *O*-3,5,6-trichloro-2-pyridyl phosphorothioate). Abate® (*O,O*-dimethyl phosphorothioate *O,O*-diester with 4,4′-thiodiphenyl) appears to be an excellent larvicide though not an outstanding adulticide, while Baygon® (*o*-isopropoxyphenyl methylcarbamate) is a highly effective adulticide but only a fair larvicide.

Literature Cited

ABEDI, Z. H., and BROWN, A. W. A. 1961. DDT-resistance hazard in North American populations of *Aedes aegypti*. Mosquito News 21(1): 1–3.

BEIDLER, E. J. 1956. Indian River Mosquito Control District. Annual report; Fla. Anti-Mosq. Assoc. 27:34–35.

BERTHOLF, J. H. 1950. DDT resistant mosquitoes in Broward County, Florida. Annual report; Fla. Anti-Mosq. Assoc. 21:80–83.

———, 1956. Broward County Anti-Mosquito District. Annual Report; Fla. Anti-Mosq. Assoc. 27:18–24.

Cain, T. J. 1950. Observations on DDT resistant species of mosquitoes found in Brevard County. Annual report; Fla. Anti-Mosq. Assoc. 21:84–85.

DAVIS, A. N., and GAHAN, J. B. 1961. New insecticides for the control of salt-marsh mosquitoes. Florida Entomologist 44(1):11–14.

———, SALMELA, J., and SPENCER, C. B., JR. 1960. Aerial spray tests against adult salt-marsh mosquitoes in Florida—1959. Proc. N. J. Mosq. Ext. Assoc. 47:92–94.

———, WEIDHAAS, D. E., and FORD, H. R. 1959. Relative susceptibility of salt-marsh mosquitoes from Georgia and Florida to insecticides. Florida Entomologist 42(3):109–111.

DEONIER, C. C., and GILBERT, I. H. 1950. Resistance of salt-marsh mosquitoes to DDT and other insecticides. Mosquitoes News 10(3):138–143.

Edmunds, L. R., HAHL, R. G., and LOWE, H. N., JR. 1958. Particle size studies using a non-thermal aerosol fog generator designed for control of adult insects. Mosquito News 18(4): 321–324.

EVANS, B. R., PORTER, J. E. KOZUCH, G., and FINK, E. J. 1960. Susceptibility lev.. of some *Aedes aegypti* (Linn.) larvae to DDT and dieldrin. Mosquito News 20(2):116–118.

GAHAN, J. B., BERTHOLF, J. H., DAVIS, A. N., JR., and SMITH, C. N. 1956. Field tests with two phosphorothioates against resistant salt-marsh mosquitoes. Mosquito News 16(2):91–93.

———, and DAVIS, A. N. 1964. Toxicity of a group of new insecticides to adults of *Aedes taeniorhynchus*. Proc. N. J. Mosq. Ext. Assoc. 51:162–165.

GJULLIN, C. M., and ISAAK, L. 1957. Present status of mosquito resistance to insecticides in the San Joaquin Valley in California. Mosquito News 17(2):67–70.

———, and PETERS, R. F. 1956. Tests with aerial-sprays of malathion for the control of mosquitoes. Mosquito News 16(2):84–86.

GLANCEY, B. M., LOFGREN, C. S., and MILLER, T. W. 1966. Malathion resistance in the black salt-marsh mosquito, *Aedes taeniorhynchus* (Wiedemann) in Florida. Mosquito News: (In press).

KELLER, J. C., and CHAPMAN, H. C. 1953. Tests of selected insecticides against resistant salt-marsh mosquito larvae. J. Econ. Entomol. 46 (6):1004–1006.

———, and McDUFFIE, W. C. 1952. The development of insecticide resistance in salt-marsh mosquitoes in Florida. Proc. N. J. Mosq. Ext. Assoc. 39:139–144.

MORRILL, A. W., JR., and WESLEY, C., JR. 1955. Studies on insecticidal fog generation for military use. Mosquito News 15(2):85–90.

MOUNT, G. A., LOFGREN, C. S., and GAHAN, J. B. 1966. Non-thermal aerosols of new insecticides for the control of *Aedes taeniorhynchus* (Wiedemann). Proc. N. J. Mosq. Ext. Assoc.: (In press)

———, ———, ———, and PIERCE, N. W. 1966. Comparisons of thermal and non-thermal aerosols of malthion, fenthion and naled for the control of stable flies and salt-marsh mosquitoes. Mosquito News: 26(2):132–138.

PORTER, J. E., EVANS, B. R., and KOZUCHI, G. 1961. Further comments on the susceptibility of *Aedes aegypti* to DDT in the Miami, Florida, area. Mosquito News 21(1):4–5.

RATHBURN, C. B., JR., and ROGERS, A. J. 1961. Tests of insecticides for the control of adult mosquitoes. 1959–1961. Annual report: Fla. Anti-Mosq. Assoc. 32:36–40.

———, ———. 1963. Thermal aerosol insecticide tests for the control of adult mosquitoes. 1961–1962. Mosquito News 23(3):218–220.

ROGERS, A. J., BEIDLER, E. J., and RATHBURN, C. B., JR. 1957. A progress report on dosage tests with mosquito adulticides. Mosquito News 17(3):190–194.

———. and RATHBURN, C. B., JR. 1964. Present status of insecticides for mosquito control in Florida. Mosquito News 24(3):286–291.

STUTZ, F. H. 1956. Dade County Anti-Mosquito District. Annual report: Fla. Anti-Mosq. Assoc. 27:29–31.

SUMMARY OF SYMPOSIUM

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It was rash to accept the chairman's invitation to summarize this symposium, for it has turned out to contain so many and diverse points. Fortunately, however, the order of the successive contributions makes sense, starting with the underlying biochemical and genetical causes of resistance, and then proceeding from the northeastern States where the problem is hesitantly developing, thence to Florida where organophosphorus-resistance is eventually being added to organochlorine resistance, and finally to California where every mosquito resistance problem that we can now think of has definitely developed.

Dr. Perry has shown us what research in the past 10 years has revealed about the biochemical mechanisms of resistance, and that a mosquito gets to be resistant essentially because it can break down the insecticide. With DDT, the detoxication mechanism removes hydrochloric acid from the molecule, and the enzyme that does it is thus a dehydrochlorinase. This dehydrochlorination has been found to occur in DDT-resistant culicines just as definitely as in resistant house flies. In anophelines the picture is not so clear, but probably Dr. Perry will agree that dehydrochlorination accounted for part of the DDT-resistance in the Turkish *Anopheles atroparvus* that he studied.

Attempts to counter this resistance in mosquitoes by adding to the DDT some dehydrochlorinase inhibitor, such as DMC or WARF-Antiresistant, proved effective at first but after a few generations of this treatment the mosquitoes developed a resistance to the DDT-synergist mixture. Substitution of DDT with compounds similar in molecular configuration but far less open to detoxication has proved more successful. Deutero-DDT, less detoxicable because the hydrogen in the center of the molecule is replaced by its isotope deuterium, is effective against DDT-resistant mosquitoes, and better than DDT against the susceptible ones. The compound CP-47412, containing cyclopropane instead of ethane as the central spine of the molecule, is perhaps even more successful. Nevertheless, the remedial insecticides for resistant strains are still usually

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LOW VOLUME APPLICATIONS OF INSECTICIDES FOR THE CONTROL OF ADULT MOSQUITOES [1]

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After the successful use of low volume aerial applications of malathion to control adult salt-marsh mosquitoes (Glancey *et al.*, 1965), additional tests were conducted to evaluate other insecticides and mixtures as low volume aerial sprays. Early in the program it became necessary to develop a portable spray unit. We wished to test application rates lower than 1 ounce per acre, and the scale and sludge from the spray tank installed in the plane, which had been used over several years with various insecticides and formulations, constantly plugged the very small openings of the orifice plates used in the Mini-Spin nozzle. We decided to bypass the plane's spray system by using a 2 gallon B & G® stainless steel spray tank pressurized to 40 p.s.i. by a carbon dioxide cylinder. A pressure regulator was used to maintain a constant pressure. The spray tank and CO_2 cylinder were strapped in place in the baggage compartment of the airplane (Figure 1). Clear plastic tubing was run from the spray tank to the pilot's compartment and hooked to an on-off valve. Another section of tubing was run forward from the valve through the fuselage and alongside the boom. All fittings were of brass. Four Mini-Spin nozzles were attached to the plastic tubing, and the nozzles were then attached to the boom (Figure 2). Thus the boom of the plane merely served as a support for a secondary plastic boom and nozzles.

The advantages offered by this system were: (1) the spray tank could be pressurized, the valve opened, and the discharge collected and measured; flow rates for the various orifice plates could be measured without the plane leaving the ground; (2) the entire assembly could be broken down and cleaned after every operation; (3) the clear plastic liner made any trash visible; and (4) the system could be mounted on any plane that has an existing boom.

The insecticides tested in this study were naled, fenthion, and mixtures of naled-malathion, naled-glycol, and fenthion-Baygon® (*o*-isopropoxyphenyl methylcarbamate). The tests were made in 50-acre plots in citrus groves naturally infested with adults of salt-marsh mosquitoes (*Aedes taeniorhynchus* (Wiedemann) predominating). Each insecticide or mixture was tested three times; one test was made in a plot with a heavy canopy, one in a plot with a medium canopy, and one in a plot with a light canopy.

The concentrated insecticides were sprayed from a Stearman airplane flying 100-foot swaths at a speed of 80 m.p.h. and an altitude of 50 to 75 feet. Since increasing the area that can be covered with the pay load of the airplane is one of the main objectives of low volume spraying, these materials were applied in the most concentrated liquid form available. Both the malathion and glycol were used as unformulated technical materials; the malathion contained 10.25 pounds of active ingredient per gallon and the glycol weighed 9.3 pounds per gallon. The naled was applied as an oil-soluble concentrate containing 14 pounds of active ingredient per gallon; the fenthion as an oil-soluble spray concentrate containing 8 pounds of active ingredient per gallon; and the Bay-

[1] Mention of a proprietary product does not necessarily imply endorsement by the U. S. Department of Agriculture.

[2] Chevron Chemical Company, P. O. Box 7067, Orlando, Florida.

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[4] Director, Brevard Mosquito Control District, Merritt Island, Florida.

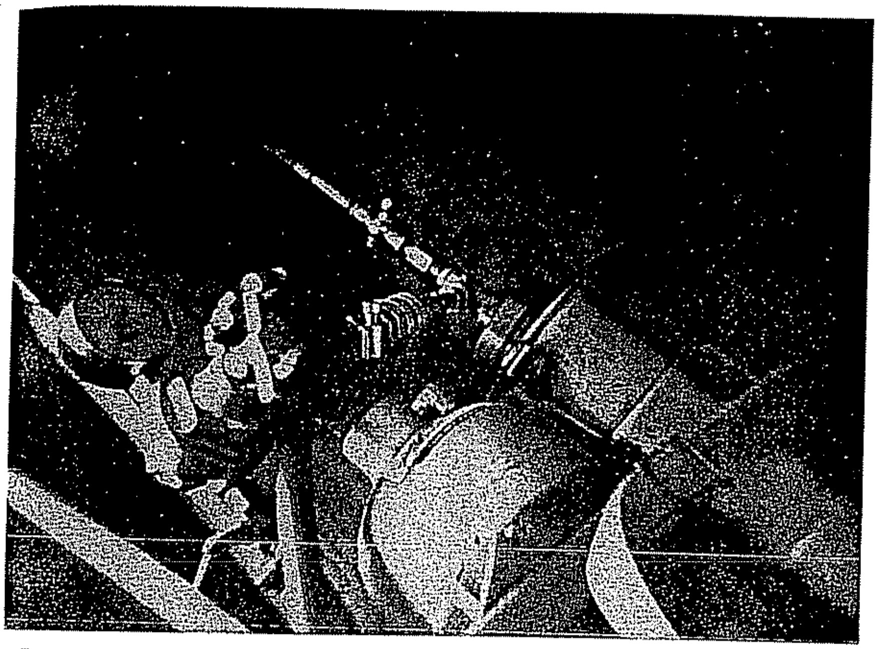

FIG. 1.—Self-contained unit used for aerial application of low volume (undiluted) aerial sprays. The unit consists of a B & G spray tank to hold the insecticide and a CO_2 cylinder with pressure regulator to provide a constant output.

gon as an emulsifiable concentrate containing 1.5 pounds of active ingredient per gallon.

Application dosages were figured on the basis of the volume of liquid (fl. oz.) and the weight of active ingredient (lbs.) per acre. The degree of control was determined by making pre- and posttreatment counts of the mosquitoes that landed on the front and back of two observers who stood side by side facing in opposite directions at 10 different locations in each of the treated areas. From these counts the number of mosquitoes per man per minute was calculated. Posttreatment counts were made after 6 and 24 hours. Attempts to make 48-hour posttreatment counts failed because of weather conditions. The results of the tests are given in Table 1.

Six hours after application, excellent control (95 percent or better) was obtained with 0.5 fl. oz. (0.05 lb.) of naled per acre, 0.5 fl. oz. (0.05 lb.) of naled plus 0.5 fl. oz. (0.04 lb.) of glycol, 0.5 fl. oz. (0.05 lb.) naled plus 0.5 fl. oz. (0.04 lb.) of malathion, and 1 fl. oz. (0.11 lb.) of naled plus 4 fl. oz. (0.32 lb.) of malathion. After 24 hours the mixture of 1 fl. oz. (0.11 lb.) of naled plus 4 fl. oz. (0.32 lb.) of malathion was the only treatment giving excellent control (97 percent). Obviously, naled at dosages as low as 0.5 fl. oz. (0.05 lb.) per acre produces early kills but does not last 24 hours. On the other hand, in tests conducted in 1964 (Glancey *et al.*, 1965), malathion at dosages of 4 fl. oz. or less produced low kills at 6 hours but high kills at 24 hours. The 1:4 mixture of naled and malathion gave very effective early and residual control.

The mixture of fenthion and Baygon was also very effective. The control with this mixture after 24 hours (93 percent) was almost as good as that with the best

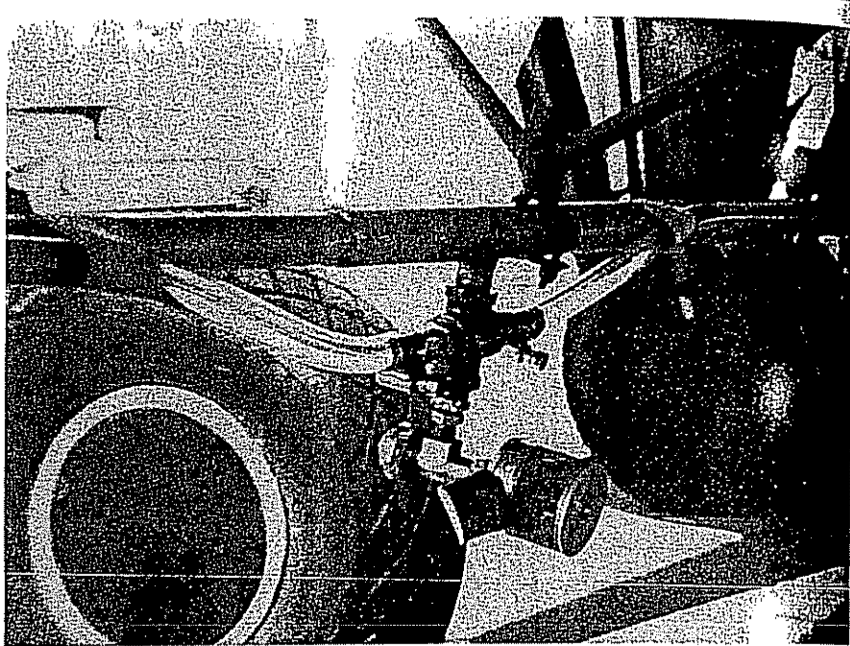

FIG. 2.—Mounting of a plastic boom and Mini-Spin nozzle. The top outlet of the tee is brazed shut to separate this experimental system from the spray system of the airplane.

TABLE 1.—Control of adult salt-marsh mosquitoes with various insecticides applied in low volume sprays from a Stearman airplane equipped with Mini-Spin nozzles. (*A. taeniorhynchus* predominating; plane speed 80 m.p.h., 100-foot swaths; 50–75 feet altitude; average of three tests.)

	Amount per acre		Pretreatment count	Percent reduction after—	
Insecticide	Pounds	Fluid ounces	(avg/man/min)	6 hours	24 hours
Naled	0.05	0.5	47	98.5	32
Naled	.05	.5	26	95	55
Glycol	.04	.5	...	....	...
Naled	.05	.5	45	98.5	59
Malathion	.04	.5	...	....	...
Naled	.05	.5	113	72	84
Malathion	.16	2.0			
Naled	.11	1.0	118	97	97
Malathion	.32	4.0			
Fenthion	.016	.25	49	17	42
Fenthion	.03	.5	89	49	64
Fenthion	.05	.8	139	83	93
Baygon	.02	1.6			

[nal]ed-malathion mixture, although the [fin]al volume was only half as large and [th]e total weight of insecticide was one-[fif]th as large.

Summary. Field tests with low volume [sp]rays of undiluted technical insecticides [fo]r the control of salt-marsh mosquitoes [we]re made in Florida citrus groves. Ap[p]lication dosages were figured on the [ba]sis of the volume of liquid (fl. oz.) and [th]e weight of active ingredient (lbs.) per [ac]re. Control of 95 percent or higher was [ob]tained 6 hours after treatment with [0.5] fl. oz. (0.05 lb.) naled per acre, 0.5 [fl.] oz. (0.05 lb.) naled plus 0.5 fl. oz. [(0].04 lb.) malathion per acre, 0.5 fl. oz. [(0].05 lb.) naled plus 0.5 fl. oz. (0.04 lb.) [gl]ycol per acre, and 1 fl. oz. (0.11 lb.) [na]led plus 4 fl. oz. (0.32 lb.) of malathion per acre. After 24 hours a mixture of 1 fl. oz. (0.11 lb.) naled and 4 fl. oz. (0.32 lb.) malathion gave 97 percent control, and a mixture of 0.8 fl. oz. (0.05 lb.) fenthion plus 1.6 fl. oz. (0.02 lb.) Baygon gave 93 percent control.

Acknowledgment. The authors acknowledge the assistance of T. Hester and K. Savage of this Division; Robert Lee and John Sullivan of the Brevard Mosquito Control District; John O'Neil of American Cyanamid Corporation; and James Connell, Chemagro Corporation.

Literature Cited

Glancey, B. M., Lofgren, C. S., Salmela, J., and Davis, A. N. 1965. Low volume aerial spraying of malathion for control of adult salt-marsh mosquitoes. Mosquito News 25:135–137.

STANDARDIZED FEEDING OF *AEDES AEGYPTI* (L.) MOSQUITOES ON *PLASMODIUM GALLINACEUM* BRUMPT-INFECTED CHICKS FOR MASS SCREENING OF ANTIMALARIAL DRUGS[1]

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In the course of a pilot study on the practicability of mass screening of antimalarial drugs against the parasitic stage (sporogonic cycle) in the mosquito vector, a number of techniques have been developed or improved. Techniques that are successful in a small number of tests in a research laboratory are not necessarily adaptable or efficient when applied to a line production type of drug screening.

Observations on the effect of anti-malarial drugs on the sporogonic cycle in the mosquito vector have been made by a number of investigators. Lumsden and Bertram (1940a) stated that the most delicate criterion for the estimation of the action of a drug was the development of the parasite in the mosquito. They selected the oocyst count as most suitable for their purpose. In another paper, Lumsden and Bertram (1940b) discussed the effects of plasmoquine and praequine on the subsequent development of the gametocytes

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[2] The assistance of L. H. Diven, J. M. Odell, [and] J. V. Gerberg is acknowledged.

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EVALUATION OF INSECTICIDES AGAINST TWO SPECIES OF *CULEX* MOSQUITOES ON OKINAWA[1]

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During August and September 1964 on the island of Okinawa we evaluated twelve insecticides as adulticides and/or larvicides against *Culex tritaeniorhynchus* Giles and *Culex quinquefasciatus* Say. These experiments were part of a continuing cooperative program between military entomologists and personnel of the Insects Affecting Man and Animals Research Branch, Entomology Research Division, U. S. Department of Agriculture.

The purpose of the program is to evaluate new insecticides and equipment against insects of medical importance on military installations around the world. Studies were conducted in Panama in 1962 and in Okinawa in 1963 (Gahan *et al.*, 1965). Our current tests were similar to those conducted in Okinawa except that we used a nonthermal aerosol generator rather than a thermal generator in the tests with adult mosquitoes and conducted laboratory as well as field tests with the larvicides.

The insecticides used and their mammalian toxicity are shown below.

Aerosol Tests

Methods. Formulations of water emulsions were used except in the test comparing the effectiveness of aerosols of oil and water. Commercial formulations of emulsifiable concentrates of four insecticides (Shell SD-8211, Mobil MC-A-600, carbanolate, and Bromophos-ethyl) were not available. Emulsifiable concentrates of the first three compounds were therefore prepared by dissolving the insecticide in a mixture of equal parts of acetone and xylene and adding 10 percent by volume of

Insecticide	Mammalian toxicity (Oral LD_{50}: mg/kg)
Abate® (*O,O*-dimethylphosphorothioate, *O,O*-diester with 4,4'-thiodiphenyl)	1,766 (rats)
Bayer 41831 (*O,O*-dimethyl *O*-4-nitro-*m*-tolyl phosphorothioate)	250 (rats)
Baygon (Bayer 39007; *o*-isopropoxyphenyl methylcarbamate)	95 (male rats); 104 (female rats)
Bromophos (CELA S-1942; *O*-(4-bromo-2,5-dichlorophenyl) *O,O*-dimethyl phosphorothioate)	3,750 (rats)
Bromophos-ethyl (CELA S-2225; *O*-(4-bromo-2,5-dichlorophenyl) *O,O*-diethyl phosphorothioate)	200 (rats)
Carbanolate (Upjohn U-12927; 6-chloro-3,4-xylyl methylcarbamate)	30–44 (rats); 300 (mice)
Fenthion	215 (male rats); 245 (female rats)
Malathion	1,375 (male rats); 1,000 (female rats)
Mobil MC-A-600 (benzo[*b*]thien-4-yl methyl carbamate)	500–700 (rats)
Naled	430 (rats)
Shell SD-7438 (*O,O*-dimethyl phosphorodithioate *S,S*-diester with toluene-*alpha, alpha*-dithiol)	280 (rats)
Shell SD-8211 (2-chloro-1-(2,5-dichlorophenyl)vinyl dimethyl phosphate	3,680 (rats); >5,000 (mice)

[1] Mention of a proprietary product does not necessarily imply endorsement of this product by the USDA

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emulsifier (Triton X-100). (A 1⅓ pound per gallon concentrate was prepared with Shell SD-8211 and 1 pound per gallon concentrates with Mobil MC-A-600 and carbanolate.) For Bromophos-ethyl 1 pound per gallon emulsifiable concentrate was prepared with xylene as the solvent and 10 percent of emulsifier. The concentrations of the commercial preparations in pounds per gallon were as follows: Baygon, 1.5; Shell SD-7438, 1.6; bromophos, 2; fenthion, Abate® and Bayer 41831, 4; malathion, 5; and naled, 8.

The tests were conducted on one side of a small airfield adjacent to the China Sea. The grass on the field was cut very short, and the entire area was open to provide an unobstructed working area. The wind velocity during the tests usually ranged from 4 to 10 m.p.h.; however, in a few tests it was as low as 2 m.p.h. and in others as high as 12 m.p.h. The wind direction varied from night to night, but usually the wind blew toward the sea (west to northwest).

The mosquitoes for the tests were collected in the field as larvae or pupae. They were placed in water in shallow pans which were inserted in screen cages about 18 inches square. The adults were allowed to emerge in the cages, and a record was maintained of their ages. Three- to eleven-day-old females were used in all tests except one. In this test a small number of one-day-old females was used to provide a full complement of cages. The afternoon before a test, the mosquitoes were aspirated from the emergence cages and placed in cylindrical exposure cages (3 inches diameter x 8 inches long) made of 16-mesh screen wire and open top jar caps. Twenty-five females were placed in each cage.

Two rows of 6-foot stakes with 2-foot crossarms at the top were set out in each test area. There were three stakes per row, 100 feet apart, and 100 feet between rows. The rows were aligned in the direction of the wind. The crossarms had a wire hook at each end. Just before a test two cages, one of each species of mosquito being tested, were hung on these hooks. In some tests with fenthion, the cages were also exposed 3 feet above the ground and at ground level. The aerosol generator was driven past the rows in a direction perpendicular to them and 100 feet upwind from the first stakes. After the aerosol fog had drifted past all the cages, they were taken off the crossarms and replaced with fresh cages. The treated mosquitoes were returned to the laboratory within 30 to 45 minutes of exposure, knocked down with carbon dioxide, and placed in clean holding cages. Posttreatment mortality counts were made the next morning, 14 to 15 hours after the exposure.

The equipment used to apply the insecticides was a truck-mounted nonthermal aerosol generator designed and developed by the U. S. Army Engineer Research and Development Laboratories. It consisted of a gasoline engine, a blower, an insecticide reservoir and pump, a simple flow control system, and a nozzle and discharge assembly. (A commercial model of this aerosol generator is manufactured and sold by the Curtis Dyna-Products Corporation, Westfield, Indiana.) During the tests the aerosol generator was operated at a speed of 5 m.p.h. and at a discharge rate of 40 gallons per hour. For each test the machine was operated over a distance of 300 feet. Under actual control operations the machine is usually driven up and down each street in a residential area; if we assume a distance of 300 feet between streets and the operating conditions listed above, the application rate on an acre basis for a 1 percent formulation would be approximately 0.037 pound (17 g.).

Three series of tests were conducted: (1) a comparison of the effectiveness of eight insecticides at various distances from the path of the aerosol generator, (2) a comparison of oil and water aerosols of fenthion, and, (3) a comparison of the kill of mosquitoes in cages placed at ground level and 3 and 6 feet above ground.

Results. The data for the eight insecticides are presented in Table 1. Against *C. tritaeniorhynchus*, Baygon and Bayer

TABLE 1.—Toxicity of eight insecticides applied with a nonthermal aerosol generator to caged mosquitoes of two species. (Avg. of 3 to 8 tests at each concentration each with 2 cages of 25 females each.)

Insecticide and concentration (oz./gal.)	Percent kill at indicated distance (ft.) from fogger							
	Culex tritaeniorhynchus				*Culex quinquefasciatus*			
	100	200	300	Avg.	100	200	300	Avg.
Baygon								
2	100	100	100	100	99.3	99.3	87	95
1	100	100	100	100	96	75	94	88
.5	100	99	96	98	79	62	57	66
.25	89	83	55	76	...	...	...	...
Bayer 41831								
4	100	100	99	99.7	100	100	100	100
2	100	93	98	97	100	100	100	100
1	98	95	89	94	99	96	95	97
.5	100	88	96	95	99	82	46	76
.25	69	49	25	48	...	...	...	...
Fenthion								
4	100	100	95	98	100	99	99.6	99.5
2	100	100	99	99.7	100	100	100	100
1	97	92	96	95	100	99.4	100	99.8
.5	45	51	59	52	99.3	100	99.2	99.5
.25	11	5	4	7	43	33	32	36
.125	...	...	...	...	6	7	6	6
Shell SD-8211								
4	100	99	95	98	100	92	76	89
2	100	99	100	99.7	81	73	65	73
1	97	96	93	95	53	65	57	58
.5	71	65	55	64	...	...	...	...
Naled								
6	100	100	99	99.7	100	100	93	98
4	100	100	97	99	100	94	79	91
2	90	99.7	98	96	94	88	85	89
1	75	45	50	57	69	45	58	57
Carbanolate								
4	100	100	98	99.3	93	84	59	79
2	90	94	97	94	86	83	53	74
1	43	50	59	51	...	...	...	...
Mobil MC-A-600								
4	97	100	97	98	88	98	65	84
2	52	71	52	58	50	75	62	62
Malathion								
12	72	46	59	59	...	...	...	...
10	33	27	12	24	...	...	...	...
8	32	18	19	23	...	...	...	...
6	28	32	12	24	...	...	...	...
4	44	38	29	37	63	58	60	60
2	...	...	...	...	65	63	64	64
1	...	...	...	...	13	19	10	14

41831 were the most effective compounds. On the basis of the average percent kill in all cages, Baygon gave 100-percent mortality at concentrations of 1 and 2 ounces per gallon and 98-percent mortality at 0.5 ounce per gallon; Bayer 41831 gave kills ranging from 94 to 99.7 percent at concentrations ranging from 0.5 to 4 ounces per gallon.

A kill of 94 percent or more was obtained at concentrations of 1 ounce per gallon with fenthion and Shell SD-8211, of 2 ounces per gallon with naled and carbanolate, and of 4 ounces per gallon with Mobil

MC-A-600. Malathion was practically ineffective; a concentration of 12 ounces per gallon was needed to produce 59 percent kill.

In the tests with *C. quinquefasciatus*, fenthion gave the best results; the average kill for all cages was above 99 percent at concentrations of 0.5 to 4 ounces per gallon; however, at 0.25 ounce per gallon the kill dropped to 36 percent. Bayer 41831 was the next most toxic: it produced over 97 percent mortality at concentrations of 1 to 4 ounces per gallon. Baygon (95 percent kill at 2 ounces per gallon) and naled (91 percent kill at 4 ounces per gallon) were the next most effective. Shell SD-8211, carbanolate, and Mobil MC-A-600 gave kills of 79 to 89 percent at the highest concentration evaluated (4 ounces per gallon). At this same concentration, malathion gave 60 percent kill.

A comparison of our results with those obtained by Gahan *et al.* (1965) shows that the relative toxicity of the three compounds evaluated in both tests was about the same for the two species. However, better kill of both species was obtained with the water emulsions of fenthion and Baygon that we used in our tests. For example, with fenthion in a thermal aerosol Gahan *et al.* obtained average kills of 58 and 80 percent with a concentration of one ounce per gallon with *C. tritaeniorhynchus* and *C. quinquefasciatus*, respectively. In our tests, the results at the comparable concentrations were 95 and 99.8 percent. The comparable results for each species with Baygon at a concentration of 2 ounces per gallon were 92 percent compared with 100 percent in *C. tritaeniorhynchus* and 58 percent compared with 95 percent in *C. quinquefasciatus*. With naled, the third insecticide tested both years, the test results were equivalent. An attempt to compare the thermal and nonthermal aerosol generators directly had to be abandoned because of difficulties in calibrating the two applicators to the same volume output.

The results of the comparison between fuel oil solutions and water emulsions of fenthion are given in Table 2. In this as in the third test, only *C. tritaeniorhynchus* were used. At both concentrations tested the aerosols with fuel oil gave slightly higher average kills than the aerosols with water; the difference was not considered significant. Additional tests will be needed to verify the point.

Table 3 compares the kill of mosquitoes exposed in cages at ground level and at 3 and 6 feet above ground. Based on the averages for all cages at each height, the highest kill was obtained at the 3-foot height (47 percent compared with 38 and 36 percent at ground level and 6 feet, respectively). It is interesting to note that the percentage kills at the different distances from the generator declined progressively for the cages at the 3- and 6-foot heights whereas, in contrast, the highest kill in the ground level cages was obtained

Table 2.—Toxicity of fenthion aerosols produced from fuel oil solutions and water emulsions in a nonthermal aerosol generator to caged females of *Culex tritaeniorhynchus*. (Avg. of 3 tests at each concentration, each with 2 cages of 25 females each; 1 test in each check.)

Type of fog and concentration of fenthion (oz./gal.)	Percent mortality at indicated distance (ft.) from fogger			
	100	200	300	Average
Oil				
1	92	83	85	87
.5	85	78	70	78
0 (check)	13	9	12	11
Water				
1	93	77	80	83
.5	86	58	59	68
0 (check)	5	6	8	6

TABLE 3.—Mortality of female *Culex tritaeniorhynchus* exposed in cages at different heights above ground to aerosols of fenthion produced with a nonthermal aerosol generator. (Fenthion concentration 0.5 oz./gal. avg. of 6 tests per height, each with 2 cages of 25 females each.)

Height of cage above ground, ft.	Percent mortality at indicated distance (ft.) from fogger			
	100	200	300	Average
0	39	26	50	38
3	62	44	36	47
6	39	36	33	36

at a distance of 300 feet, apparently because the particles of insecticides were settling to the ground as they drifted from the applicator.

LARVICIDE TESTS

METHODS. Laboratory tests were conducted with both mosquito species to determine the relative toxicity of eight compounds as larvicides. Acetone solutions of the larvicides were prepared from formulations of emulsifiable concentrates except for Shell SD-8211, for which the technical product was used. The standard test procedure for larvicides outlined in the WHO larval resistance test kit was used except that: (1) the insecticides were prepared in acetone solution instead of alcohol, and (2) the volume of solution added to each container was not kept constant at 1 ml. The actual volumes added varied from 0.1 to 2 ml., depending on the concentration of the stock solution. Larvae were collected in the field the same day the test was started. Only late third or early fourth instar larvae were used. Twenty larvae were placed in each 600-ml. test beaker; three replications with duplicate beakers were made with *C. tritaeniorhynchus* and two replicates with duplicate beakers for the *C. quinquefasciatus*.

In the field tests, the larvicides were evaluated against infestations of *C. tritaeniorhynchus* in rice paddies. These natural infestations were much lower than usual during 1964, probably because many farmers on Okinawa were switching from the production of rice to sugar cane and the resulting decrease in breeding area made it easier for the insect control units to treat the entire infested area. Because we lacked sufficient test areas, the procedures of Gahan *et al.* (1965) (entire rice paddies used as single plots) were not followed. Instead, plots 10 feet wide and 25 to 50 feet long were established along the edges of infested paddies. This was done only in paddies where the water was stationary. While this was not a completely satisfactory procedure, general observations of treated and check plots indicated little kill of larvae outside the plots, and the control obtained was in line with anticipated results based on the laboratory tests and the experience of other investigators.

The insecticides were applied as uniformly as possible with 2-gallon compressed air sprayers. About 2 ml. of formulation were applied per square foot. The actual dosages of insecticide applied ranged from 0.001 to 0.25 pound per acre; on a square foot basis this is an application rate of about 0.01 to 2.6 mg.

Three to six plots were treated at each application rate, except that only two plots were treated with the very high dosages of Abate® and Shell SD-7438. The effectiveness of the treatments was determined by the reduction in the number of third and fourth instar larvae picked up in 20 dips before and after application. The average number of larvae per dip for the various plots ranged from 1 to 273, with the majority in the range of 2 to 10.

RESULTS. The results of the laboratory tests are presented in Tables 4 and 5.

Abate® was outstanding in toxicity to both species. The LC_{50} was 0.00049 p.p.m. for *C. tritaeniorhynchus* and 0.00067 p.p.m. for *C. quinquefasciatus*. Shell SD-7438, fenthion, Bromophos-ethyl, Bayer 41831, and Bromophos were next in ef-

TABLE 4.—Mortality of larvae of *Culex tritaeniorhynchus* exposed to various larvicides in laboratory tests. (Avg. of 3 replicates with duplicate beakers, 20 late 3rd or early 4th instar larvae per beaker.)

Insecticide	Percent mortality in 24 hr. at concentration (p.p.m.) indicated														LC50	LC90
	.04	.02	.015	.01	.008	.006	.004	.003	.002	.001	.0008	.0006	.0004	.0002		
Abate®	..	..	..	..	..	..	..	..	..	98	93	66	35	0	.00049	.00075
Shell SD-7438	..	..	..	..	99	99	91	..	42	4	..	..	..	..	.0023	.0041
Fenthion	..	..	..	..	100	98	77	33	0	..	..	..	..	..	.0032	.0048
Bromophos-ethyl	..	..	..	100	94	87	33	..	2	..	..	..	..	..	.0044	.0066
Bayer 41831	..	..	..	100	99	71	20	..	2	..	..	..	..	..	.0045	.0066
Bromophos	..	99	..	87	57	26	2	..	..	..	..	..	..	..	.0078	.012
Shell SD-8211	..	89	65	11	4	3	..	..	..	..	..	..	..	..	.014	.023
Naled	100	70	..	12	4	..	..	..	..	..	..	..	..	..	.017	.026

TABLE 5.—Mortality of larvae of *Culex quinquefasciatus* exposed to various larvicides in laboratory tests. (Avg. of 2 replicates with duplicate beakers, 20 late 3rd or early 4th instar larvae per beaker.)

Insecticide	Percent mortality in 24 hr. at concentration (p.p.m.) indicated																		LC50	LC90
	.2	.1	.08	.06	.05	.04	.03	.02	.01	.008	.006	.004	.003	.002	.001	.0008	.0006	.0004		
Abate®	..	..	..	..	..	..	..	..	..	..	..	..	..	100	83	62	41	7	.00067	.0012
Fenthion	..	..	..	..	..	..	..	..	99	88	70	29	9	..	..	..	..	..	.0049	.0078
Bayer 41831	..	..	..	..	..	..	..	100	83	56	33	3	..	..	..	..	..	..	.0076	.011
Bromophos	..	..	..	..	..	..	..	99	75	62	32	6	0	..	..	..	..	..	.0076	.013
Shell SD-7438	..	..	..	..	..	100	100	98	67	44	18	..	..	..	..	..	..	..	.0086	.016
Bromophos-ethyl	..	..	..	100	100	77	51	36	..	0	..	..	..	..	..	..	..	..	.024	.040
Naled	..	100	99	72	59	34	6	..	..	..	..	..	..	..	..	..	..	..	.045	.069
Shell SD-8211	98	48	14	4	0	..	0	..	..	..	..	..	..	..	..	..	..	..	.103	.154

fectiveness, with LC_{50}'s of 0.0023 to 0.0078 p.p.m. for *C. tritaeniorhynchus;* Bromophos-ethyl was less effective against *C. quinquefasciatus.* Shell SD–8211 and naled were the least toxic.

Malathion, the insecticide currently used for larviciding on Okinawa, was not included in our tests. Young and Pennington (unpublished data) in a series of resistance tests in 1964 employing the standard WHO procedures showed that the LC_{50} for malathion against *C. tritaeniorhynchus* in 1962 ranged from 0.0066 p.p.m. to 0.011 p.p.m.; against *C. quinquefasciatus*, the range was 0.0077 p.p.m. to 0.0291 p.p.m. More recent tests have shown an increased tolerance of malathion by both species; during the past year LC_{50} ranges for the species were, respectively, 0.0272 p.p.m. to 0.0768 p.p.m. and 0.0125 p.p.m. to 0.0798 p.p.m.

The data from the field tests (see Table 6) correlate well with the laboratory results. Abate® was extremely effective; it gave 92 percent control at 0.0025 pound per acre. Control of 90 percent or more was obtained with Shell SD-7438 at 0.01 pound per acre, with Bromophos-ethyl at 0.025 pound per acre, with fenthion, Shell SD-8211, Bayer 41831, and Bromophos at 0.05 pound per acre, and with malathion at 0.25 pound per acre. The average percent reduction in the 12 check plots was 23.6 percent, not excessive considering the many variables in the sampling procedures such as pupation of fourth instar larvae, changing water levels, and differences in ability of individuals to dip larvae.

The control of the two species obtained in our series of tests with malathion and fenthion was a little better than that obtained by Gahan *et al.* in 1963. For example, with malathion they had to use dosages of 0.5 pound per acre to obtain 99 percent control; we obtained that percent control with 0.25 pound per acre. The reasons for this difference are not known though it may be attributed to the much heavier larval infestations in 1963; thus, in that situation nonuniform application would be more apt to result in survival of larvae.

TABLE 6.—Control of larvae of *Culex tritaeniorhynchus* in tests in rice field plots. (Avg. of 2 to 6 tests.)

	Percent reduction in larvae in 24 hr. at doses (lb./acre) indicated							
Larvicide	.25	.1	.05	.025	.01	.005	.0025	.001
Abate®	..	99.9	99.5	99.9	96	99	92	73
Shell SD-7438	.	99.6	99	99	95	52	29	..
Bromophos-ethyl	.	98	93	90	78	..	.	..
Fenthion	..	..	99	85	82	26	.	..
Shell SD-8211	..	98	94	87	71	..	..	..
Bayer 41831	..	99.7	94	68	68	..	..	..
Bromophos	.	..	99	49	58	..	..	..
Malathion	99	68	52	..	..	..	..	..

SUMMARY. In field tests on Okinawa, caged female mosquitos (*Culex* sp.) were exposed to aerosols produced by a nonthermal generator. In tests with *C. tritaeniorhynchus* Giles, kills of 94 percent or more were obtained with concentrations as low as 0.5 ounce per gallon of Baygon (*o*-isopropoxyphenyl methylcarbamate) and Bayer 41831 (*O,O*-dimethyl *O*-4-nitro-*m*-tolyl phosphorothioate) with 1 ounce per gallon of fenthion and Shell SD-8211 (2-chloro-1-(2,5-dichlorophenyl) vinyl dimethyl phospate), with 2 ounces of naled and carbanolate (6-chloro-3,4-xylyl methylcarbamate), and with 4 ounces of Mobil MC-A-600 (benzo[*b*]thien-4-yl methyl carbamate). Against *C. quinquefasciatus* Say, the concentrations required to give at least 91 percent kills were 0.5 ounce per gallon with fenthion, 1 ounce with Bayer 41831, 2 ounces with Baygon

and 4 ounces with naled. The other insecticides and malathion did not give 90 percent kills at 4 ounces.

In a separate set of tests with fenthion against *C. tritaeniorhynchus* only, fuel oil formulations gave slightly more control than those prepared in water. A better average kill was obtained in cages placed 3 feet above ground than in those at ground level or 6 feet above ground.

Tests were conducted against natural populations of *C. tritaeniorhynchus* larvae in rice paddies. Control of 90 percent or better was obtained with Abate® (*O,O*-dimethylphosphorothioate *O,O*-diester with 4,4′-thiodiphenyl) at 0.0025 pound per acre, Shell SD-7438 (*O,O*-dimethyl phosphorodithioate *S,S*-diester with toluene-*alpha,alpha*-dithiol) at 0.01 pound per acre, fenthion, Bromophos (*O*-(4-bromo-2,5-dichlorophenyl) *O,O*-dimethyl phosphorothioate), Bayer 41831, Bromophos-ethyl (*O*,(4-bromo-2,5-dichlorophenyl) *O,O*-diethyl phosphorothioate), and Shell SD-8211 at 0.05 pound per acre, and malathion at 0.25 pound per acre.

References Cited

GAHAN, J. B., YOUNG, W. W., PENNINGTON, N. E., and LABRECQUE, G. C. 1965. Thermal aerosol and larvicide tests with new insecticides to control two species of *Culex* mosquitoes on Okinawa. Mosq. News 25(2):165–169.

LOCATION OF UNIVOLTINE *AEDES* EGGS IN WOODLAND POOL AREAS AND EXPERIMENTAL EXPOSURE TO PREDATORS

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INTRODUCTION. Mosquito eggs laid on water or upon soil would appear to be vulnerable to predacious arthropods, yet relatively few such predators are recorded. According to Christophers (1960), psocids fed on eggs exposed in storage, and Buxton and Hopkins (1927) reported that in Samoa eggs were removed from experimental pots by ants. Laird (1947), working in New Britain, found a hydrachnid mite that fed on mosquito eggs. In the United States, Stage and Yates (1939) obtained evidence of predation by carabid beetles.

Arthropod predators of mosquito eggs were investigated at Chatterton, Ontario, in studies of the natural control of pest mosquitoes, particularly *Aedes trichurus* (Dyar) and *Aedes stimulans* (Walk.). Both species lay their eggs during May and June in the moist soil surrounding shrinking woodland pools. These hatch in the following March when the pools are reflooded. Thus the eggs may remain exposed in or upon the soil from 3 to 5 months unless the water table is raised by early autumn rains. This paper reports on the site of egg populations and the presence of insect predators.

MATERIALS AND METHODS. During September, 1958, preliminary soil samples 0.25 sq. meter in area and 2.0 cm. thick were taken along a transect in each of two pools, from a point at the highest water level of April 4 to the lowest of May 2. Each sample was placed in a plastic bag and stored for 4 months at 32–34° F. and later flooded in a pan with tap water.

More extensive sampling was done in October within three rectangular plots of 50, 12, and 12 sq. meters respectively, each of which enclosed a different pool area in the swamp. Samples were 0.25 sq. meter in area and 2.5 cm. thick, including debris, and were taken 0.5 m. apart along straight lines in order to sample one-quarter of the total area. Each sample was divided into four sub-samples to facilitate handling. The location of the samples in respect to pool contours and plant cover

1966 Mount, G. A., C. S. Lofgren, J. B. Gahan, and N. W. Pierce
Comparisons Of Thermal And Nonthermal Aerosols Of Malathion, Fenthion, And Naled For Control Of Stable Flies And Salt-Marsh Mosquitoes
Mosquito News 26: 132-138 (Amvac Ref. #1344)

1344

———, and PASS, B. C. 1965. Low-volume aerial sprays for mosquito control. Paper presented at the national meeting of the ESA New Orleans. Dec.

MESSENGER, KENNETH. 1963. Low-volume spraying will be a boom to applicators 18(12): 63-6.

MOORE, STEVE III. 1965. Effect of low-volume aerial application of technical grade malathion on populations of flies and mosquitoes in urban community. Seventeenth Illinois Custom spray operator's training School. Jan. 20-21, Urbana, Illinois.

MULHERN, T. D., GJULLIN, C. M., LOOP, J. V., RAMKE, D., FROLLI, R. F., REED, D. E. and MURRAY, W. D. 1965. Low-volume airplane sprays for the control of mosquito larvae. Mosq. News 25(4):442-7.

COMPARISONS OF THERMAL AND NONTHERMAL AEROSOLS OF MALATHION, FENTHION, AND NALED FOR CONTROL OF STABLE FLIES AND SALT-MARSH MOSQUITOES

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Lofgren *et al.* (1966) obtained high mortalities of caged *Culex tritaeniorhynchus* Giles and *C. quinquefasciatus* Say by dispersing water emulsions of several insecticides from a nonthermal aerosol generator. Their results were somewhat similar to those obtained by Gahan *et al.* (1965), who used a thermal aerosol generator to disperse fuel oil solutions of the same insecticides against the same two species of mosquitoes. However, no results of direct comparisons between thermal and nonthermal aerosols for control of flying insects have been reported. The primary objective of this study was to obtain comparative data pertaining to both types of aerosols for control of stable flies [*Stomoxys calcitrans* (L.)] and salt-marsh mosquitoes [*Aedes taeniorhynchus* (Wiedemann) and *A. sollicitans* (Walker)].

The thermal aerosol generator used in this study was a Leco model 120 [1] and the nonthermal aerosol generator was a Curtis model 55,000 [1] designed and developed by the U. S. Army Engineers Research and Development Laboratories, Fort Belvoir, Virginia (Morrill and Wesley, 1955 and Edmunds *et al.*, 1958). Both generators were calibrated to deliver 40 gallons of liquid per hour and the thermal generator was operated at a temperature of 850° F.

The insecticides used were malathion, fenthion, and naled. Fuel oil solutions of these insecticides were applied with the thermal generator, whereas both fuel oil solutions and water emulsions were applied with the nonthermal generator. Fuel oil solutions were prepared from technical malathion or from oil-soluble concentrates containing 8 pounds of fenthion or 14 pounds of naled per gallon. A sludge inhibitor (mixed amide amine oleate from modified fatty acids and polyamines) was used in the fuel oil formulations at rates of 0.5 to 1 percent as needed to retard the formation of precipitates. Emulsifiable concentrates containing 5, 4, and 8 pounds per gallon of malathion, fenthion, and naled, respectively, were used to prepare the water emulsions. The emulsions were always applied the same day they were prepared.

TESTS WITH CAGED STABLE FLIES AND MOSQUITOES. The experimental plots, located at an airport near Gainesville, Florida, were fairly level and open. The stable flies used in these tests were from a laboratory colony established with larvae

[1] Mention of proprietary products does not necessarily imply endorsement by the U.S.D.A.

collected at a livestock farm near Panama City, Florida. Specimens of *A. taeniorhynchus* were from a laboratory colony started by Davis (1958). All insects were 2–7 days old when tested. They were exposed in cylindrical cages made of 16-mesh screen wire. The cages used for stable flies were 3 inches in diameter x 8 inches long and those employed for mosquitoes were 1.75 inches in diameter x 5.5 inches long. Cages of stable flies (four per test) were placed on two rows of stakes 125 feet apart at distances of 125 and 250 feet downwind from and perpendicular to a line over which the truck-mounted aerosol generators passed. The cages of mosquitoes (four per test) were placed on two rows of stakes 150 feet apart at distances of 150 and 300 feet from the aerosol discharge line. All cages were placed at a height of 5 feet above the ground.

The aerosol generators were always moved at a speed of 5 m.p.h. In each test, the aerosol was allowed to drift completely across the experimental plot before the cages were removed from the stakes. Stable flies were returned to the laboratory after each series of tests (the tests lasted 1–2 hours) and transferred to clean screen cages in a cold room (34° F). Immediately after each exposure, mosquitoes were blown into plastic tubes lined with clean paper. Except during exposure, all insects were protected in the field by keeping them in insulated chests containing ice in cans. Stable flies were provided a 10 percent honey-water solution for a 24-hour holding period and mosquitoes were provided 10 percent sugar-water solution for an 18-hour holding period in a room maintained at 80° F. Mortality counts were made at the end of the holding periods. Probit analysis,[2] as described by Finney (1952), was used to calculate the LC_{90}'s for the various aerosols.

Control groups of stable flies and mosquitoes were exposed to thermal aerosols of fuel oil with no insecticide and nonthermal aerosols of fuel oil and water with no insecticide to check natural mortality encountered during these tests. Additional checks were also made by observing untreated insects in the laboratory.

Tests with stable flies were conducted on 16 different days at times ranging from 1 to 4 p.m. Air temperatures ranged from 71° to 90° F, with an average of about 79° F. Wind speeds ranged from 2 to 12 m.p.h. and averaged about 6 miles per hour. Tests with mosquitoes were conducted on 13 different evenings at times ranging from 6:30 to 9 p.m. Air temperatures ranged from 73° to 85° F and averaged about 80° F. Wind speeds ranged from 2 to 10 m.p.h. and averaged about 4 miles per hour. All tests were conducted during inversions. From two to five tests with four cages of insects per test were run with various concentrations of each insecticide.

The results of the tests with stable flies are presented in table 1. The mortality percentages are averages of results obtained at exposure distances of 125 and 250 feet. The results with male and female stable flies were averaged together since there was no substantial difference between the susceptibility of the sexes to the three insecticides. Malathion was tested at concentrations of 5, 10, and 20 percent. Mortalities obtained with the nonthermal aerosol of malathion diluted in water were higher than those obtained with the other aerosols; however, the differences were not extremely large. Fenthion and naled were tested at concentrations ranging from 0.31 to 5 percent. With both compounds, differences in mortality between the types of aerosols were slight, and none of the differences in the LC_{90}'s were statistically significant at the 95-percent level of probability. The averages of all results, regardless of the type of aerosol used, indicated LC_{90}'s of 2.1 and 1.4 percent for fenthion and naled, respectively.

The results of the tests with caged

[2] Data were processed according to a program developed by R. J. Daum, Biometrical Services, U.S.D.A. for the IBM 1620 computer.

TABLE 1.—Mortality of caged adult stable flies exposed to thermal and nonthermal aerosols of malathion, fenthion, and naled.

Type of aerosol	Diluent	Percent mortality at indicated concentration (%)[a] 20	10	5	2.5	1.25	0.62	0.31	LC_{90} (%)	95% confidence limits
					Malathion					
Thermal	Fuel oil	69	62	39	..	..	..	..	>20	....
Nonthermal	Fuel oil	83	46	31	..	..	..	..	>20	....
	Water	92	70	40	..	..	..	..	18.4	13.2–45.6
					Fenthion					
Thermal	Fuel oil	..	..	97	94	82	44	46	2.3	1.7–3.9
Nonthermal	Fuel oil	..	..	..	96	82	59	39	1.9	1.3–3.8
	Water	..	..	99	89	80	62	26	2.1	1.5–4.4
					Naled					
Thermal	Fuel oil	..	..	99	97	89	61	34	1.5	1.2–1.8
Nonthermal	Fuel oil	..	..	100	94	92	52	33	1.6	1.2–2.5
	Water	..	..	100	100	97	64	30	1	.8–1.3

[a] Corrected by Abott's formula: average of male and female stable flies exposed at distances of 125 and 250 feet.

Table 2.—Mortality of caged female *Aedes taeniorhynchus* exposed to thermal and nonthermal aerosols of malathion, fenthion, and naled.

Type of aerosol	Diluent	Percent mortality at indicated concentration (%)[a] 8	4	2	1.5	1	0.5	0.25	0.1	LC_{50} (%)	95% confidence limits
						Malathion					
Thermal	Fuel oil	99	97	88	..	73	11	..	..	2.2	1.6–4
Nonthermal	Fuel oil	98	92	79	..	69	18	..	..	3.1	2.2–5.4
	Water	94	93	82	..	58	13	..	..	3.2	2.3–5.6
						Fenthion					
Thermal	Fuel oil	..	..	..	98	94	72	50	28	.92	.67–1.7
Nonthermal	Fuel oil	..	..	..	98	97	67	67	51	.96	.56–6.1
	Water	..	..	..	95	98	66	52	25	.98	.69–2
						Naled					
Thermal	Fuel oil	..	..	96	89	82	64	45	..	1.5	.96–5.5
Nonthermal	Fuel oil	..	..	96	93	92	57	68	..	1.3	.87–3.1
	Water	..	..	93	94	89	38	24	..	1.3	1–1.9

[a] Corrected by Abbott's formula; average of mosquitoes exposed at 150 and 300 feet.

females of *A. taeniorhynchus* are given in table 2. The mortality percentages are averages of results obtained at 150 and 300 feet. Malathion, fenthion, and naled were tested at concentrations ranging from 0.5 to 8 percent, 0.1 to 1.5 percent, and 0.25 to 2 percent, respectively. With all three compounds, differences in mortality between the two types of aerosol used were small, and none of the differences in the LC_{90}'s were significant at the 95-percent level of probability. The averages of all results, regardless of the type of aerosol used, indicated LC_{90}'s of 2.8, 0.95, and 1.4 percent for malathion, fenthion, and naled, respectively.

Tests with Natural Populations of Salt-Marsh Mosquitoes. Tests with natural populations of salt-marsh mosquitoes (*A. taeniorhynchus* and *A. sollicitans*) were conducted at Scottsmore (Brevard County), Cedar Key (Levy County), and St. James City (Lee County), Florida. At Scottsmore, the experimental plots were sections of citrus groves, whereas at the other two locations they consisted of moderately to heavily wooded sections of land partially covered with undergrowth. The predominant species on all the plots was *A. taeniorhynchus*.

Naled was tested at a concentration of 1.5 percent in thermal and nonthermal aerosols at all three locations. All malathion tests were conducted at Cedar Key with a 6 percent concentration. The applications were made at 5 miles per hour for a distance of approximately ¼ mile along roads that would allow the wind to drift the aerosols across the plots. The quantity of insecticide was measured before and after each test to confirm the discharge rate of each aerosol generator. Plots were selected on the basis of uniformity in density and type of vegetation and abundance of mosquitoes; however, the treatments were rotated from one test to another to minimize any differences that might have existed in the plots.

The relative abundance of mosquitoes in each plot was sampled by counting the number landing per man per minute on two observers at six stations. In the citrus groves, counting stations were located in two rows near the center of the plots at distances of approximately 100, 150, and 200 feet from the roads along which the aerosols were discharged. The rows were 150 feet apart. In the wooded plots at Cedar Key and St. James City, the stations were about 75–200 feet from the roads where the insecticides were discharged and 50–100 feet apart. Pretreatment counts were made 1–24 hours before treatment. Counts were made 1–3 hours and 15–24 hours after treatments with naled. Counts were made 3 and 24 hours after treatments with malathion.

In three of the tests with 1.5 percent naled, caged mosquitoes were exposed in the plots to compare their mortality with reductions obtained in the natural populations. Females of *A. taeniorhynchus* were collected in areas adjacent to the plots with battery-powered aspirators and transferred to 16-mesh screen wire cages. The cages were placed 100–150 feet from the aerosol discharge roads in the vicinity of the counting stations. Three cages of approximately 10 mosquitoes each were exposed in each plot. Two were placed at 6 feet and one at 2 feet above the ground. Mortality counts were made at about the same time as the counts of the natural populations in the plots (1–3 hours after treatments).

The tests at Scottsmore and Cedar Key were conducted in the evening between 5:30 and 7 p.m. The tests at St. James City were conducted in the morning between 7 and 8 a.m. Air temperatures ranged from 81° to 90° F, and averaged about 86° F. Wind speeds ranged from <2 to 8 m.p.h. and averaged about 2.5 m.p.h. All of the tests were conducted during inversions.

The control of the natural population obtained in the plots is shown in table 3. Thermal aerosols of 6 percent malathion in fuel oil gave 83 percent reduction in 3 hours, whereas nonthermal aerosols of 6 percent malathion in water gave 86 percent reduction at the same interval of time. Plots which received no insecticide had an average reduction of 37 percent at 3 hours. Counts at the 24-hour interval

TABLE 3.—Control of natural populations of salt-marsh mosquitoes with thermal and nonthermal aerosols of malathion and naled.

Type of aerosol	Diluent	No. of replications	Pretreatment count (man/min.)	Percent reduction at indicated interval after treatment[a] 1–3 hr. Average	1–3 hr. Range	15–24 hr. Average
			Malathion (6%)			
Thermal	Fuel oil	2	7	83[b]	81–84	35
Nonthermal	Water	2	7	86[b]	86–86	20
None	..	2	10	37[b]	....	+24
			Naled (1.5%)			
Thermal	Fuel oil	8	23	77	63–97	+17[c]
Nonthermal	Fuel oil	4	34	82	69–90	+37[c]
Nonthermal	Water	7	11	79	63–94	41
None	..	8	24	26	....	+23

[a] + indicates percent increase.
[b] 3 hour counts only.
[c] Treatments included in one test where reinfestation was extremely high at 24 hours.

showed that plots treated with both thermal and nonthermal aerosols were reinfested.

Thermal and nonthermal aerosols of 1.5 percent naled produced reductions of 77–82 percent at intervals of 1–3 hours after applications. Plots receiving no insecticide had an average reduction of 26 percent at the same intervals of time. Both types of aerosols showed reinfestation within 15–24 hours after application. In one series of tests with thermal and nonthermal aerosols containing 1.5 percent naled in fuel oil, the reinfestation was extremely high at 24 hours. Nonthermal aerosols of 1.5 percent naled in water were not included in this series of tests.

The results of the comparison between caged and free-flying salt-marsh mosquitoes exposed to naled are presented in table 4. When thermal aerosols in fuel oil were used, reductions averaged 75 percent with free-flying mosquitoes and mortality averaged 70 percent with caged mosquitoes within 1–3 hours after application. Nonthermal aerosols in water produced a reduction of 62 percent of the free-flying mosquitoes and mortality of 76 percent of caged mosquitoes at the same intervals of time.

DISCUSSION. The mortalities of caged stable flies exposed to aerosols of malathion, fenthion, and naled were somewhat higher at comparable concentrations than those obtained in previous tests (Mount *et al.*, in press); however, these differences can be accounted for by the more favorable climatic conditions at the time the aerosols were applied. These results appear to eliminate malathion as an aerosol for prac-

TABLE 4.—Comparison of results obtained with free-flying and caged salt-marsh mosquitoes, 1–3 hours after exposure to thermal and nonthermal aerosols of 1.5 percent naled. (Data corrected by Abbott's formula.)

Mosquitoes	Thermal aerosols[a]	Nonthermal aerosols[b]	Average
Free-flying (% reduction)	75	62	68.5
Caged (% mortality)	70	76	73

[a] 2 replications
[b] 3 replications

tical control of adult stable flies, whereas both fenthion and naled appear very promising.

The results of the tests against caged females of *A. taeniorhynchus* agree with those obtained under similar conditions by Rathburn *et al.* (1964) and Rathburn and Rogers (1961). Fenthion was the outstanding compound in these tests. This result was expected since fenthion was more toxic than naled or malathion in wind-tunnel tests reported by Davis and Gahan (1961). Malathion and fenthion were considerably more effective against females of *A. taeniorhynchus* than against stable flies. On the other hand, the LC_{90}'s for naled were identical for both species.

The results with natural populations of salt-marsh mosquitoes confirm the data obtained with caged insects and indicate there were no significant differences between the reductions produced by the different types of aerosols. However, at comparable concentrations, the reductions of natural populations were not as high as mortalities of caged mosquitoes exposed on open plots (table 2). This result was expected since the tests with natural populations were conducted on dense, wooded plots. Mortalities of caged mosquitoes exposed on the wooded plots (table 4) were about the same as reductions of free-flying mosquitoes.

SUMMARY. Tests with caged stable flies, *Stomoxys calcitrans* (L.), caged female *Aedes taeniorhynchus* (Wiedemann), and natural populations of salt-marsh mosquitoes, *A. taeniorhynchus* and *A. sollicitans* (Walker), demonstrated that thermal and nonthermal aerosols were about equally effective when malathion, fenthion, and naled were used as toxicants. Water was equal to fuel oil as a diluent for insecticides dispersed as nonthermal aerosols. In wooded plots treated with thermal and nonthermal aerosols of 1.5 percent naled, mortalities of mosquitoes exposed in 16-mesh screen wire cages were about the same as reductions of free-flying mosquitoes.

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Literature Cited

DAVIS, A. N., and GAHAN, J. B. 1961. New insecticides for the control of salt-marsh mosquitoes. Fla. Entomol. 44(1):11–14.

EDMUNDS, L. R., HAHL, R. G., and LOWE, H. H., JR. 1958. Particle size studies using a nonthermal aerosol fog generator designed for control of adult insects. Mosq. News 18(4):321–4.

FINNEY, D. J. 1952. Probit analysis. Cambridge [England] Press 2nd ed. 318 p.

GAHAN, J. B., YOUNG, W. W., PENNINGTON, N. E., and LABRECQUE, G. C. 1965. Thermal aerosol and larvicide tests with new insecticides to control two species of *Culex* mosquitoes on Okinawa. Mosq. News 25(2):165–9.

LOFGREN, C. S., PENNINGTON, N. E., and YOUNG, W. W. 1966. Evaluation of insecticides against two species of *Culex* mosquitoes on Okinawa. Mosq. News 26(1):52–59.

MORRILL, A. W., JR., and WESLEY, C., JR. 1955. Studies on insecticidal fog generators for military use. II. Solvents for insecticidal fog formulations. Mosq. News 15(2):86–90.

MOUNT, G. A., LOFGREN, C. S., and GAHAN, J. B. Malathion, naled, fenthion, and Baygon in thermal fogs for the control of the stable fly (dog fly) [*Stomoxys calcitrans* (L.)] (Diptera:Muscidae). Fla. Entomol. (In press)

RATHBURN, C. B., JR., CLEMENTS, B. W., JR., and ROGERS, A. J. 1964. Comparative thermal aerosol tests with Dibrom and malathion against *Aedes taeniorhynchus* (Wied.) and *Culex nigripalpus* Theob. Report 35th Ann. Mtg. Fla. Anti-Mosq. Assoc. 35–38.

———, and ROGERS, A. J. 1961. Tests of insecticides for the control of adult mosquitoes, 1959–60. Report 32nd Ann. Mtg. Fla. Anti-Mosq. Assoc. 36–40.

1965 Gahan, J. B., W. W. Young, N. E. Pennington, and G. C. Lebrecque
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1340

THERMAL AEROSOL AND LARVICIDE TESTS WITH NEW INSECTICIDES TO CONTROL TWO SPECIES OF *CULEX* MOSQUITOES ON OKINAWA[1]

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On the island of Okinawa, *Culex tritaeniorhynchus* Giles is considered the principal carrier of Japanese B encephalitis. It is also the most prevalent species in rice paddies. *Culex pipiens quinquefasciatus* Say is a vector of filiariasis that breeds in large numbers in drainage ditches and portions of rice fields where weeds or rice stalks have decomposed.

During August and September, 1963, the authors spent 6 weeks on the island of Okinawa studying control measures that might be used against these pests. Two types of evaluation were made. A large series of thermal aerosol tests was conducted with the Tifa®-Fog Generator against adults of both species confined in screen cages. The insects used in this study were collected as larvae in rice fields or drainage ditches and reared to adults in the laboratory. Larvicides were also applied to rice paddies infested with *Culex tritaeniorhynchus*.

Seven compounds were evaluated. Fenthion (Bayer 29493), dichlorvos (DDVP), naled (Dibrom®), Bayer 39007 (*o*-isopropoxyphenyl methylcarbamate), malathion, and DDT were used as larvicides and adulticides whereas trichlorfon (Dipterex®) was tested only as a larvicide. For the adulticide tests technical samples of fenthion, dichlorvos, naled, malathion, and DDT were prepared as solutions in fuel oil; because Bayer 39007 has low solubility in organic solvents it was added to the fuel oil as an emulsion concentrate containing 1.5 lbs. of the active ingredient per gallon. Most of the larvicides were employed as water emulsions prepared from concentrates containing 5 lbs. of malathion (57 percent), 4 lbs. of fenthion, 1.67 lbs. of dichlorvos, 8 lbs. of naled, 1.5 lbs. of Bayer 39007, or 2 lbs. of DDT per gallon. Trichlorfon was applied as a solution in water.

THERMAL AEROSOL TESTS. Most of the thermal aerosol studies were conducted at the north end of an Army aircraft landing field bordered on one side by the China Sea. At this location there was usually some wind blowing. Although it did not always blow in the same direction from one night to another, it seldom changed while the testing was in progress. One series was run farther inland on a parade ground where the wind frequently changed direction and intensity.

Six stations were established in each plot. They were arranged in two parallel rows consisting of 3 stations per row. The stations in each row were located at 100-foot intervals in line with the wind movement from the closest passage point of the insecticide applicator. The rows were 175 feet apart. Six-foot stakes with a 3-foot crossarm were placed at each station. If the wind changed direction during a testing period these stakes had to be moved to keep them downwind of the applicator; but the same space interval was main-

[1] Mention of a proprietary product does not necessarily imply endorsement of this product by the U. S. D. A.

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tained. A cylindrical screen cage 5 or 8 inches long and 3 inches in diameter that contained 25 females of either *Culex tritaeniorhynchus* or *Culex pipiens quinquefasciatus* was attached to each end of the crossarm. The longer cages were made of galvanized wire but the smaller ones were copper.

The aerosol applications were made with a Tifa 4145® (P.E. #608) that was operated at 5 m.p.h. and calibrated to deliver 33 gallons of solution per hour. The machine moved at right angles to the rows of stakes. The fogger was started approximately 175 feet before it reached the first row and continued to dispense insecticide until it was at least 175 feet past the second row, a distance of about 1/10 mile. Applications were started as soon after sunset as the wind decreased to a speed of less than 8 m.p.h. Within 30 minutes after exposure to the fog, the insects were returned to the laboratory, where they were anesthetized with carbon dioxide and transferred to clean cages. Mortality was recorded 14 to 15 hours later. Each test was repeated 3 times. The average mortality obtained at each 100-foot interval for each concentration of insecticide is given in table 1. Six cages of mosquitoes were exposed to each concentration of insecticide, and a total of 720 cages of insects were used in this part of the study.

Fenthion and naled were highly effective; the average mortality ranged from 90 percent to 100 percent at two-thirds or more of the stations when concentrations of 2 to 6 oz. per gallon were used. Bayer 39007 was about equal to these materials against *Culex tritaeniorhynchus* but was inferior to them against *C. pipiens quinquefasciatus* at the 2 oz. concentration. Di-

TABLE 1.—Summary of results obtained against two *Culex* species of mosquitoes in fogging tests (average of 3 replicates of 2 cages each).

		Percent kill at indicated distance from fogger							
	Dosage	*Culex tritaeniorhynchus*				*Culex quinquefasciatus*			
Insecticide	(oz./gal.)	100 ft.	200 ft.	300 ft.	Avg.	100 ft.	200 ft.	300 ft.	Avg.
Fenthion	1	74	40	61	58	98	78	63	80
	2	100	98	88	95	100	98	100	99
	4	90	99	99	96	100	100	100	100
Naled	1	90	69	47	69	73	48	36	52
	2	99	100	87	95	100	98	85	94
	4	100	100	92	97	100	86	84	90
	6	100	100	100	100	100	100	100	100
Bayer 39007	1	99	89	75	88	..	..	..	..
	2	91	92	94	92	67	64	44	58
	4	98	89	89	92	94	98	98	97
Dichlorvos	2	76	38	39	51	47	33	43	38
	4	71	56	42	56	74	62	52	63
	6	100	99	91	97	97	46	28	57
Malathion	1	48	60	56	55	40	11	23	25
	2	34	26	16	25	82	89	57	76
	4	40	30	23	28	81	88	64	78
	6	79	71	74	75	91	87	73	84
DDT	2	7	10	9	9	2	4	3	3
	4	..	..	..	..	3	2	4	3
	6	4	15	6	8	1	2	2	2
Fuel Oil	..	10	5	16	10	2	4	2	3

chlorvos produced above 90 percent kill with the 6 oz. dosage at all three stations against *Culex tritaeniorhynchus* but only at one station with *C. pipiens quinquefasciatus*, and was not highly effective against either species at lower concentrations. Malathion caused above 90 percent mortality at only one station. Dichlorvos appeared somewhat better than malathion against *Culex tritaeniorhynchus* but the reverse was true against *C. pipiens quinquefasciatus*. DDT was worthless against both species.

LARVICIDE TESTS Before starting the larvicide tests, pretreatment counts were made in various portions of rice fields to determine the areas of highest infestation. The insecticides then were applied as water emulsions with a compressed air sprayer having a 2-gallon capacity and a fan-type nozzle. Each of the plots in the rice field, set off by levees for cultural purposes, was used as an experimental plot. The application was made by the operator walking along the top of the levee and spraying the area between the levees bounding the plot. In some plots it was necessary to drift the insecticide as much as 10 to 15 feet to obtain complete coverage. Since only a small portion of a field was included in any one plot, several dosages of one or more insecticides could be applied to the same field. Applications were made on a pounds per acre basis. The dosage varied with the insecticide but ranged from 0.025 to 0.5 pound per acre. The percentage of insecticide in the spray ranged from 0.05 percent to 1 percent. The control obtained was determined by comparing the number of larvae found in 20 dippers full of water collected before and 24 hours after treatment. The results in table 2 show the toxicity of the chemicals to the third and fourth instars as well as all of the larvae present and are averages of three tests.

Based on the calculated LC-90, fenthion appeared to be the best larvicide. It was approximately 90 percent effective at concentrations of 0.066 and 0.093 pound per acre and was 1.6 to 1.8 times better than dichlorvos, 2.4 to 2.7 times better than trichlorfon, 2.3 to 3.2 times better than Bayer 39007, and 2.8 to 3.1 times better than naled. DDT and malathion were the poorest materials of the group; against the third and fourth instars, fenthion was 3.6 times as effective as malathion and 10.6 times as effective as DDT. No LC-90 was calculated for DDT and malathion against the total infestation as the mortality obtained with the highest concentration used averaged less than 90 percent.

The 24-hour reduction in number of

TABLE 2.—Summary of results obtained in larvicide tests against *Culex tritaeniorhynchus*.

Insecticide	Percent kill in 24 hours at indicated dosage in lbs./acre							
	0.025	0.05	0.1	0.25	0.5	LC-50	LC-90	Slope
				Third and Fourth Instars				
Fenthion	65	89	94	99.1	..	0.015	0.066	2.00
Dichlorvos	87	64	73	98	..	<.025	.118	1.10
Trichlorfon	..	65	72	97	99	.038	.161	2.03
Bayer 39007	..	30	51	96	..	.077	.21	2.96
Naled	..	44	95	93	97	.031	.186	1.67
Malathion	.	48	47	88	99.8	.075	.240	2.53
DDT	49	81	89	88	79	.003	.7	0.54
				All Instars				
Fenthion	20	90	89	99.2	.	.036	.093	3.08
Dichlorvos	49	65	62	98	..	.026	.146	2.12
Trichlorfon	..	59	67	92	96	.039	247	1.60
Bayer 39007	..	23	51	96	.	.084	.214	3.22
Naled	..	22	88	89	93	.061	286	1.90
Malathion	..	42	43	39	82	.138	>5	1.00
DDT	60	61	58	73	82	.012	>.5	0.48

third and fourth instar larvae usually exceeded that obtained among the total population. However, larvae are more susceptible to most insecticides in the early instars than in the later ones. The apparent discrepancy was probably caused by (1) depletion of the number of fourth instar larvae by pupation as well as insecticidal action, (2) increase in the first instar larvae by hatching after the larvicide had lost some of its effectiveness, and (3) collections of newly hatched larvae before the insecticide had time enough to act.

DISCUSSION. During the past 10 to 15 years, malathion and DDT have been the most frequently used insecticides in thermal aerosols. This study shows rather clearly that in places similar to Okinawa other insecticides commercially available should be considered for treating the two *Culex* species of mosquitoes. DDT was indicated to be almost worthless against these two species at application rates as high as 6 oz. per gallon. Although malathion did kill many mosquitoes, fenthion, naled, Bayer 39007, and dichlorvos were superior to it against *C. tritaeniorhynchus* and fenthion, naled, and possibly Bayer 39007 were superior to it against *C. pipiens quinquefasciatus*.

There is evidence in the literature to show that fenthion and naled are outstanding but that dichlorvos is of questionable value in thermal aerosols. Rathburn and Rogers (1961) obtained higher kills of *Aedes taeniorhynchus* adults with fenthion at 1.25 oz. per gallon and naled at 1.75 oz. per gallon than a combination containing malathion at 4 oz. per gallon plus 3 percent Lethane 384® [2-(2-butoxyethoxy)ethyl thiocyanate]. Hagmann (1961) reported that fenthion had considerable promise against adult females of *A. sollicitans* (Walker). In other tests against *A. taeniorhynchus*, however, Schoof *et al.* (1962) found dichlorvos at least equal to malathion at 135 feet from the applicator but poor at greater distances; and Rathburn and Rogers (1963) reported this compound was not effective even at 8 oz. per gallon. No published reports on the effectiveness of Bayer 39007 as a thermal aerosol have been located.

Other investigators also have obtained considerable evidence in field tests to show that dichlorvos and fenthion are highly effective larvicides against mosquitoes. Isaak (1957) reported dichlorvos was good at 0.15, 0.2, and 0.25 pound per acre in pastures flooded with clear water but not good in water heavily polluted with organic matter. When McFarland (1957) tested dichlorvos for the control of *Culex stigmatosoma* Dyar and *C. pipiens* L. breeding in pools, dilutions of 1:100 and 1:200 gave complete kill of larvae and pupae within 6 hours; a 1:400 dilution killed 85 percent to 90 percent within 6 hours but did not give complete kill in 24 hours. His dilutions produced dosages that ranged from 1 to 4 oz. of toxicant per acre.

In tests conducted by Lewallen and Gjullin (1960) against fourth instar larvae of *Aedes nigromaculis* (Ludlow) and *Culex tarsalis* Coquillett in irrigated pastures, fenthion gave 100 percent control at a dosage of 0.05 lb. per acre and was more effective than methyl parathion. Similar tests by Mulla *et al.* (1960) in irrigated pastures showed that fenthion was better than malathion against *Culex tarsalis* Coq. Ramakrishnan *et al.* (1960) also found fenthion superior to malathion against *Culex fatigans* Wiedemann (=*C. pipiens quinquefasciatus*) in India.

SUMMARY. During August and September, 1963, a series of tests was conducted on Okinawa to evaluate new insecticides for the control of the two most troublesome species of mosquitoes present on that island. In thermal aerosol tests run against caged adults of *Culex tritaeniorhynchus* Giles and *C. pipiens quinquefasciatus* Say, fenthion and naled produced mortalities of 90 percent to 100 percent at two-thirds or more of the test stations when concentrations of 2 to 6 oz. per gallon were used. Bayer 39007 (*o*-isopropoxyphenyl methylcarbamate) was about equal to these materials against *C. tritaeniorhynchus* but inferior to them against *C. pipiens quinquefasciatus* at the 2 oz. concentration. These three materials were

more effective than dichlorvos or malathion. DDT was ineffective.

Larvicide applications were made to rice paddies infested with *C. tritaeniorhynchus*. Fenthion appeared to be the best larvicide. It was 90 percent effective at concentrations of 0.066 and 0.093 lb. per acre and was 1.6 to 1.8 times better than dichlorvos, 2.4 to 2.7 times better than trichlorfon, 2.3 to 3.2 times better than Bayer 39007, and 2.8 to 3.1 times better than naled. DDT and malathion were the poorest materials tested. Indications were the toxicity of these compounds lasted only a short time after application to the breeding areas.

References Cited

HAGMANN, L. E. 1961. Fog formulation tests. Proc. 48th Ann. Mtg. New Jersey Mosquito Exterm. Assoc. pp. 129-30.

ISAAK, L. W. 1957. Mosquito control insecticides—where do we go from here? Proc. & Papers 25th Ann. Conf. Calif. Mosq. Cont. Assoc. p. 94.

LEWALLEN, L. L. and GJULLIN, C. M. 1960. Mosquito larvicide field tests in irrigated pastures of the San Joaquin Valley, Calif. Mosquito News 20(2):168-70.

MCFARLAND, G. C. 1957. Results of field trials with DDVP in mosquito control. Mosquito News 17(4):296-98.

MULLA, M. S., ISAAK, L. W., and AXELROD, H. 1960. Laboratory and field evaluation of new insecticides against mosquito larvae. Mosquito News 20(3):256-61.

RAMAKRISHNAN, S. P., SHARMA, M. I. D., and KALRA, R. L. 1960. Laboratory and field studies on the effectiveness of organo-phosphorus insecticides in the control of *C. fatigans*. Indian J. Malar. 14(4):545-66. (Abstr. in Review of Applied Entomol. Vol. 50, p. 71, 1962).

RATHBURN, C. B., JR., and ROGERS, A. J. 1961. Tests of insecticides for the control of adult mosquitoes 1959-60. Rpt. 32nd Ann. Mtg. Fla. Anti-Mosq. Assoc. pp. 36-40.

———. 1963. Thermal aerosol insecticide tests for the control of adult mosquitoes, 1961-62. Mosquito News 23(3):218-20.

SCHOOF, H. F., ELMORE, C. M., JR., and DUFFY, J. P. 1962. Effectiveness of fog, dust, and mist applications of several organophosphorus compounds against *Aedes taeniorhynchus*. Mosquito News 22(4):329-32.

STERILANT EFFECT OF SOME MATERIALS ON *AEDES AEGYPTI* (L.) FEEDING ON TREATED MICE

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Chemicals which interfere with development of insects, especially their reproductive capabilities, are presently creating considerable interest due to their possible use in pest control. The effectiveness, and both practical and potential use of such compounds in control and eradication programs have been discussed in reviews by Lindquist (1961), Knipling (1962), and Smith *et. al.* (1964). Some of the earliest research was done on *Drosophila* by Goldsmith *et. al.* (1948) and Goldsmith and Frank (1952). More research has been conducted on materials which affect metabolism in house flies (*Musca domestica* L.) such as that reported by Mitlin *et. al.* (1957), LaBrecque *et. al.* (1960), and LaBrecque (1961).

LaBrecque (1961) reported that three alkylating agents (tepa, aphoxide, and aphomide) were effective house fly sterilants and Weidhaas *et al.* (1961) found that when they were fed to adults in honey solutions they caused sterility in two species of mosquitoes, *Anopheles quadrimaculatus* Say and *Aedes aegypti* (L.). In further work Weidhaas (1962) showed that these chemicals would sterilize the mosquitoes either as larvae or as adults. During 1961-62 Darrow and

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1965 Rogers, A.J., Rathburn, C.B. Jr., and R.W. Clements, Jr.
Tests with Aerial Fogs and Sprays Against Adult Mosquitoes
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TESTS WITH AERIAL FOGS AND SPRAYS AGAINST ADULT MOSQUITOES

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Although insecticides dispersed at ground level can be very effective in killing adult mosquitoes, utilization of ground equipment is limited to those areas having access roads. The outbreak of mosquito-borne encephalitis that occurred in the Tampa Bay area of Florida in 1962 focused attention on the need for fast, effective vector control in large urban areas that are interspersed with inaccessible, undeveloped lands. Consequently, research with aerial applications against the proven vector, *Culex nigripalpus* Theobald (Chamberlain, 1963) was started in 1963 by the Control Research Section of the Entomological Research Center at Vero Beach. Owing to the interests of several mosquito control districts in aerial applications for control of salt-marsh mosquitoes, some tests with aerial fogs were conducted against *Aedes taeniorhynchus* in 1962 prior to the outbreak of encephalitis. The objective of the 1962 tests was to refine the aerial fogging operation described by Davis, *et al.*, (1960) as used for the control of adult salt-marsh mosquitoes.

Although *Aedes taeniorhynchus* were included in the 1963–64 tests, the principal objective of the research following the encephalitis epidemic was to develop an effective aerial operation for the control of *Culex nigripalpus*. Of special interest were the several types of habitats prevalent in the Tampa Bay area, especially swamps of red maple, *Acer rubrum* (L.), and hardwood forests, mostly *Quercus* sp., where large concentrations of *Culex nigripalpus* were known to occur. Brush plots of saw-palmetto, *Serenoa repens* (Bartr.), and gallberry, *Ilex glabra* (L.), also were used in the tests as well as open areas having only short grass similar to residential areas. This is a report of the results of this research from 1962 through 1964.

METHODS. In all tests, 2- to 8-day-old adult mosquitoes, reared in the laboratory from wild stock, were exposed in wire screen cages. Cages were of two types: the standard 3 x 6 inch wire screen cylinder (Rogers, *et al.*, 1957) and a flat, round cage 8 inches in diameter and 1 inch high having a solid metal side and screened on both sides. By means of a battery-powered aspirator, mosquitoes were placed in the flat cages through a one-half inch hole in the metal side, which was plugged with a rubber stopper. All tests with aerial sprays were conducted with this type of cage placed on 6 x 6 inch aluminum plates having the corners bent 90° to make four triangular prongs ⅞-inch high. The plates were placed on the ground with the cages resting on the upturned corners. The prongs were smeared with petroleum jelly to discourage ants.

The 3 x 6 inch cylindrical cages were used exclusively in aerial fog tests in 1962 and in most of the fog tests in 1963–64; however, the flat cages were also used in some of the latter tests. Where the wire cylinders were used, they were placed on wooden stakes at 1 inch or 6 feet above ground level, or both.

Approximately 25 female mosquitoes of each species were put in separate cages and placed side by side in the test plots. The tests were conducted in Indian River County in plots of about 40 to 100 acres in size and similar in flora and physical features to habitats characteristic of the Tampa Bay area. Treatments were ap-

[1] Authors were members of the staff of the Entomological Research Center, Vero Beach, Florida when these studies were made.

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plied either during early morning or late afternoon.

In the majority of the tests, cages were placed at stations spaced 50 feet apart along lines about 300 feet apart near the center of the plot. Twelve to 24 cages of each species (300 to 600 mosquitoes) were used per test, except in a few instances where only 6 cages were used. Complete plot coverage, flown on marked flight centers, was used for all spray tests and for most of the fog tests. In some of the fog tests, only 2 to 3 swaths were applied upwind of the cages. The same plots and stations were utilized both for aerial sprays and fogs. Mosquitoes were moved to clean cages in the field immediately after exposure to sprays and after approximately one hour exposure to fogs. Cages were held over night in the laboratory and covered with cotton pads saturated with sugar water. Mortality counts of female mosquitoes only were made 24 hours after treatment.

Thermal aerosols were produced by injecting oil solutions of insecticides into the exhaust system of the plane's motors (Salmela, *et al.*, 1960). A 220 h.p. Stearman and a DC-3 airplane were used for the fog tests. In 1963, a 450 h.p. Stearman airplane was used for all spray tests. This airplane was equipped with No. 37 drill-size nozzles having a spring-loaded flap cover against which the insecticide was sprayed at 20 p.s.i. All spray tests in 1964 were conducted with a 220 h.p. Stearman equipped with No. 24 drill-size, hollow-cone nozzles operated at 20 p.s.i.

Insecticide formulations for all spray tests were made by diluting oil soluble concentrates in No. 2 diesel oil. Ten percent to 100 percent of "fog" oil[2] was used in the thermal aerosol formulations except in two tests where diesel oil was compared with "fog" oil.

Samples of the particles in the thermal aerosols and sprays were taken on glass slides coated with magnesium oxide. Thermal aerosol particles were also sampled with a cascade impactor.

Results. Table 1 summarizes results of aerial spray tests conducted in 1963. In hardwood forests of average growth density on the East Coast of Florida, naled at a dosage of 0.1 lb. per acre in 4 quarts volume per acre gave excellent control of both species of mosquitoes when wind velocities at an elevation of 40 feet were about 4 m.p.h. Malathion at 0.4 lb. and fenthion at 0.1 lb. per acre were less effective even in 6 quarts volume; the kill of *Culex nigripalpus* in this plot was especially poor with malathion and fenthion. Naled at 0.1 and 0.15 lb. per acre was less effective in a similar forest plot having very dense growth, even when applied in 6 quarts volume per acre. In a swamp of red maple trees having a dense upper story with sparse understory, naled gave good kills of both *Aedes* and *Culex* at 0.15 lb. in 6 quarts per acre but not at 0.1 lb. in 4 quarts; the latter dosage of naled was effective in dense brush areas having no tree cover.

Results of aerial spray tests conducted with a 220 h.p. Stearman airplane during 1964 are summarized in Table 2. Naled at 0.05 lb. per acre applied in 1 quart volume over a swath of 200 feet killed 100 percent of *Aedes* and *Culex* in open plots having only short grass cover but gave poor results in dense brush and hardwood forest plots. Good kill was obtained in the brush plot with this operation by increasing the dosage of naled to 0.1 lb. per acre.

Malathion gave excellent kills of *Aedes* and good kills of *Culex* in grass plots at dosages of 0.2, 0.3, and 0.4 lb. per acre but was much less effective in brush plots at these dosage rates. No tests were conducted with fenthion in brush and grass plots.

When research with aerial fogs was initiated in 1962, tests were designed to evaluate the effect of the thermal aerosol on adult mosquitoes as it drifted with the wind across the area to be treated, as with ground equipment. Accordingly, test

[2] Sun Oil Co., X-light grade or Standard Oil Co. No. 345 Spray Oil.

TABLE 1.—Results of aerial spray tests against caged adult mosquitoes (*Aedes taeniorhynchus* (Wied.) and *Culex nigripalpus* Theobald) placed at ground level in several habitats in Florida, 450 h.p. Stearman airplane, 80 m.p.h., 1963.[1]

Habitat	Toxicant	Dosage lbs./a.	Volume qts./a.	No. tests	Wind[2] m.p.h.	Temp[2] °F.	Percent kill *Aedes*	Percent kill *Culex*
Hardwood forest, average density	naled	0.10	4	2	4	66	98	100
		0.10	4	1	10[3]	70	74	56
		0.10	6	5	5	70	93	97
		0.15	6	3	4	74	91	99
	malathion	0.30	6	2	3	77	89	61
		0.30	6	2	12[3]	75	59	26
		0.40	6	2	2	71	89	61
	fenthion	0.10	6	3	5	72	77	55
Hardwood forest, very dense	naled	0.10	6	5	1	74	82	89
		0.15	6	4	1	77	79	76
Red maple swamp, very dense canopy	naled	0.15	6	3[4]	2	73	99	99
		0.1	4	2	3	71	57	81
Brush (palmetto-gallberry)	naled	0.10	4	2	3	71	99	94
		0.15	6	3	3	74	98	100

[1] All tests flown on marked swaths 100 feet wide.
[2] Average wind velocity at 40 feet and average temperature at 6 feet above ground.
[3] Included to show effect of high winds on kill.
[4] Only one test with *Aedes taeniorhynchus*.

TABLE 2.—Results of aerial spray tests against caged adult mosquitoes (*Aedes taeniorhynchus* (Wied.) and *Culex nigripalpus* Theobald) placed at ground level in several habitats in Florida, 220 h.p. Stearman airplane, 80 m.p.h., 1964.

Habitat	Toxicant	Dosage lbs./a.	Swath (feet)	Volume qts./a.	No. tests	Wind[1] (m.p.h.)	Temp[1] °F.	Percent kill *Aedes*	Percent kill *Culex*
Short grass (no cover over cages)	naled	0.05	200	1	3	5	79	100	100
		0.1	200	1	5	5	79	100	100
		0.1	100	2	3	5	75	100	100
	malathion	0.4	100	2	2	5	..	100	82
		0.3	200	1	1	5	76	100	90
		0.2	200	1	1	6	79	98	88
Brush (palmetto-gallberry)	naled	0.05	200	1	3	5	79	72	61
		0.1	200	1	5	5	79	95	97
		0.1	100	2	3	5	75	95	98
	malathion	0.4	100	2	2	5	..	77	31
		0.3	200	1	1	5	76	64	26
		0.2	200	1	1	6	79	45	10
Hardwood forest, average density	naled	0.05	200	1	2	4	..	68	50

[1] Average wind velocity at 40 feet and average temperature at 6 feet above ground.

TABLE 3.—Results of aerial fog tests against caged adult mosquitoes (*Aedes taeniorhynchus* (Wied.) and *Culex nigripalpus* Theobald) in Florida, 220 h.p. Stearman airplane, 1962–64.

		Swath			Percent kill							
					Cages 6 feet above ground				Cages at ground level			
					Bare ground		Trees		Bare ground		Trees	
Toxicant	Formulation-Volume[1]	width (feet)	No.	No. tests	*Aedes*	*Culex*	*Aedes*	*Culex*	*Aedes*	*Culex*	*Aedes*	*Culex*
Malathion	10.0–150	100	o	1	..	..	52	4	..	..	15	2
	8.0–320	330	3[2]	8	97	..	..	..	..	..	..	..
	8.0–320	300	o	1	..	..	9	3	..	..	10	1
	8.0–320	100	o	7	..	..	51	19	..	..	26	9
	8.0–320	100	o	3[3]	..	..	86	70	..	..	66	37
	5.3–600	100	o	1	..	..	..	..	98	96	30	13
	9.0–600	100	o	1	..	..	..	38	..	..	53	31
Naled	3.0–150	330	2[2]	4	68	38	..	..	40	12	..	..
	3.0–650	330	3[2]	1	96	100	..	..	89	73	..	..
	3.0–150	330	o	1	100	100	..	..	100	100	..	..
	1.4–320	330	3[2]	1	100	100	..	..	100	99	..	..
	1.4–320	330	o	1	100	100	..	..	100	90	..	..
	1.2–600	100	o	1	..	..	68	55	..	..	48	43

[1] Gals./100 of malathion 90 or naled 14—volume in gals./hour.
[2] All swaths upwind from cages; cages 165 and 330 feet from last swath.
[3] Orange grove; all other data for trees indicate dense hardwood forests.
o Complete plot coverage.

cages were exposed above ground level in a manner similar to that used by Davis, *et al.* (1960). However, it was soon recognized that aerial applications normally are made during daylight hours when mosquitoes are at rest, whereas ground equipment is used at night when mosquitoes are in flight. In the case of both species used in these tests, the mosquitoes rest on the ground during daylight hours; therefore, in order for test results of aerial applications to be meaningful against these species it was necessary to place test specimens at ground level, which is where natural populations are when aerial applications normally were made. This is especially important when the poor deposit characteristics of aerosol-size particles are considered. Consequently, test results shown in Tables 3 and 4 reflect the effects of cage position and habitat as well as operational factors on mosquito kills with aerial fogs.

Usually, only one fog test could be conducted in a single day; therefore, when test conditions appeared to be good and results were unsatisfactory, a change was made in formulation, volume, or equipment before the next test. This procedure resulted in the large number of single tests included in Tables 3 and 4.

Results show that in general the kill with fogs was related more to cage position and habitat cover than to formulation, volume, or swath. With few exceptions, mosquito kill with fogs was very good where cages were located on bare ground, both at ground level and at 6 feet above ground, regardless of insecticide or operation. However, where cages were positioned in brush and dense tree growth, results were consistently poor. It is also of interest to note that kills of *Culex nigripalpus* in wooded plots with aerial fogs were generally much lower than for *Aedes taeniorhynchus*. Mosquito kill with aerial fogs at ground level in brush plots generally were intermediate between those for bare ground and tree plots.

There was no difference in results of tests comparing diesel oil and "fog" oil as diluents, so these tests were not treated separately in Table 3.

There was an overlap in the size of particles of sprays and fogs sampled in this study. The data in Table 5 are from glass microscope slides placed in open areas and under tree cover in hardwood forest plots during spray and fog tests. The numbers of particles shown are those counted on one complete traverse near the center of the slide along the long axis. When the number of particles and their average diameters for the fog tests at 320 and 600 g.p.h. are compared with corresponding figures for the spray tests at 6 quarts per acre, at comparable wind velocities, the data appear quite similar. However, in samples taken with a cas-

TABLE 4.—Results of aerial fog tests against caged adult mosquitoes (*Aedes taeniorhynchus* (Wied.) and *Culex nigripalpus* Theobald) in Florida with a DC-3 airplane; air speed 125 m.p.h., 1200 gallons per hour—1963.

		Percent kill							
		6 feet above ground				Ground level			
		Bare ground		Trees		Bare ground		Trees	
Toxicant	Formulation-Swath[1]	*Aedes*	*Culex*	*Aedes*	*Culex*	*Aedes*	*Culex*	*Aedes*	*Culex*
Malathion	4.5–300[2]	100	99	12	14	100	96	6	5
	8.0–[3, 4]	..	..	14	10	..	..	2	2
Naled	1.0–200[4]	..	..	..	..	100	97	..	..

[1] Gals./100 of malathion 90 or naled 14—swath in feet.
[2] Two tests bare ground, one in trees.
[3] Swaths variable, not marked.
[4] One test only.

TABLE 5.—Deposits of insecticidal particles of aerial sprays and thermal aerosols on glass slides coated with a film of magnesium oxide.

	Type plane	No. of Tests	Avg. wind speed at 40 feet (m.p.h.)	Volume (qts./ a. or gal./hour)	Swath (feet)	Type of cover	Avg. No. particles per slide[1]	Percent reduction under cover	Avg. diameter
Spray	450 h.p. Stearman	9	1	6 qts.	100	none	55	..	84
						forest	24	58	56
		12	4	6 qts.	100	none	96	..	89
						forest	28	71	74
	220 h.p. Stearman	10	6	1 qt.	200	none	9	..	91
		4	5	2 qts.	100	none	17	..	95
Thermal aerosol.	220 h.p. Stearman	1	4	150 g.p.h.	100	none	45	..	17
						forest	22	51	22
		3	4	600 g.p.h.	100	none	77	..	50
						forest	22	71	33

[1] Corrected figures based upon slides exposed an equal length of time prior to treatment.

TABLE 6.—Particle size of thermal aerosols produced by a 220 h.p. Stearman airplane discharging 320 gallons per hour as sampled by a Cascade Impactor.

No. of tests	Approximate altitude of flight (feet)	Distance of sample from plane (feet)	Wind speed at 40 feet alt. m.p.h.	Percent of particles in indicated size range (microns)				
				<1	1–5	6–10	11–20	>20
2	60	Under plane	1	99.48	0.59	0.06	0.01	0.02
1	15–20	50	5	98.35	1.48	0.08	0.60	0.00
1	15–20	165	5	96.98	2.42	0.48	0.09	0.00

cade impactor, more than 90 percent of the particles in the aerial fogs were smaller than 5 microns (Table 6). Particles in this size range will not deposit in sufficient numbers on slides to give valid samples; therefore none are shown in Table 5.

DISCUSSION. These tests show that habitat was an important factor affecting results and that there was no single spray operation which was effective in all mosquito habitats, except possibly the operation required by conditions imposed by those plots having the greatest density of plant growth. While malathion sprays gave good kill of both *Aedes* and *Culex* in relatively open areas, of the insecticides and operations tested, naled sprays appear to offer the best prospects for providing fast, effective control of *Culex nigripalpus* in the principal habitats of this encephalitis vector in Florida.

It has been known for many years that true aerosol-size particles do not deposit well on the ground (Yeomans, 1950) and therefore are effective primarily in space treatments. In the case of adult mosquitoes, this indicates application at night during the activity period of these insects.

Use of the thermal exhaust principle for atomizing DDT solutions with aircraft for control of anopheline larvae has been reported by several workers (Kruse and Metcalf, 1946; Magy, 1949); however, a study of these data shows that these operations produced particles up to 200 microns or larger in size. Most of the earlier reports refer to these operations as "thermal aerosols," but Sebora, *et al.* (1946) used the term "exhaust-generated sprays," which seems more descriptive.

Lindquist, *et al.* (1945) used the thermal exhaust method for applying DDT against adult *Aedes taeniorhynchus* in Florida, discharging a volume of 2 quarts per acre from an L-4B Cub airplane. A test with 5 percent DDT was a failure. Another test using 20 percent DDT gave good results, but the authors expressed the opinion that the greatest kill was obtained with the spray-size particles in the "smoke-spray." Tests with DDT sprays (5 percent at 2 qts/acre) in this series were reported to be generally successful. Present evidence, therefore, seems to indicate that the thermal-exhaust principle of applying insecticide solutions with aircraft for control of adult mosquitoes is not an efficient operation.

Likewise, conventional airplane sprays, while effective, must also be regarded as inefficient because of the large percentage of the insecticide that is prevented from reaching the ground by impingement on plants in wooded areas (see Table 5).

The authors are in agreement with Lewallen (1962) that there is a great need for development of equipment and procedures designed specifically for vector control with aircraft, present operations being mostly an adaptation of those that were developed for control of agricultural pests. A dispersal system that will produce particles only in a size range suitable for penetration of foliage and deposit on the ground appears to be one of the more desirable objectives for development work with aircraft. Recent reports of low-volume concentrate sprays against grasshoppers (Messenger, 1963) and the cereal leaf beetle (Wilson *et. al.*, 1965) appear to be a step forward toward this objective.

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References Cited

CHAMBERLAIN, ROY W. 1963. Transmission of St. Louis encephalitis, with special reference to *Culex nigripalpus* Theobold. Rpt. 34th Ann. Mtg. Fla. Anti-Mosq. Assn. pp. 31–34.

DAVIS, A. NELSON, SALMELA, JACK, and SPENCER, JR., C. B. 1960. Field tests with malathion fogs dispersed from an airplane for control of adult salt-marsh mosquitoes. Mosq. News 20(3):281–86.

KRUSE, C. W., and METCALF, R. L. 1946. An analysis of the design and performance of airplane exhaust generators for the production of DDT aerosols for the control of *Anopheles quadrimaculatus* Public Health Reports 61(32): 1171–1184

LEWALLEN, LAWRENCE L. 1962. Low dosage, low volume application of insecticides by aircraft for mosquito control. Rpt. 4th Agric Aviation Research Conf. Agric. Research Services, U.S.D.A. pp. 119–121.

LINDQUIST, ARTHUR W., MADDEN, A. H., HUSMAN, C. N., and TRAVIS, B. V. 1945. DDT dispersed from airplanes for control of adult mosquitoes. J. Econ. Ent. 38(5):541–44.

MAGY, HARVEY L. 1949. Studies using DDT applied in airplane thermal exhaust aerosols for the control of anopheline larvae in rice fields in California. Mosq. News 9(3):101–108.

MESSENGER, KENNETH. 1963. Low volume aerial spraying will be a boon to applicators. Ag Chem. 18(12):63–66.

ROGERS, ANDREW J., BEIDLER, E. J., and RATHBURN, JR., CARLISLE B. 1957. A cage test for evaluating mosquito adulticides under field conditions. Mosq. News 17(3):194–98.

SALMELA, JACK, SIDLOW, A. J., and DAVIS, A. NELSON. 1960. A new thermal aerosol generator for dispersing insecticidal fogs from a Stearman airplane. Mosq. News 20(3):275–80.

SEBORA, L. H., DEONIER, C. C., WISECUP, C. B., HUSMAN, C. N., and LONGCOY, O. M. 1946. Performance of aerial spray equipment used to disperse DDT at Orlando, Florida. Mosq. News 6(4):169–177.

WILSON, M. CURTIS, RUPPEL, ROBERT F., and TREESE, ROBERT E. 1965. Low-volume concentrate sprays applied by aircraft for control of the cereal leaf beetle. J. Econ. Ent. 58(1):11–14.

YEOMANS, A. H. 1950. Directions for applying windborne aerosols for control of insects out-of-doors. U. S. Dept. Agric. Bul. ET-282. 8 pp.

1964 Rogers, A. J., and C. B. Rathburn, Jr.
Present Status Of Insecticides For Mosquito Control In Florida
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technicians and sub-professional personnel. Considerable emphasis by all three services has been placed on vector control training programs and, as we have mentioned the annual two weeks of active duty "for training" keeps the Reserves in up-to-the minute touch with our military program—and we with theirs.

SUMMARY. We have attempted to describe the interactions between the military control and the civilian mosquito abatement which we feel are mutually valuable. Where the military need for control is not matched by a need on the part of the surrounding community, we augment such control either with our own forces or by contract with civilian agencies. Where there are strong programs on both sides of the fence, we lend support to the civilian efforts by the indoctrination and training of our personnel who live, or will live, in communities and provide a growing body of support to mosquito abatement. By grants to research, the military aid in the discovery of materials, techniques and equipment which will improve the efficacy of efforts by all agencies. And by participation in civilian conferences and the temporary resorption into our ranks of civilian mosquito workers who are Reservists, we help to speed up the flow rate at which information on practical control techniques passes around. We feel that at least some of the generally increasing interest among the populace in genuine mosquito control is due to the example of the military programs which are on view around the world. We also feel that the military and the civil programs are too closely interwoven to be successfully separated and we hope it continues to be that way.

PRESENT STATUS OF INSECTICIDES FOR MOSQUITO CONTROL IN FLORIDA

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In Florida, insecticides are used extensively for the control of *Aedes taeniorhynchus, Aedes sollicitans, Culex quinquefasciatus, Culex nigripalpus,* and *Psorophora confinnis;* and to a lesser extent against *Aedes aegypti, Mansonia* spp., fresh-water *Aedes* and *Anopheles* spp.

With the intensive research on arboviruses now being conducted in the state, it is not possible to say what other species might be added to the list for serious attention by control districts in the near future. New information already has justified second thoughts about some of the fresh-water *Aedes* and at least one anopheline. Reliable information on the present status of insecticides against certain of these species is fairly complete; for others it is, at best, sketchy or incomplete.

[1] Contribution No. 139 Entomological Research Center.

CHLORINATED HYDROCARBONS. *Aedes taeniorhynchus* and *Ae. sollicitans* present a single problem from the standpoint of control, with *taeniorhynchus* being by far the dominant salt-marsh species over most of the state.

It was against these species that the armed forces during World War II, and the mosquito control districts in the immediate post-war period, demonstrated that mosquitoes could be controlled over large areas with DDT applied by aircraft as a larvicide—adulticide. However, by 1949 DDT resistance was demonstrated in several counties (Deonier and Gilbert 1950; Bertholf 1950; Cain 1950; King 1950). There followed a short period during which other chlorinated hydrocarbons were used with varying degrees of success (Keller and McDuffie 1951; Keller and Chapman 1953).

However, by 1955 a number of Florida

mosquito control districts were reporting failures with BHC and dieldrin, the most widely used substitutes for DDT (Beidler, 1956; Bertholf 1956; Stutz 1956; Thomas 1956; Wenner 1957). Warner (1956) reported generally poor results from tests with thermal aerosols containing BHC and DDT against salt-marsh *Aedes* in the Florida Keys, and McWilliams and Munn (1957) reported that larvae of salt-marsh *Aedes* collected near the U. S. Naval Base at Key West were resistant to DDT, lindane, and dieldrin. Tests conducted at the Entomological Research Center in 1957 with DDT aerosols against *Ae. taeniorhynchus* from seven widely separated areas of the state confirmed that DDT resistance was general throughout the salt-marsh areas of Florida (Rogers and Rathburn, 1958).

Although most of the districts had discontinued the use of chlorinated hydrocarbons by 1955, resistance has persisted during the past 9 years. Davis *et al.* (1959) reported that larvae of salt-marsh *Aedes* from Florida were 8 to 10 times more resistant to DDT, BHC, and dieldrin than larvae from Georgia and that there was no more than a two-fold difference in susceptibility to any of five organophosphorus insecticides. In fact, larvae from Florida were more susceptible to malathion than the larvae from Georgia. Adults from Georgia were 7.8 times more susceptible to DDT and adults from Florida were 2.4 times more susceptible to malathion.

In October, 1961 the Indian River Mosquito Control District treated a large brood of *Ae. taeniorhynchus* in a pickleweed (*Batis-Salicornia*) marsh approximately 10 acres in size; the marsh had no tree canopy. Two gallons per acre of DDT emulsion containing 0.5 lb. DDT per gallon were applied by airplane. Inspection 24 hours after treatment showed no significant reduction in the larval population. Larvae from a nearby marsh had an LC-50 of .02 p.p.m. to DDT in 1961, theoretically a susceptible level (Fig. 1).

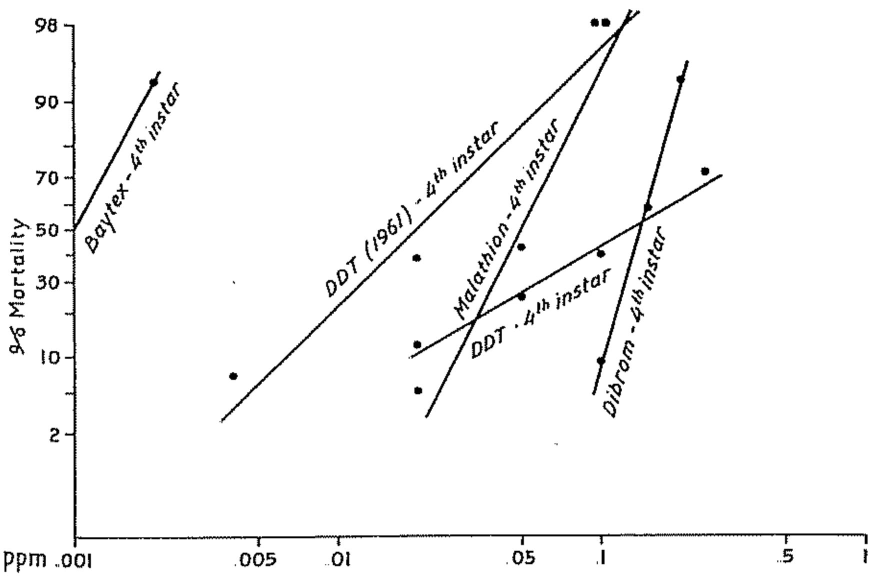

FIG. 1.—Dosage-mortality curves for several insecticides against larvae of *Aedes taeniorhynchus* (Wied.) in the WHO Resistance Test. 1961 and 1964. (Mortalities for Baytex at 0.008 and 0.004 p.p.m. were 23% and 6% respectively).

Aerial spray tests were conducted by the Entomological Research Center against caged adult mosquitoes on a grass landing strip during 1963 with *Ae. taeniorhynchus* and *Cu. nigripalpus* included in each test. In tests conducted on the same day, DDT at 0.4 lb. per acre in one gallon of diesel oil killed only 19 percent of the *Aedes* and 64 percent of the *Culex;* malathion at 0.2 lb. killed 99 percent of *Aedes* and 98 percent of *Culex;* and Dibrom at 0.1 lb. in water emulsion and in oil killed 100 percent of both species, as did malathion at 0.3 lb. in oil (unpublished data).

Aedes larvae collected from salt marshes in Indian River County in 1964, where no chlorinated hydrocarbons have been used since 1955, had an LC-50 for DDT in the WHO Resistance Test of 0.15 p.p.m. (Table 1; Fig. 1). Adults of *Aedes* reared from larvae collected in these marshes had an LC-50 greater than 4 percent for one hour exposure in the WHO adult test and 3.4 percent for 4 hours exposure. The LC-50 for *Cu. nigripalpus* to DDT in these tests was greater than 4 percent for both exposure periods (Table 2; Fig. 3). It is concluded that there has been no significant reversion, if any, to DDT susceptibility within this *Ae. taeniorhynchus* population during the past 9 years.

TABLE 1.—Susceptibility of larvae of *Culex nigripalpus* Theob. and *Aedes taeniorhynchus* (Wied.) to several insecticides in the WHO Resistance Test.[1]

Insecticide	Instar	LC 50—p.p.m. *Cu. nig.*	LC 50—p.p.m. *Ae. taen.*
DDT-1961	4	..	0.023
DDT	3	0.280	..
Malathion	4	..	0.150
	3	0.028	..
Baytex	4	0.034	0.050
	3	0.002	..
Dibrom	4	0.003	0.001
	4	0.047	0.140

[1] All tests conducted in 1964 except as indicated.

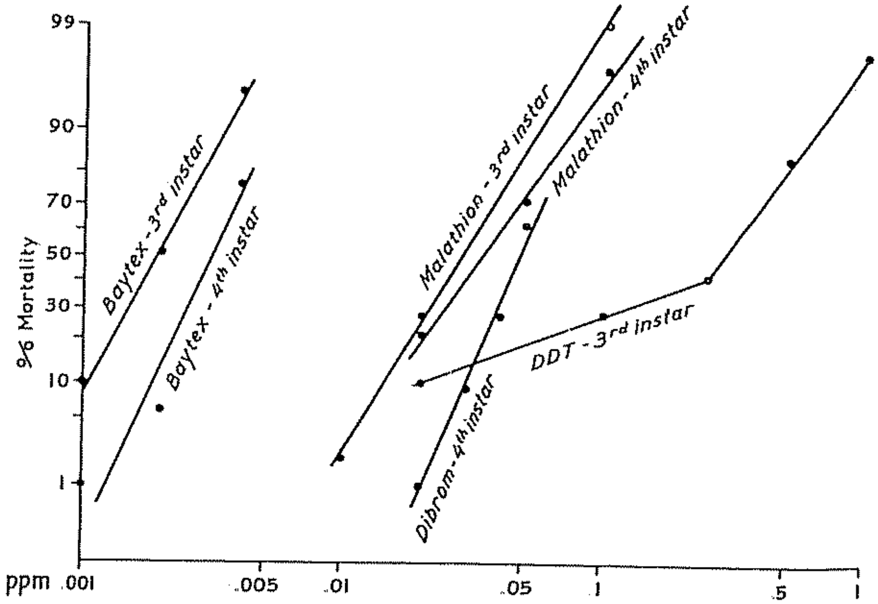

FIG. 2.—Dosage-mortality curves for several insecticides against larvae of *Culex nigripalpus* Theob in the WHO Resistance Test, 1964.

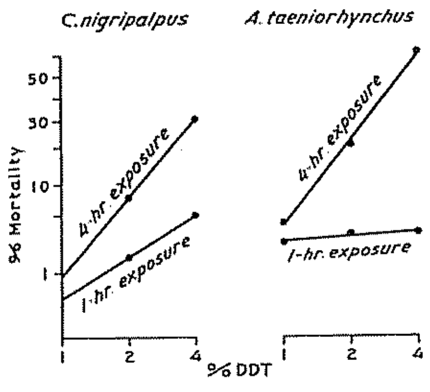

FIG. 3.—Dosage-mortality curves for DDT against adults of *Culex nigripalpus* Theob. and *Aedes taeniorhynchus* (Wied.) in the WHO Resistance Test, 1964.

The poor results with DDT against *Cu. nigripalpus* in these tests cannot be ascribed to physiological resistance resulting from selection pressure, because this species was never the object of planned control operations in Florida with chlorinated hydrocarbons. A more likely explanation is a greater natural resistance of this species to DDT. Also, there is no ready explanation for the low LC-50 of DDT to *Ae. taeniorhynchus* larvae from these same marshes in 1961 (Table 1).

Evans *et al.* (1960) reported that larvae of *Aedes aegypti* from Miami were 5.4 times more resistant to DDT at the LC-50 level than larvae from New Orleans and suggested that DDT resistance might be developing in *aegypti* at Miami. Porter *et al.* (1961) extended these tests and confirmed the resistance of *Ae. aegypti* in Miami to DDT. Abedi and Brown (1961) reported that *Aedes aegypti* originating from Key West, Florida were tolerant to DDT, the initial LC-50 being 0.3 p.p.m. These authors showed further that selection with DDT through the fourth generation increased the DDT-tolerance by 7 times.

TABLE 2.—Susceptibility of adults of *Culex nigripalpus* Theob. and *Aedes taeniorhynchus* (Wied.) to DDT in the WHO Resistance Test.

Insecticide	Exposure time-hrs.	LC 50—% toxicant *Cu. nig*	*Ae. taen.*
DDT	1	>4	>4
	4	>4	3.4

Data on the susceptibility of other problem mosquitoes in Florida to chlorinated hydrocarbons are at best incomplete. In comparative thermal aerosol tests conducted at Vero Beach in 1957, it was shown that *Culex quinquefasciatus* adults from Indian River County were slightly less susceptible to DDT than were DDT-resistant *Ae. taeniorhynchus;* poor kills also were obtained against *Psorophora confinnis;* whereas kills with DDT against *Aedes aegypti* and *Anopheles quadrimaculatus* from laboratory colonies, and against *Psorophora ciliata* from the field, were equal to or superior to those with malathion (Rogers and Rathburn, 1958).

ORGANOPHOSPHATES. Reports by Gjullin and Peters (1955) and Culver, Caplan and Batchelor (1955) in California and by Smith (1956) in Florida demonstrated the effectiveness and safety of malathion for area control of DDT-resistant adult mosquitoes. These reports stimulated research with organophosphates as mosquito adulticides at the Entomological Research Center at Vero Beach, Florida commencing in 1956.

Because of the experience with DDT resistance, the Florida State Board of Health in 1957 recommended to the Florida Mosquito Control Districts that the organophosphates be used only as space treatments for the control of adult mosquitoes, a program that is imperative for a subtropical tourist state like Florida. The purpose of this recommendation was to try to avoid or delay resistance to the organophosphates, which could be expected to occur quickly as a result of selection pressure if used on larval populations.

Tests with malathion in thermal aerosol at 8 oz. (actual) per gallon in No. 2 diesel oil, applied at 40 gallons per hour, at a vehicle speed of 5 miles per hour, gave an average kill of 93 percent of caged DDT-resistant *Aedes taeniorhynchus* in

1956. This test has been repeated periodically since that time with no reduction in kill or indication of resistance. The average percent kill in this test in 1963 was 98 percent (Table 3). Thus, malathion has been used as an adulticide in Florida for 8 consecutive years with no indication of resistance. This is attributed to the cooperation of the Florida Mosquito Control districts in complying with the recommendation of the Florida State Board of Health to avoid using these organic compounds as larvicides.

Keller and Chapman (1953) (Also see Brown, 1958, 1961; and Micks *et al.* 1961) Brevard County marshes that had received intensive treatment with DDT were

TABLE 3.—Thermal aerosol tests with malathion [1] against *Aedes taeniorhynchus* (Wied.), 1956–1963.

Year	No. of tests	Percent mortality
1956	8	93
1957	23	90
1958	6	90
1961	5	92
1963	8	98

[1] Eight oz./gal. (actual) in diesel oil applied at 40 gals./hr., vehicle speed of 5 miles per hour.

reported that salt-marsh *Aedes* larvae from slightly more tolerant of EPN and malathion than larvae from nearby marshes that had been treated only occasionally with DDT. However, since no organophosphates had been used for mosquito control in these marshes prior to the time of these tests, this slight difference in larval susceptibility must be explained by vigor tolerance or some other phenomenon. The organophosphates have been used successfully for the control of adult mosquitoes in the vicinity of these marshes since 1956.

Of course, it cannot be stated that resistance will not develop eventually when these compounds are used only as space treatments against adults, but this approach to the resistance problem has worked well in Florida for the past 8 years, where up to 1¾ millions of gallons of formulated insecticides are used annually for control of adult mosquitoes.

Present dosage recommendations for ground aerosol operations with malathion are 6 oz. per gallon for control of *Aedes taeniorhynchus* and *Ae. sollicitans* and 8 oz. per gallon against *Culex nigripalpus*, an encephalitis vector. Dibrom (naled) is used at 1½ oz. against *Ae. taeniorhynchus* and 1¾ oz. against *Cu. nigripalpus*. Baytex (fenthion) is recommended at 1¼ oz. per gallon against *Ae. taeniorhynchus* in ground fogging. This insecticide has not been tested against other species as yet. These dosage recommendations are based upon a discharge rate of 40 gallons per hour, vehicle speed of 5 miles per hour, and a swath of 300 to 400 feet, or one city block.

Malathion, Dibrom, and Baytex presently are the only insecticides recommended for control of adult mosquitoes in Florida.

LARVICIDES. Although larviciding alone is not regarded as a practical procedure for mosquito control in Florida because of the unique conditions that characterize mosquito production in the State, the great value of larvidices is fully appreciated.

In keeping with the policy of avoiding the new organic insecticides for larviciding, only granular paris green and No. 2 diesel oil are currently recommended for larviciding in Florida. Research with granular formulations of paris green during the past several years has resulted in a larvicide that is effective against most of the important species in the State and is reasonable in cost when compared with other granular larvicides. For aerial application, it is necessary to use granular formulations for larviciding in many of the larval habitats in Florida.

Diesel oil is still widely used for ground larviciding, and research on improved formulations and methods of application is being pursued. Oil still has many advantages over other larvicides, provided the cost can be reduced.

DISCUSSION. Although the chlorinated

hydrocarbon insecticides have not been used extensively in Florida during the past 9 years, the salt-marsh *Aedes*, and possibly other species, are still highly resistant to DDT. In an effort to avoid or delay resistance to the organophosphates, these insecticides have only been used as space treatments for the control of adult mosquitoes, not for larviciding. This procedure has worked well for the past 8 years, there being no confirmed report of physiological resistance to the organophosphates in the State at this time.

References Cited

ABEDI, Z. H., and BROWN, A. W. A. 1961. DDT-Resistance hazard in North American populations of *Aedes aegypti*. Mosq. News 21(1): 1–4.

BEIDLER, E. J. 1956. Report of the Indian River Mosquito Control District. Rpt. 27th Ann. Mtg. Fla. Anti-Mosq. Assn. pp. 34–35.

BERTHOLF, J. H. 1950. DDT-Resistant mosquitoes in Broward County, Florida. Rpt. 21st Ann. Mtg. Fla. Anti-Mosq. Assn. pp. 80–83.

———. 1956. Report of the Broward County Anti-Mosquito District. Rpt. 27th Ann. Mtg. Fla. Anti-Mosq. Assn. pp. 18–24.

BROWN, A. W. A. 1958. Insecticide resistance in arthropods. Monograph No. 38. WHO, Geneva.

———. 1961. The challenge of insecticide resistance. Bull. Ent. Soc. Amer. 7(1):6–19.

CAIN, THOMAS L., JR. 1950. Observations on DDT-resistant species of mosquitoes found in Brevard County. Rpt. 21st Ann. Mtg. Fla. Anti-Mosq. Assn. pp. 84–85.

CULVER, DWIGHT, CAPLAN, PAUL, and BATCHELOR, GORDON S. 1955. A summary of human exposures to malathion and chlorthion during aerosoling operations. Proc. 23rd. Ann. Conf. Calif. Mosq. Cont. Assn. pp. 86–89.

DAVIS, A. N., WEIDHAAS, D. E., and FORD, H. R. 1959. Relative susceptibility of salt-marsh mosquitoes from Georgia and Florida to insecticides. Fla. Ent. 42(3):109–11.

DEONIER, C. C., and GILBERT, I. H. 1950. Resistance of salt-marsh mosquitoes to DDT and other insecticides. Mosq. News 10(3):138–43.

EVANS, BURTON R., PORTER, JOHN E., KOZUCHI, GEORGE, and FINK, EDWARD J. 1960. Susceptibility levels of some *Aedes aegypti* (Linn.) larvae to DDT and dieldrin. Mosq. News 20(2):116–18.

GJULLIN, C. M., and PETERS, RICHARD F. 1955. Effectiveness of some organic phosphorus and other insecticides as aerosols against mosquitoes. Proc. 23rd Ann. Conf. Calif. Mosq. Cont. Assn. pp. 111–12.

———, and CHAPMAN, H. C. 1953. Tests of selected insecticides against resistant salt-marsh mosquito larvae. Jour. Econ. Ent. 46(6):1004–6.

KELLER, JOHN C., and MCDUFFIE, W. C. 1951. Resistance of salt-marsh mosquitoes to insecticides in Floride. Proc. 38th Ann. Mtg. N. J. Mosq. Exterm. Assn. pp. 54–56.

KING, W. V. 1950. Studies of DDT-resistant mosquitoes in Florida. Rpt. 21st Ann. Mtg. Fla. Anti-Mosq. Assn. pp. 77–79.

MCWILLIAMS, JOSEPH G., and MUNN, B. L. 1957. Studies of mosquito resistance to insecticides at some naval activities. Mosq. News 17(4):258–60.

MICKS, DON W., COX, WILLIAM M., and MCNEILL, J. C., IV. 1961. The status of insecticide resistance in some mosquito species of Texas. Mosq. News 21(3):229–32.

PORTER, JOHN E., EVANS, BURTON R., and KOZUCHI, GEORGE. 1961. Further comments on the susceptibility of *Aedes aegypti* to DDT in the Miami, Florida area. Mosq. News 21(1):4–5.

ROGERS, ANDREW J., and RATHBURN, CARLISLE, B., JR. 1958. Aerosol tests with DDT and malathion comparing five species of mosquitoes and comparing salt-marsh *Aedes* from eight localities in Florida and Georgia. Mosq. News 18(2):74–80.

SMITH, CARROLL N. 1956. Control of resistant mosquitoes with malathion and Bayer 21/199. Rpt. 27th Ann. Mtg. Fla. Anti-Mosq. Assn. pp 15.

STUTZ, FRED H. 1956. Report of the Dade County Anti-Mosquito District. Rpt. 27th Ann. Mtg. Fla. Anti-Mosq. Assn. pp. 29–31.

THOMAS, LUTHER. 1956. Report of the West Pasco County Mosquito Control District. Rpt. 27th Ann. Mtg. Fla. Anti-Mosq. Assn. pp. 47–48.

WARNER, WILLIAM W. 1956. A preliminary report on the chemical control of the salt-marsh *Aedes* with thermal aerosol apparatus on the Florida Keys. Rpt. 27th Ann. Mtg. Fla. Anti-Mosq. Assn pp. 126–39.

WENNER, LEE 1957. Report of the Brevard County Mosquito Control District. Rpt. 28th Ann. Mtg. Fla. Anti-Mosq. Assn pp. 8–9.

1964 Rathburn, C. B., Jr., B. W. Clements, Jr., and A. J. Rogers
Comparative Thermal Aerosol Tests With Dibrom And Malathion Against Aedes Taeniorhynchus (Weid) And Culex Nigripalpus Theob.
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(142)

COMPARATIVE THERMAL AEROSOL TESTS WITH DIBROM AND MALATHION AGAINST *AEDES TAENIORHYNCHUS* (WIED.) AND *CULEX NIGRIPALPUS* THEOB.[1]

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In the summer of 1962, the Tampa Bay region of Florida was the center of an outbreak of St. Louis encephalitis. *Culex nigripalpus* was implicated as a major vector of the virus in the epidemic area (Chamberlain, 1963) and mosquito control operations were intensified, especially the application of malathion and Dibrom with thermal aerosol generators for the control of adult mosquitoes.

Prior to 1963 dosage recommendations for ground fogging in Florida were based upon test results against *Aedes taeniorhynchus*, the species of principal interest. However, in tests conducted by the authors in the spring of 1963 with aerial fogs against caged adults of *Aedes taeniorhynchus* and *Culex nigripalpus*, the kills of *Aedes* were significantly higher than for *Culex* where both species were exposed in the same tests (Unpublished data). The U.S.D.A. laboratory at Orlando, Florida also demonstrated that *Culex nigripalpus* adults are less susceptible to malathion sprays than the adults of salt-marsh *Aedes* (personal communication). Therefore, because of the special interest in controlling *Culex nigripalpus*, malathion and Dibrom were tested against this species in ground-dispersed thermal aerosols in the spring and early summer of 1963. Adults of *Aedes taeniorhynchus* were included in each test for comparison. This is a report of the results of these tests.

METHODS. The methods used were similar to those reported by Rogers, *et al.* (1957). All tests were conducted in the early evening hours on level, open areas having little or no underbush. Four cages of mosquitoes, two of each species, containing approximately 25 female mosquitoes per cage were attached to stakes. One cage of each species was placed at six feet and another at two feet above the ground. The stakes were placed at intervals of 165 and 330 feet downwind from and perpendicular to the line of travel of the fogging vehicle. Each test or replicate consisted of the cages of each species from three sets of stakes placed a block (approximately 300 feet) apart or a total of 12 cages.

All mosquitoes used in the tests were between 2 and 8 days old and had been fed only sugar water. After exposure to the fog, the mosquitoes were transferred to clean cages and a fresh pad of cotton saturated with sugar water was placed on the top of each cage. Mortality counts, of female mosquitoes only, were made 12 hours after treatment.

All tests were conducted with either a Leco 80[2] or a TIFA 40[3] thermal aerosol generator calibrated to deliver 40 gallons per hour. The Leco was operated at a burner temperature of 850° F. and at a formulation pressure required to give the desired output of 40 gallons per hour or approximately 13 p.s.i. The TIFA was operated at a burner temperature of 1000° F. and a formulation pressure of 25 p.s.i. The fogging vehicle was driven at 5 miles per hour. The operation of the machines was checked constantly during the tests, and the volume discharged was measured accurately for each test. Tests in which the output varied more than six percent were discarded. Wind velocities during the tests at six feet elevation were

[1] Contribution No. 129. Entomological Research Center, Florida State Board of Health, Vero Beach, Florida.

[2] Lowndes Engineering Co.

[3] Todd Shipyards Corp.

between 1 and 5 miles per hour and the temperature betwen 67° and 81° F. It has been determined previously that there is no difference in mosquito kill with these two machines when used within the conditions of atmospheric temperatures and wind velocities at which these tests were conducted (unpublished data). The fog coverage at each station was visually checked and if poor coverage was noted the test was discarded.

Both malathion and Dibrom were formulated in No. 2 diesel oil from malathion 90 and Dibrom 14 respectively. Due to the formation of precipitates with these insecticides when formulated in diesel oil, appropriate inhibitors were used. Thiosperse[4] was used at 0.25 percent by volume in malathion formulations and Ortho Additive 10–20[5] at 0.5 percent in Dibrom formulations.

RESULTS. It is evident from data in Table 1 that either of the previously

The unusually wide ranges of mortality for both species with Dibrom at 1½ ounces per gallon were due to poor kills at 330 feet in separate tests. In each instance fog coverage of all cages appeared to be normal and satisfactory kill of the other species was obtained in each of the tests. Therefore, in the absence of an acceptable explanation for these aberrant results, data from these tests are included.

DISCUSSION. The data in Table 1 are comparative since both *Aedes taeniorhynchus* and *Culex nigripalpus* were included in each test. However, due to changes in weather during the testing period, availability of test mosquitoes and other causes, it was not always possible to conduct a test with each formulation on the same night. It has been previously determined, however, that comparable results could be expected under conditions where the temperature is greater than 65° F. and the wind velocity is below 5 miles per

TABLE 1.—Results of tests conducted in 1963 with malathion and Dibrom applied as thermal aerosols against caged adults of *Aedes taeniorhynchus* (Weid.) and *Culex nigripalpus* Theob.

Insecticide	Ounces[1] per gallon	Mosquito species	No. of tests	Percent mortality Average	Range
Malathion	8	*Aedes taeniorhynchus*	8	98	94–100
		Culex nigripalpus	8	93	84–100
Malathion	6	*Aedes taeniorhynchus*	7	98	93–100
		Culex nigripalpus	7	85	78–93
Dibrom	1.75	*Aedes taeniorhynchus*	9	96	85–100
		Culex nigripalpus	9	93	73–99
Dibrom	1.50	*Aedes taeniorhynchus*	6	90	55–100
		Culex nigripalpus	6	86	49–100

[1] Ounces of actual toxicant per gallon in No. 2 diesel oil.

recommended dosages of 6 oz. of malathion or 1½ oz. of Dibrom per gallon (Rathburn and Rogers, 1963) produce a satisfactory kill of *Aedes taeniorhynchus*. However, the ranges and average kills of *Culex nigripalpus* obtained at these dosage levels is considered unsatisfactory. For satisfactory kill of this species, the higher dosage of 8 oz. of malathion or 1¾ oz. of Dibrom is required.

hour. Since all tests were conducted within these conditions, they may be assumed to be comparable.

A principal reason for publishing the results of these tests is to call attention to the difference in species susceptibility to insecticides among mosquitoes and the desirability of establishing effective dosage levels for each important species to a particular insecticide.

Fortunately, Dibrom was used at the effective dosage rate of 1¾ oz. per gallon for control of *Culex nigripalpus* during

[4] American Cyanamid Co.
[5] California Chemical Co.

the 1962 outbreak of encephalitis in Florida, even prior to its incrimination as a vector. This was because Dibrom had only been tested against *Aedes taeniorhynchus* at the 1 oz. and 1¾ oz. levels prior to 1962 (Rathburn and Rogers, 1961) and the only known effective dosage at the start of the 1962 encephalitis outbreak was 1¾ oz. per gallon. The recommended dosage rate of 1½ oz. of Dibrom per gallon for *Aedes taeniorhynchus* (Rathburn and Rogers, 1963) was not established until November of 1962.

References

CHAMBERLAIN, ROY W. 1963. Transmission of St. Louis encephalitis, with special reference to *Culex nigripalpus* Theobold. Rpt. 34th Ann. Mtg., Fla. Anti-Mosq. Assn. pp. 31–34.

RATHBURN, CARLISLE B., JR., and ROGERS, ANDREW J. 1961. Tests of insecticides for the control of adult mosquitoes, 1959–60. Rpt. 32nd Ann. Mtg., Fla. Anti-Mosq. Assn. pp. 36–40.

———, and ROGERS, ANDREW J. 1963. Thermal aerosol insecticide tests for the control of adult mosquitoes, 1961–62. Mosquito News 23 (3):218–220.

ROGERS, ANDREW J., BEIDLER, E. J., and RATHBURN, CARLISLE B., JR. 1957. A cage test for evaluating mosquito adulticides under field conditions. Mosquito News 17(3):194–198.

RECENT INVESTIGATIONS ON THE USE OF BHC AND EPN TO CONTROL CHIRONOMID MIDGES IN CENTRAL FLORIDA

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Chironomid midges are a serious nuisance in certain areas of Florida. The principal species, *Glyptotendipes paripes*, becomes so numerous at times that almost all outside activity is prohibited. In the Winter Haven area, several of the lakes that are widely used for recreational purposes produce large numbers of adult midges almost daily from March through November. Many of the lakes have a larval density of 500 or more per square foot in the sandy areas, but usually more than half the lake bottom is covered by muck. Few of the important species of chironomids inhabit this muck area, but *Chaoborus* midges do breed in muck-bottom lakes and appear to be increasing in numbers in several lakes in central Florida.

Of the many compounds tested, only two, BHC and EPN, have been used extensively as midge larvicides. Although each of these chemicals was very successful at the beginning, within a year of their initial applications there were definite indications according to Lieux (1955) that they were no longer effective in certain lakes. Resistance was suspected as reported by Lieux and Mulrennan (1956) but was not substantiated since there is no known method of rearing this species of chironomid or keeping them alive in the laboratory for the time required to establish tolerance levels. Therefore, most of the previous evidence of resistance against these compounds was based on observations of adult midge populations following the application of the insecticide.

BHC was first widely used as a midge larvicide in 1953 but was generally discontinued by 1955 because it was not giving adequate control in certain lakes. However, in a few areas of the state it has been used almost continually with apparent success. This apparent prolonged success of BHC is, however, based purely on observations made by laymen, and is not supported by scientific evaluation of the treatments. EPN was used extensively in lakes at Winter Haven in 1954 but was judged ineffective after 1955 and has been used only sporadically in recent years.

The 1963 investigations were conducted

1963 Rathburn, C. B., Jr., and A. J. Rogers
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THERMAL AEROSAL INSECTICIDE TESTS FOR THE CONTROL OF ADULT MOSQUITOES, 1961–62 [1]

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In 1961 the authors reported on tests with several insecticides applied as thermal aerosols against caged adult *Aedes taeniorhynchus* Wied. (Rathburn and Rogers, 1961). This is a continuing program designed to keep the mosquito control districts of Florida abreast of current developments in this field. The present paper is a report on results of tests conducted during 1961–62.

METHODS. Methods used in these tests were similar to those reported by Rogers *et al.* (1957). All tests were conducted in the early evening hours after sunset on level open areas having little or no underbrush. Two cages of mosquitoes, each containing approximately 25 females, were attached to each stake, one at 6 feet and the other at 2 feet from the ground. The stakes were placed at intervals of 165 and 330 feet downwind from and perpendicular to the line of travel of the fogging vehicle. Each test replicate consisted of the cages from three sets of stakes placed a block (approximately 330 feet) apart or a total of 12 cages.

All tests were conducted with a Leco 80 [2] thermal aerosol generator operated at a burner temperature of 850° F. and calibrated to deliver 40 gallons per hour. The fogging vehicle was driven at 5 miles per hour. Machine operations were checked constantly during the tests and the insecticides were measured before and after each test. Tests in which the output varied more than 6 percent were discarded. The wind velocities at the times the tests were conducted were between 1 and 7 miles per hour and the temperatures between 64° and 81° F.

All mosquitoes used in the tests were between 2 and 8 days old and had been fed only sugar water. After exposure to the fog the mosquitoes were transferred to clean cages. Mortality counts, of female mosquitoes only, were made at 12 hours after treatment.

A variety of factors, including wind and temperature, can affect test results. Owing to the effect of these variables, some paired tests were made using a standard formulation and an unknown on the same night. The average mortality of the standard formulation for many replications is well established, as well as the range of mortality to be expected under a variety of conditions. Thus, from the results obtained with the standard formulation, it was determined whether the tests were conducted under good or poor conditions and whether the results obtained with a candidate formulation were in the higher or lower portion of its range of mortality.

INSECTICIDES. Because thermal fogging with ground equipment is used primarily in urban areas, candidate insecticides for these tests are carefully selected on the basis of their relative toxicity to warm-blooded animals, thus the number of prospective materials is rather limited. Insecticides tested in 1961–62 were DDVP, Dilan, dibrom (Naled) and malathion. A limited number of tests with dibrom included in this report also were included in the 1961 report. Label approval of this insecticide for urban fogging early in 1962 stimulated further testing to refine dosage levels.

RESULTS. Results of the 1961–62 tests are shown in Table 1. Discrete tests are those in which the individual insecticides were tested separately, that is, without comparing results against a standard formulation tested on the same night, as was the case with the paired tests. Percent

[1] Contribution No. 125, Entomological Research Center, Florida State Board of Health

[2] Lowndes Engineering Co.

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mortality is the average combined kill obtained at 165 feet and 330 feet from the line of discharge with a single swath. It is not intended to imply that results reported in this paper would apply to species other than *Aedes taeniorhynchus*.

It is evident from results shown in Table 1 that neither DDVP nor Dilan was effective in these tests, even at relatively high dosage levels. Schoof *et al.* (1962) also reported poor results with DDVP thermal fogs against *Aedes taeniorhynchus*.

TABLE 1.—Results of discrete and paired tests with insecticides applied as thermal aerosols against caged adult *Aedes taeniorhynchus* Wied. 1961–62.

Insecticide	Ounces per gallon [1]	No. of tests	Percent mortality	Range
Discrete tests				
DDVP	4	9	54	6–78
	8	1	20	.
Dilan	8	5	17	4–36
	16	6	15	1–36
Dibrom	1	9	71	56–81
	1¼	18	83	18–99
	1½	10	92	79–100
	1¾	5	96	92–100
Paired tests				
Dibrom	1¼	7	76	36–98
Standard [2]	..	7	97	86–100
Dibrom	1½	5	90	79–100
Standard [2]	..	2	96	95–97
Malathion	6	10	91	72–100
Standard [2]	..	5	87	72–98

[1] Ounces by weight of actual toxicant per gallon in No. 2 diesel oil.
[2] Four oz. by weight of malathion plus 3 percent by volume of Lethane 384 in diesel oil

Dibrom at 1¼ oz. per gallon was less effective than the standard formulation used in the paired tests, and this is supported by the discrete tests at the same dosage level. Dibrom at 1½ oz. per gallon gave good results in the discrete tests and also compared favorably with the standard formulation in the paired tests. Dibrom at 1¾ oz. per gallon was slightly more effective than 1½ oz. per gallon.

Malathion at 6 oz. per gallon proved to be equally as effective as the standard malathion-Lethane formulation. Some tests have been conducted with malathion at lower dosages but the data are not conclusive at this time; therefore, additional testing of this chemical will be required to determine if it can be used effectively at less than 6 oz. per gallon.

The differences in the mortality obtained with the standard formulation are probably due to variations between tests of wind, temperature and other factors. The average mortality obtained with over 50 replications of the standard formulation under a variety of conditions is about 90 percent with a range of about 60 to 100 percent.

DISCUSSION. The conditions of these tests permit maximum opportunity for contact of the test cages by the insecticides, the cage itself being the only barrier. On the other hand, the caged mosquitoes are not free to fly around in the fog as free-flying insects would be, thus increasing the chances for the latter to accumulate a larger dosage of the insecticide. Also, it is not known at this time just what effect overlapping swaths, as in operational fogging, might have in increasing the dosage applied to a given area, or how natural barriers such as buildings and dense vegetation might interfere with effective coverage in actual control operations. However, based upon results obtained in the Florida mosquito control districts over a period of several years, using recommendations based upon this testing program, it is felt that these tests provide a reasonably accurate measure of effective dosage levels for this type of mosquito control operation.

ACKNOWLEDGMENT. The dibrom for these tests was supplied by the Ortho Division, California Chemical Company, DDVP was supplied by Shell Chemical Company, and the Dilan was furnished by the Arizona Fertilizer and Chemical Company. Contributions to this work by all staff members of the Control Research Section of the Entomological Research Center are also gratefully acknowledged.

References

RATHBURN, CARLISLE B., JR., and ROGERS, ANDREW J. 1961. Tests of insecticides for the control of adult mosquitoes, 1959–60. Rpt. of 32nd Ann. Meeting Fla. Anti-Mosq. Assn., pp 36–40.

ROGERS, ANDREW J., BEIDLER, E. J., and RATHBURN, JR., CARLISLE B. 1957. A cage test for evaluating mosquito adulticides under field conditions. Mosq. News 17(3):194–198.

SCHOOF, H. F., ELMORE, JR., C. M., and DUFFY, J. P. 1962. Effectiveness of fog, dust, and mist applications of several organophosphorus compounds against *Aedes taeniorhynchus*. Mosq. News 22(4):329–32.

1961 Davis, A. N., and J. B. Gahan
New Insecticides For The Control Of Salt-Marsh Mosquitoes
Florida Entomologist 44:11-14 (Amvac Ref. #1337)

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1337

NEW INSECTICIDES FOR THE CONTROL OF SALT-MARSH MOSQUITOES

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As malathion was found to be an effective adulticide for salt-marsh mosquitoes, *Aedes taeniorhynchus* (Wied.) and *A. sollicitans* (Wlk.), when dispersed in aerial sprays (Gahan *et al.*, 1956) and ground-generated aerosols (Rogers *et al.*, 1957), it has become the principal insecticide used against these species in Florida. Although there have been no reports that it is less effective now than when first used, efforts are being continued to find other materials that will be even more effective. This paper reports the results that have been obtained during 1959-1960 against these species of salt-marsh mosquitoes with 2 new materials that appear to be superior to malathion, are not highly toxic to warm-blooded animals, and are expected to be commercially available in this country. Included are the results of tests run to evaluate their effectiveness in the laboratory as larvicides and adulticides, and in the field as adulticides.

Bayer 29493 (*O,O*-dimethyl *O*-(4-methylthio-*m*-tolyl) phosphorothioate, marketed in some countries as Baytex) is a brown liquid that has a faint odor. It is soluble in most organic solvents and insoluble in water. Dibrom (1,2-dibromo-2,2-dichloroethyl dimethyl phosphate) is a liquid that is slightly soluble in aliphatic solvents, highly soluble in aromatic solvents, and insoluble in water. The latter compound is stable under anhydrous conditions, but is almost completely hydrolyzed in water within 48 hours.

LABORATORY TESTS AGAINST LARVAE: A series of laboratory tests was conducted to evaluate the effectiveness of these 2 compounds as larvicides. They were compared with malathion and DDT against fourth-instar larvae of a laboratory reared colony of *Aedes taeniorhynchus*. The chemicals were added to 250 ml. of distilled water in glass beakers as solutions in a small amount of acetone. Twenty-five larvae were introduced into each beaker and the mortalities were recorded after 24 hours. Each compound was tested at 5 to 7 concentrations selected to produce a range of mortalities. Two beakers were used for each concentration. The results of these tests are shown in Table 1.

TABLE 1. PERCENT KILL OF SALT-MARSH MOSQUITO LARVAE AFTER 24-HOUR EXPOSURES IN WATER TREATED WITH SELECTED LARVICIDES.

Larvicide	Concentration (p.p.m.) 1	0.1	0.05	0.025	0.01	0.005
Bayer 29493	—	—	—	100	99	48
Malathion	—	92	49	3	0	0
Dibrom	100	84	27	5	0	—
DDT	54	54	32	14	11	10

Bayer 29493 was at least 10 times as effective as any of the other materials. Malathion was superior to Dibrom and DDT, but the differences between malathion and Dibrom were slight. Previous field work with malathion and DDT has shown they are not outstanding larvicides against salt-marsh mosquitoes at the present time. Resistance to DDT has become so extensive that the use of this chemical has been curtailed greatly, and studies by Davis and Gahan (1957) have shown that malathion must be used at dosages above 0.1 pound per acre to produce good control. Although no field larvicide tests have been conducted with Bayer 29493, it appears to be effective enough to provide satisfactory control at low application rates.

LABORATORY TESTS AGAINST ADULTS.—Bayer 29493 and Dibrom were evaluated as contact sprays against adult mosquitoes from the laboratory colony of *Aedes taeniorhynchus*. The insects were exposed to a range of concentrations of each insecticide in a wind tunnel. The wind tunnel consisted of a cylindrical tube 4 inches in diameter through which a column of air was moved at 4 m.p.h. by a suction fan. The mosquitoes in a cylindrical screen cage were placed in the center of the tube. One-fourth milliliter of insecticide solution was atomized at a pressure of 1 p.s.i. into the mouth of the tunnel and the mosquitoes were exposed momentarily to the insecticide as it was drawn through the cage. After treatment the insects were transferred to untreated screen holding cages and furnished a solution of honey in water. The mortalities were recorded after 24 hours. The results of these and similar tests with malathion and DDT appear in Table 2.

TABLE 2.—PERCENT MORTALITY OF SALT-MARSH MOSQUITOES 24 HOURS AFTER TREATMENT WITH VARIOUS INSECTICIDES IN WIND-TUNNEL TESTS.

	Concentration (percent)							
Insecticide	0.5	0.25	0.1	0.05	0.025	0.01	0.005	0.0025
Bayer 29493	—	—	—	—	100	93	65	23
Dibrom	—	—	—	—	100	78	17	2
Malathion	—	—	—	100	100	47	3	—
DDT	91	82	46	23	—	—	—	—

Bayer 29493 was slightly more effective than Dibrom, and about twice as effective as malathion. DDT was about 1/10 as effective as malathion at the LC-50 and 1/28 as effective at the LC-90.

FIELD TESTS AGAINST ADULTS.—Bayer 29493, Dibrom, and malathion were applied to 50-acre plots in citrus groves that were naturally infested with adults of *Aedes taeniorhynchus*. Fuel oil solutions of the insecticides at various concentrations were sprayed from a Stearman airplane flying 100-foot swaths at a speed of 85 miles an hour and an altitude of 50 to 75 feet. All sprays were applied at the rate of 3 quarts per acre, early in the morning under favorable meteorological conditions. Each concentration was tested 3 times.

Control was determined by making pre- and post-treatment counts of the mosquitoes that landed on the front and back of two observers who stood side by side facing in opposite directions at 10 different locations in each of the treated areas. From these counts the number per man per minute was calculated. Post-treatment counts were made after 6 hours. Other observations were made after 24 hours, but by that time mosquitoes had infiltrated from unsprayed areas and the control was below its maximum. The results of these tests are given in Table 3.

TABLE 3.—EFFECTIVENESS OF 3 COMPOUNDS AS AERIAL SPRAYS AGAINST NATURAL POPULATIONS OF SALT-MARSH MOSQUITOES.

Insecticide (pound/acre)		Pretreatment counts	Percent control after 6 hours
Bayer 29493	0.05	66	99
	.025	89	87
	.01	30	61
Dibrom	.05	55	100
	.025	25	99
	.012	53	56
Malathion	.1	103	97
	.05	26	90
	.025	112	41

Bayer 29493 and Dibrom were highly effective, producing 99% reductions at 0.025-0.05 pound per acre. Bayer 29493 also gave 87% control at 0.025 pound per acre. Malathion produced 90% control at 0.05 pound and 97% control at 0.1 pound. Neither malathion nor Dibrom was highly effective at 0.025 pound per acre.

DISCUSSION. Bayer 29493 and Dibrom appear to be safe to use around inhabited areas. According to information furnished by their manufacturers they are less toxic than DDT to warm-blooded animals, but more toxic than malathion. The acute oral LD-50 reported for rats is 310 mg./kg. for Bayer 29493, and 430 mg./kg. for Dibrom. The acute dermal LD-50 of Dibrom on rats is 1,100 mg./kg.

No information is available on the toxicity of Dibrom to fish. The results of this study indicate the chemical is not an outstanding larvicide, so its effects on fish probably will be of no importance in determining whether this insecticide will be used. However, Bayer 29493 shows promise of being a very useful larvicide and its activity against fish is important. Jung (1959) studied the effect of this compound on *Lebistes reticulatus* and found it produced 100% mortality in 48 hours at a concentration of 10 p.p.m. but no mortality in 48 hours at 1 p.p.m. The latter concentration is 100 times that required to kill 99% of the larvae of *Aedes taeniorhynchus*, so it should be possible to select dosages that are effective against these mosquitoes but not dangerous to fish.

If Bayer 29493 and Dibrom can be marketed at a price that will make them competitive with malathion, both can be very useful in adult control operations against salt-marsh mosquitoes. Bayer 29493 also could prove to be a highly effective larvicide.

Summary

Bayer 29493 and Dibrom were more effective than malathion or DDT in laboratory and field tests against adults of *Aedes taeniorhynchus* (Wied.). In field tests both compounds produced 99% reduction within 6 hours at a dosage of 0.05 pound per acre, and Bayer 29493 gave 87% control at 0.025 pound. Bayer 29493 was at least 10 times as effective as any of the other materials in laboratory larvicide tests.

Literature Cited

Davis, A. N., and *J. B. Gahan.* 1957. Field tests with four phosphorus insecticides against salt-marsh mosquitoes in Florida. Mosquito News. 17(3): 180-3.

Gahan, J. B., J. H. Bertholf, A. N. Davis, Jr., and *C. N. Smith.* 1956. Field tests with two phosphorothioates against resistant salt-marsh mosquitoes. Mosquito News. 16(2): 91-3.

Jung, H. F. 1959. A new phosphoric ester residual insecticide with a low order of toxicity. Bull. World Health Organ. 21: 215-21.

Rogers, A. J., E. J. Beidler, and *C. B. Rathburn, Jr.* 1957. A progress report on dosage tests with mosquito adulticides. Mosquito News. 17(3): 190-4.

1961 Rathburn, C. B., and A. J. Rogers
Tests Of Insecticides For The Control Of Adult Mosquitoes, 1959-1960
Proceedings of the Florida Anti-Mosquito Association 36-40 (Amvac Ref. #1338)

TESTS OF INSECTICIDES FOR THE CONTROL OF ADULT MOSQUITOES, 1959-1960

By

Carlisle B. Rathburn, Jr. and Andrew J. Rogers

During the years 1959-60 several new insecticides were tested by the Entomological Research Center as thermal aerosols for the control of adult mosquitoes. Although malathion and Lethane 384 presently are the recommended and most widely used materials for mosquito adulticiding in Florida, research is continuing in order to find a suitable substitute in the event that resistance to malathion develops.

Attention is always directed toward obtaining a less expensive or more effective insecticide for the control of adult mosquitoes. In choosing materials to be tested, consideration is given to mammalian toxicity, mosquito toxicity, cost and ease of formulation. It is felt that for use as a thermal aerosol where people, their food, clothing and dwellings are concerned, mammalian toxicity should be given prime consideration. However, mammalian LD_{50} values alone must not be the sole criterion. Since amounts necessary to give sufficient kill of adult mosquitoes vary, insecticides with low mammalian LD_{50} values may require such high dosages for adequate kill that they become a health hazard, and to the contrary, those with high mammalian LD_{50} values might be used at sufficiently low dosages to control mosquitoes that they would be considered safe for use in populated areas. However, in the latter case, there could be a serious hazard to personnel handling the concentrate.

Thus in testing new insecticides in the field as mosquito adulticides, only those insecticides which have shown some promise in laboratory experiments and which are deemed sufficiently safe to humans at concentrations lethal to mosquitoes are considered.

Chemicals tested were: Korlan 7A, Dow Chemical Company; Hercules 426, Hercules Powder Company; Dibrom, California Spray Chemical Corp.; Bayer 29493, Chemagro Corp.

Davis and Calen (1) previously reported on results with Bayer 29493 and Dibrom. Although their tests were conducted with aerial sprays against natural populations and evaluated by means of landing rates, the results compare favorably with those given here.

Methods

All of the tests described herein were conducted in the field according to previously described methods.(2). In general, the tests were conducted in the

[1] Todd Insecticidal Fog Generator, Todd Shipyards Corp., Brooklyn, N. Y.

early evening hours on level, open areas, with little or no underbrush. Two cages of mosquitoes, each containing approximately 25 females, were attached to a stake, one at the six foot level and the other two feet from the ground. The stakes were placed at intervals of 165 and 330 feet downwind from and perpendixular to the line of travel of the fogging vehicle. Each test or replicate consisted of the cages from three sets of stakes placed a block (approximately 330 ft.) apart, or a total of 12 cages.

All tests, except those of the Dibrom and Bayer 29493, were conducted with a Jeep-mounted TIFA[1] aerosol generator calibrated to deliver 40 gals. per hour at 25 lbs. per sq. in. formulation pressure and operated at a temperature of 1000° F. The tests with Dibrom and Bayer 29493 were conducted with a Leco[2] fogger calibrated to deliver 40 gals. per hour at 13.5 per sq. in. formulation pressure and operated at a temperature of 850° F. In all tests the Jeep was driven at five miles per hour by means of a low-speed speedometer. Machine operations were checked constantly during the tests and the insecticides were measured before and after each test. Tests in which the output varied more than 5% were discarded.

Mortality counts of female mosquitoes were made at 12 hours for all tests and also at 36 hours for Hercules 426 and Korlan 7A.

Results

The results shown in Table 1 are averages of five tests except where noted. Tests of a particular insecticide and dosage were conducted under variations of wind velocity and temperature. Since the wind velocity and temperature probably have some effect upon the resulting mosquito kill, averages for the wind velocities and temperatures are shown.

The average 53 replications with the malathion-Lethane 384 formulation obtained over a period of almost three years is included for comparison.

Dibrom at 1.75 oz. per gallon (approximately .07 lb. per acre) and Bayer 29493 at 1.25 oz. per gallon (approximately .05 lb. per acre) were highly effective in these tests. As shown in Table 1, smaller dosages of these compounds were less effective.

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[2] Lowndes Engineering Company, Valdosta, Ga.

Results with Korlan 7A at 8 oz. per gallon were variable and poor at 12 hours, but were good at 36 hours. Hercules 426 at 8 oz. and 16 oz. per gallon gave variable but generally poor results both at 12 hours and at 36 hour counts.

With the introduction of matathion for use as a thermal aerosol, equipment failures due to the clogging of pumps and strainers from a sludge became a problem. This sludge resulted from the combination of malathion and diesel oil and was not present with either alone. Vartanian, et el. (3), working with several mosquito control districts in Florida, developed an additive (Thiosperse[1]), which, when added to the malathion-diesel oil mixture, eliminated the sludge. Although not a toxicant, it was deemed advisable to test this additive in order to determine its effect upon the formulation and the resulting mosquito kill. A series of tests was conducted consisting of seven replications each, with and without the additive. In the tests with the additive, the recommended 0.25 per cent by volume was added to the standard 4 oz. per gallon malathion + 3% (V/V) Lethane 384 formulation. As shown in Table 2, the additive appeared to have no effect on the resulting mosquito kill.

Discussion of Results

Since the objective of mosquito adulticiding with space sprays is to reduce the mosquito population in a short time, the poor knockdown and kill with Korlan at 12 hours places this material in a poor position for this purpose even though results were good at the 36-hour count.

Both Dibrom and Bayer 29493 showed much promise in these tests but apparently neither of these insecitcdes have yet received label approval for this type of application.

The reason for the higher average kill with Hercules 426 at 8 oz. per gallon (Table 1.) when compared to the kill at 16 oz. per gallon (Table 2.) is not known. Concentrates used in the tests were received in two separate shipments, but the authors have no knowledge that this was a factor in the results.

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1 American Cyanamid Co.

Table 1.

Results of Thermal Aerosol Tests With Several Insecticides Against Adults of *Aedes taeniorhynchus* Wide.

Insecticide	Rate Oz.Gal.	Wind Avg.MPH	Temp. Avg. F.	% Kill-Avg. of 165 + 330 Feet 12 Hrs. Avg.	Range	36 Hrs. Avg.	Range
Dibrom	1.75	3	75	96	92-100	-	-
	1.00	4	79	73	57-81	-	-
Bayer 29493	1.25	3	75	96	94-99	-	-
	1.00	4	79	85	73-97	-	-
	0.50	5	78	69	60-77	-	-
Korlan 7A	8.0	3	71	58	25-100	92[4]	85-100
Hercules 426	8.0	4	70	33	15-58	66[1&4]	49-89
	16.0	2	76	11[3]	2-16	11[3]	3-16
Malathion + Lethane 384	4.0 3% (V/V)	3	71	91[2]	60-100	-	-

(1) Avg. of 4 replications (36 hrs. only)
(2) Avg. of 58 replications.
(3) Avg. of 3 replications.
(4) Uncorrected mortalities - checks were used in only 3 of the 5 replications (36 hrs.only) and averaged 4% mortality.

Table 2.

Results of Field Aerosol Tests Comparing the Standard Malathion-Lethane 384 Formulation With and Without Additive[1] Against Adults of *Aedes taeniorhynchus* Wied.

Additive[1]	Wind	Temp.	% Kill - avg. of 165 + 330 Ft.[2]	
%	Avg. MPH	Avg. ^{o}F	Avg.	Range
0.25	3	68	88	71-97
0	3	68	89	72-98

(1) Thiosperse - American Cyanamid Company

(2) Avg. of 7 replications each

Literature Cited

(1) Davis, A. N., and Gahn, J. B. 1961. New insecticides for the control of salt marsh mosquitoes. Fla. Entomologist 44 (1): 11-14

(2) Rogers, A.J., Beidler, E.J. and Rathburn, C.B., Jr., 1957. A cage test for evaluating mosquito adulticides under field conditions. Mosquito News 17 (3): 194-198.

(3) Vartanian, R.D., O'Neil, J.B. and Fortenbaugh, R. B. 1960. Malathion fogging compositions for use in thermal aerosol dispersal equipment. American Cyanamid Co., Agricultural Division, New York, N. Y.

1961 Joseph, S.R., Berry, R.A. Jr., and L.W. Smith
Some Results on Insecticdes Used As Mist Aprays For Adult Mosquito Control
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153

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SOME RESULTS ON INSECTICIDES USED AS MIST SPRAYS FOR ADULT MOSQUITO CONTROL*

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Since the organization of the Maryland Mosquito Control Project in 1956, the continuing need for data on the effectiveness of adulticide applications in towns and communities has been recognized. With the ever-increasing development of new insecticides, along with the ever-existing potential of resistance developing to old materials, it has also been necessary to keep alert on new insecticides as possible substitutes for currently used mosquito adulticides.

In Maryland, much of the spraying to control adult mosquitoes has been done with mist blowers The mist blower has been used as a necessity arising from the fact that a limited amount of equipment has had to service a considerable number of communities. This required a long working day and spray applications could be made when conditions were unfavorable for fogging. Since mists can be applied under a wider range of weather conditions than fogs, adulticiding has been done mostly with mist blowers.

Using caged adult mosquitoes, two types of tests were used to determine the effectiveness of the various insecticides. Spray applications were made to determine the effectiveness of the insecticides when used in open areas such as fields and lawns as well as in congested communities where houses, trees and shrubbery tend to interfere with the distribution of the spray. In these latter applications some of the caged mosquitoes were placed behind houses where direct mist application was not possible.

Materials

The mist blower used in these tests was the John Bean Rotomist, Model 100-E, mounted on a flat bed, one-ton truck. The blowers were equipped with quadruple nozzles designed to deliver 100 gallons of spray per hour at 400 pounds pressure. All insecticides used were mixed with water directly in the spray tank. The mosquito cages were similar to those described by Rogers et al. (1957) and were made by soldering a screw-cap metal rim of a standard mason jar top to each end of a screen cylinder about six inches long. Mosquitoes for these tests were brought into the laboratory as larvae or pupae and reared as described by Rogers et al. (1957) directly into the cages. The number of mosquitoes per test cage ranged from 15 to more than 200.

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Methods

Cages containing the adult mosquitoes were removed from the rearing jars prior to the test and all dead and moribund mosquitoes were removed at this time. Small pieces of tape were used to mark each cage. The cages were then transported to the test site. For the open-field tests, the cages were placed at 100-foot intervals down wind, at right angles to the spray route, and suspended on metal rods one and four feet above the ground. For the populated area tests, the cages were distributed within the city block at various distances from the perimeter. In the city block tests the maximum distance which any cage was located from the mist blower was about 150 feet. Two control cages were placed some distance away in an unsprayed area during the test.

Prior to the test, the sprayer tank and lines were flushed. Water and insecticide were added to the tank in the desired quantities and mixed thoroughly. Spraying was carried out for several minutes in another area before the test cages were sprayed. The speed of the spray truck at the time of spraying was four miles per hour and the spray was directed downwind in all the open-field tests. Weather conditions, including temperature, wind-velocity, wind direction and relative humidity were reported at the time of each test. After the spray applications the cages were left in position for ten minutes and then transported to the laboraory for mortality counts.

Discussion

Under some conditions, particularly if the wind or air currents were favorable, 100% kills were obtained at a distance of 600 feet, but for practical purposes, good kills cannot be expected beyond 300 feet. For that reason results beyond 300 feet have not been included.

The results of these tests, see table, show that of the three insecticides, BHC, malathion, and DDT (most commonly used in mosquito control work in Maryland) BHC and malathion were, on the average, most effective. Excellent results were obtained in the open-field tests against *Culex pipiens, pipiens L.* and mixed populations of *Aedes sollicitans* (Wlk.) and *Aedes taeniorhynchus* (Wied.) at distances up to 300 feet. BHC at six pounds gamma isomer per 100 gallons gave high mortality of all *C. pipiens* within one hour and complete mortality within four hours. It was only slightly less effective against salt-marsh mosquitoes. This formulation has been widely used in Maryland and still appears to be very effective.

Against salt-marsh mosquitoes, malathion at ten pounds per 100 gallons gave good kills in all cages within one hour and complete kills to a distance of 300 feet within four hours.

DDT was less effective. A concentration of 32 pounds was required for 100% mortality against *C. pipiens* to a distance of 200 feet within one hour. Complete kills were not obtained at a distance of 300 feet with DDT formulations.

Adulticide Tests with Caged Mosquitoes to Evaluate Mist Applications.

Insecticide	Concentration lbs. actual toxicant per 100 gallons	Number of tests	Average % Mortality					
			100 ft.		200 ft.		300 ft.	
			1 hr.	4 hrs.	1 hr.	4 hrs.	1 hr.	4 hrs.
Open - field tests								
DDT	20*	1	20	74	3	16	0	2
	24	1	70	76	34	62	0	0
	32	1	100	100	96	100	14	48
BHC	3 (gamma)	2	15	32	7	15	0	2
	6 (gamma)	2	100	100	97	100	98	100
	6 (gamma)*	1	99	99	76	87	69	97
Malathion	5	2	20	97	6	99	7	99
	10*	1	98	100	88	100	74	100
Dibrom	8	2	100	100	100	100	100	100
	8	1	100	100	100	100	89	91
Bayer-29493	13.6	1	1	100	0	100	0	100
G C - 4072	8	1	83	100	98	100	92	100
Dimethoate	8	1	33	100	20	95	0	11
	8*	1	20	100	2	93	0	85
Trithion	4	1	0	93	1	15	4	15
Control	(28 cages)		0	2				
	(10 cages)*		2	5				
City - block tests								
			50 ft		75 ft.		100 ft	
DDT	20	1	59	73	0	30	0	16
BHC	6	2	100	100	99	100	62	62
Malathion	15	1	100	100	100	100	100	100
Control	(10 cages)		3	6				

*Mixed populations of *A. sollicitans* and *A. taeniorhynchus*. All others *C. pipiens*.

The results from the spray applications made in congested areas, or city block tests, were similar to those obtained in the more open areas. Again BHC and malathion proved to be more effective than DDT. Resistance to DDT has not been considered to be widespread in Maryland and a limited number of tests on *C. pipiens* larvae have shown susceptibility levels well below the resistance level established by the World Health Organization.

Both BHC and malathion have been shown to have a fumigating action in laboratory tests as shown by Ihndris and Sullivan in 1958. In city-block spray applications there was considerable evidence that fumigating action contributed to the effectiveness of BHC and malathion. Under direct exposure or contact DDT sprays were fairly effective at 32 pounds per 100 gallons for killing both *C. pipiens* and mixed populations of *A. sollicitans* and *A. taeniorhynchus*. However, when exposure was not direct DDT was unsatisfactory. On the other hand, BHC and malathion gave good mortalities in the cages protected to some extent by shrubbery, buildings, etc., from the direct currents of the air blasts. DDT at 20 pounds gave an average kill of 59% in one hour at 50 feet and no kill at 75 feet and 100 feet After four hours the average kills were 73%, 30%, and 16% respectively. Two tests using BHC at 6 pounds showed nearly complete kills at 50 feet and 75 feet after one hour and 62% at 100 feet. Results were essentially the same after four hours. Malathion at 15 pounds showed complete kill in all cages to a distance of 100 feet.

In addition to the work with DDT, BHC, and malathion, tests were made to evaluate five other insecticides Some of the more promising were Dibrom, Bayer-29493, and Allied Chemicals' GC-4072. Of these Dibrom, at 8 pounds per 100 gallons, was most effective, producing rapid and complete kills with mixed populations of *A. sollicitans* and *A. taeniorhynchus* up to a distance of 300 feet. Bayer-29493 at 13.6 pounds was slow acting, showing no kill within one hour, but producing a complete kill of *C. pipiens* to a distance of 300 feet within four hours. GC-4072 at 8 pounds gave high kills within one hour and 100% mortality within four hours. Other materials tested included Dimethoate and Trithion. These were somewhat less effective, but showed sufficient promise to warrant additional testing.

References

Ihndris, R. W. and Sullivan, W. N. 1958. Laboratory fumigation tests of organic compounds. Jour. Econ. Ent. 51(5): 638-639.

Rogers, A. J., Beidler, E. J., and Rathburn, C. B. 1957. A cage test for evaluating mosquito adulticides under field conditions. Mos. News 17(3): 194-198.

1961 Mallack, J., Kulp, L.A., Joseph, S.R., and R.A. Berry, Jr.
Dibrom as an Adulticide for Mosquito Control
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148

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DIBROM AS AN ADULTICIDE FOR MOSQUITO CONTROL*

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In the Maryland mosquito control program, which includes over 341 towns and populated areas in 15 counties, mist spraying operations have been used quite satisfactorily. The insecticides most commonly used in these spraying operations are benzene hexachloride and malathion, with limited amounts of DDT. During each year, tests on caged adult mosquitoes are undertaken with these and other insecticides.

There is a three-fold purpose behind these investigations. The first is to continually evaluate their effectiveness. The second is to detect as quickly as possible the development of resistance and the last is to evaluate any promising materials which can be substituted for those now being used in control activities.

The usual procedure for these evaluations includes the testing of insecticides on caged adult mosquitoes in both open fields and in city blocks located in populated communities. This is done primarily to closely approximate conditions normally found in actual routine spraying or fogging operations.

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It was during the 1959 testing program that the excellent potentialities of Dibrom as a mosquito adulticide were found. As a result of these findings additional studies on Dibrom were undertaken in 1960.

These tests were performed in order to determine effective dosages and to obtain information on the relative efficiency of the material when applied with a mist blower, an airplane and a fogger.

Mist Spraying

In the mist spraying work 13 separte tests were made using Dibrom emulsion (8 lbs of toxicant per gallon) at dilutions that ranged from 2.5 to 10.0 lbs. of actual toxicant in 100 gallons of water. The equipment used was a John Bean Model 100-E Rotomist. It was operated so as to deliver 100 gallons per hour at 400 lbs. pressure with a vehicle speed of 4 miles per hour. Except for three tests in which *Aedes taeniorhynchus* were used, all tests were with *Culex pipiens pipiens* L. Adults were obtained by collecting fourth instar larvae which were reared to adults in the laboratory. Adult mosquitoes were placed in marked cages and then quickly transferred to the test site. Here the cages were arranged so as to be 100, 200 and 300 feet from the operating sprayer. There were two cages at each location. One was one foot above the ground level, the other was four feet. Immediately prior to testing, the spray tank was thoroughly washed with clean water. The Dibrom spray was prepared, thoroughly agitated and sprayed for 3 to 5 minutes immediately before testing, in an area far removed from the test site.

The test area was then sprayed and after a period of 3 to 5 minutes, to allow for particle settlement, the cages were collected and returned to the laboratory. Here the cages were held in a large screened enclosure over pans of water, in order to maintain a high humidity. Mortality counts were made at intervals of 1, 4 and 8 hours after spraying. There were two unsprayed controls for each test series

The results (see Table) show that Dibrom has high toxicity, and rapid knockdown. Caged mosquitoes at the 100-foot distance were generally killed at all concentrations which ranged from 2.5 to 10.0 lbs. of toxicant in 100 gallons of water. At distances of 200 and 300 feet dependable results were not obtained at dosages of less than 6 lbs of actual toxicant. For assured results, indications are that the ideal dosage is somewhere near 8 lbs.

Airplane Spraying

One large-scale field test was made to evaluate the effectiveness of Dibrom as an aerial spray for the control of adult salt-marsh mosquitoes (*Aedes taeniorhynchus* and *Aedes sollicitans*). Three cages of mosquitoes were placed on an open golf course ond one cage was located under a cover of trees. Emulsifiable Dibrom at the rate of approximately 0.2 lbs actual toxicant in one gallon of water was applied on each acre. Approximately 400 acres were sprayed and the swath width was about 100 feet.

Table.—Dibrom - 8. Field tests on caged adult mosquitoes.

Concentration (lbs. of actual toxicant per 100 gallons of spray mixture)	Number of tests	Average percent mortality					
		100 feet		200 feet		300 feet	
		1 hr.	4 hr.	1 hr.	4 hr.	1 hr.	4 hr.
10	2	100		100		100	
8	2	100		100		100	
6	2	100		100		58	81
5	3	67	69	72	80	49	59
4	1	100		100		100	
2.5	3	83	91	46	72	4	7
Control - 1	....	0	0	0	0	1	1
Control - 2	....	0	0	0	0	1	1

Excellent results, of a very temporary nature, were obtained from the spraying. Mosquitoes returned to the golf course in annoying numbers after 24 hours. Complete kills (100%) were obtained in the open areas within 20-25 minutes after application. Kills in the cage, given protection under the cover of trees, were almost as rapid. Here 98% were dead within 20 minutes. After 50 minutes, 100% were dead. Mortality in the control cages was 2% after 90 minutes.

Fogging

Eleven tests were made using Dibrom in a fog. Insecticide concentrations that ranged from 1.5 to 12.0 lbs. of actual toxicant in 50 gallons of No. 2 fuel oil were used. The fogging was done with a Todd "Tifa," Series 40-E, fogger mounted on a pickup truck which traveled at the rate of 2 to 3 miles per hour. Landing rate counts and in some cases catches from the Standard New Jersey mosquito light trap were used to evaluate effectiveness. At least three stations were used for landing rate counts with periods of up to 15 minutes for each station. Counts were made the evening before and after fogging. The fogging was always done in the early morning between 6 and 8 a.m.

With a dosage of 12 lbs. of Dibrom in 50 gallons of fuel oil both landing counts and light trap records showed a noticeable reduction of adult mosquitoes. The average reduction for two tests was 81% based on landing counts and 92% based on light trap catches. At the 10-lb. dosage, three tests indicated a 43% reduction on landing counts and 67% on light trap records. An 8-lb dosage showed a 7% reduction in landing rate counts and 29% where light trap records were considered. Tests with dosages of 3 lbs. or less indicated no reduction in mosquito populations. Often the landing counts indicated an increase.

1960 Davis, A. N., J. Salmela, and C. B. Spencer, Jr.
Aerial Spray Tests Against Adult Salt-Marsh Mosquitoes In Florida. – 1959
Proceedings of the New Jersey Extermination Association
47: 92-94 (Amvac Ref. #1336)

1960

(1336)

Mathis, Willis, Christopher Elmore and H. F. Schoof. 1955. Further studies on the chemical control of rice field mosquitoes in Mississippi. Mosq News 15(3): 148-153.
Mitchell, Evelyn Groesbeeck. 1907. Mosquito Life. New York, G. P. Putnams' Sons, 281 pp.
Mulhern, Thomas D. 1940. A summary of mosquito control accomplishments in New Jersey in 1939. Proc. 27th Mtg. N. J. Mosq. Exterm. Assoc. pp 53-91.
———. 1942. A summary of mosquito control work in New Jersey in 1941. Proc 29th Mtg N. J. Mosq. Exterm Assoc. pp. 60-98.
———. 1943. A summary of mosquito control work in New Jersey in 1942 Proc. 30th Mtg. N. J. Mosq. Exterm. Assoc. pp. 133-179.
———. 1944. A summary of mosquito control work in New Jersey in 1943. Proc 31st Mtg. N. J. Mosq. Exterm. Assoc. pp. 72-98.
———. 1946. A summary of mosquito work in New Jersey in 1945. Proc. 33rd Mtg. N. J. Mosq Exterm. Assoc. pp. 89-102, 168-182.
———. 1947. A summary of mosquito work in New Jersey in 1946. Proc. 34th Mtg. N. J. Mosq. Exterm Assoc. pp. 165-181.
Quarterman, K. D., J. A. Jensen, Willis Mathis and William W. Smith. 1955. Flight dispersal of rice field mosquitoes in Arkansas. Jour. Econ Ent. 48(1): 30-32.
Rozeboom, L. E. 1942. The mosquitoes of Oklahoma. Okla. Agr. Exp Sta. Tech. Bul. T-16, 56 pp.
Rutschky, Charles W., Thomas C. Mooney, Jr. and Jerome P. Vanderberg. 1958. Mosquitoes of Pennsylvania. Pa. Agr. Exp. Sta. Bul. 630, 26 pp.
Smith, John B. 1904a. Notes on some mosquito larvae found in New Jersey. Ent. News 15(5): 145-152.
———. 1904b. Report of the New Jersey Agricultural Experiment Station upon the mosquitoes occurring within the State. 482 pp.
Tinker, Milton E. 1956. Personal communication.
Whitehead, F. E. 1951a. Rice-field mosquito control by pellet-borne insecticides. Ark. Agr. Exp Sta. Bul. 511, 30 pp.
———. 1951b. Host preference of *Psorophora confinnis* and *P. discolor*. Jour. Econ. Ent. 44(6): 1019.
———. 1957. Flight range of rice field mosquitoes. Ark. Agr. Exp. Sta. Bul 590, 7 pp.

CARROLL: Thank you, Mr. Darsie. Our next paper, prepared by A. Nelson Davis, Agricultural Research Service, Orlando, Florida, and C. B. Spencer and L. J. Salamela, Brevard County Mosquito Control District, Florida, is to be presented by Mr. Davis. Also, we are going to present at the same time a paper entitled: "New Thermal Aerosol Generator for Dispersing Malathion from a Stearman Airplane." Mr Davis.

AERIAL SPRAY TESTS AGAINST ADULT SALT-MARSH MOSQUITOES IN FLORIDA — 1959

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The use of organophosphorus insecticides in mosquito control is increasing, principally because of the resistance which many species have developed to the chlorinated hydrocarbon insecticides. In Florida, malathion was initiated for general use by mosquito control agencies in 1956, following successful field tests by Gahan *et al.* (1956). After 4 years of extensive use against adults no resistance to this insecticide has been

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[2]Brevard Mosquito Control District.

demonstrated. However, the increasing utilization of malathion enhances the probability of resistance developing in areas where intensified control measures are practiced. In an effort to find other materials that could be substituted for malathion, a large group of chemicals known to be toxic to mosquito larvae were tested in the laboratory against adults of *Aedes taeniorhynchus* (Wied.) (Davis 1959, and unpublished data). Four materials that exhibited high toxicity in the laboratory were compared with a malathion standard in a series of field tests in 1959 against salt-marsh mosquitoes (predominately *taeniorhynchus*).

The tests were conducted near salt marshes in the vicinity of Shiloh, Brevard County. The plots consisted of 50-acre sections of citrus groves. Six plots were selected that offered a minimum of reinfestation from surrounding areas. Four or five of these plots were treated on each of six testing dates while one untreated plot served as a control to measure the natural fluctuation of mosquito densities. The treatments were so arranged that no plot received the same dosage of a material more than once.

The following insecticides were tested as fuel-oil solutions: Bayer 29493 (Baytex; *O*, *O*-dimethyl *O*-(4-methylthio-*m*-tolyl) phosphorothioate). Dibrom (1, 2-dibromo-2,2-dichloroethyl dimethyl phosphate), malathion, and Bayer 22684 (*O*-2-chloroethyl *O*-2, 2-dichlorovinyl *O*-methyl phosphate).

Sevin (1-naphthyl methylcarbamate) was tested in fuel-oil suspensions.

Applications were made with a Stearman (PT-17) airplane flying 80 m.p.h., at an altitude of 50 to 75 feet. This plane was equipped with underwing spray booms and adjusted to disperse 3 quarts of spray per acre at swath intervals of 100 feet. Applications were made during the initial 1½ hours of daylight, under favorable meteorological conditions. Wind velocities varied from less than 1 m.p.h. to occasional gusts up to 10 m.p.h. The flight lines were crosswind over all test plots and marked with smoke released from the end of a 2-inch magnesium pipe 15 to 25 feet above the ground. The pipe was attached to the rear bumper of a truck and connected to the exhaust pipe with a short section of hose. Smoke was obtained by introducing small quantities of fuel oil. under low pressure, into the exhaust manifold of the truck engine. The white smoke produced an excellent marker by which the pilot could align the swaths and aided in obtaining an even coverage of spray.

The relative abundance of mosquitoes the day before treatment and 3. 6. and 24 hours after treatment was determined by counting the number landing on two observers at 10 stations in each plot. The results of these tests are shown in the table.

In general, the maximum reduction was usually observed at 6 hours after treatment, whereas at 24 hours the effect of infiltration from untreated areas was apparent. The infiltration was not uniform in all tests, but none of the materials provided effective residual control at the dosages used. On the basis of the results obtained 6 hours after treatment, TABLE.—*Control of adult salt-marsh mosquitoes with aerial sprays. (Results adjusted for variations in check plots by Abbott's formula. 3 replications.)*

Insecticide and dosage (lb./acre)	Pretreatment count (per man per min.)	Percent control after —		
		3 hours	4 hours	24 hours
Bayer 29493 ....0.05	66	93	99	58
.025	89	77	87	34
.01	30	51	61	42
Dibrom 0.1	55	100	100	61
.05	25	99	99	0
.025	53	56	56	54
Malathion 0.1	103	84	97	75
.05	26	86	90	61
.025	112	44	41	48
Bayer 22684* 0.1	20	99	100	38
.05	74	72	72	21
Sevin** 0.5	99	23	33	25
.25	36	57	55	....

*2 replications
**1 test

satisfactory control was obtained with Bayer 29493, Dibrom, and malathion at 0.05 pound per acre. Bayer 22684 was highly effective at 0.1 but not at 0.05 pound per acre. Sevin was ineffective.

Summary. — Aerial spray tests were conducted against adult salt-marsh mosquitoes, predominantly *Aedes taeniorhynchus* (Wied.), in Florida citrus groves. Six hours after treatment the control exceeded 89% with fuel-oil solutions of Bayer 29493, Dibrom, and malathion. Bayer 22684 was highly effective at 0.1 but not at 0.05 pound per acre. Sevin was ineffective at a dosage of 0.5 pound per acre.

References Cited

Davis, A. Nelson. 1959. Laboratory tests with organic compounds against adult salt-marsh mosquitoes. N. J. Mosquito Extermin. Assoc. Proc. 46: 186-9.
Gahan, James B., J. H. Bertholf, A. N. Davis, Jr., and Carroll N. Smith. 1956. Field tests with two phosphorothioates against resistant salt-marsh mosquitoes. Mosquito News 16(2): 91-3.

CARROLL: Thank you, Mr. Davis. We are a little bit ahead of schedule this morning's meeting and I wonder whether there may be, since we have time for it, any questions from the floor which you would like to direct to any of our speakers. If not I would like to suggest that we devote this bit of extra time that we have to visiting our exhibitors, getting acquainted with our friends in the commercial part of our exhibits. This concludes our morning session. There is, of course, a ladies luncheon and our next session is scheduled for 2 o'clock.

Adjournment