Journal of the American Mosquito Control Association, 11(3):311–314, 1995

EFFICACY OF A 1:1 AND 1:5 MIXTURE OF TECHNICAL PERMETHRIN AND PIPERONYL BUTOXIDE AGAINST *ANOPHELES QUADRIMACULATUS* AND *PSOROPHORA COLUMBIAE*[1]

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ABSTRACT. *Anopheles quadrimaculatus* and *Psorophora columbiae* adults were treated with a 1:1 and 1:5 mixture of technical permethrin and piperonyl butoxide. These mixtures (0.00075 lb AI/acre) at 100, 200, and 300 ft. downwind of application killed a similar ($P \leq 0.05$) percentage of *Ps. columbiae* ranging from 45.1 to 68.8% and 85.7 to 100.0% after 1 and 24 h posttreatment, respectively. Similar results were obtained at 1 and 24 h posttreatment against *An. quadrimaculatus* (0.00075 lb AI/acre) where percentage mortality ranged from 42 to 62% and 63 to 78% after 1 and 24 h posttreatment, respectively. At 24 h posttreatment, significantly more mortality ($P \leq 0.05$) occurred in *An. quadrimaculatus* than in *Ps. columbiae* for both the 1:1 and 1:5 formulations above, except at 100 ft. downwind. A higher dosage against *An. quadrimaculatus* (0.001 lb AI/acre) resulted in a higher mean mortality at 1 h posttreatment (45.1–79.1%) and 24 h posttreatment (59.2–86.0%) than at the lower dosage. A 25% increase in permethrin (0.001 lb AI/acre) vs. a 400% increase in piperonyl butoxide alone gave increases in mortality of 30.4% vs. 8.6%, respectively.

INTRODUCTION

In the rice-growing regions of eastern Arkansas, ultra-low volume (ULV) larviciding with *Bacillus thuringiensis* var. *israelensis* (*B.t.i.*) (Sandoski et al. 1985) and ULV adulticiding, both aerially and ground-applied, with synthetic pyrethroids (Groves et al. 1994) are the most prevalent control practices. Within this region both *Anopheles quadrimaculatus* Say and *Psorophora columbiae* (Dyar and Knab) are considered to be the 2 primary pest mosquito species targeted (Meisch and Coombes 1975).

Two species of caged mosquitoes were subjected to field applications of ULV concentrations of technical permethrin and piperonyl butoxide. Wild populations of adult *An. quadrimaculatus* and *Ps. columbiae* were selected for tests that were conducted at the Rice Research and Extension Center (RREC) near Stuttgart, AR. Caged mosquito tests were conducted to evaluate whether a 1:1 mixture of technical permethrin and piperonyl butoxide had a greater impact upon adult mosquito mortality than did a 1:5 mixture. Differences in mortality among distances and between species were also evaluated. An additional test using only *An. quadrimaculatus* was conducted to examine the effect of a marginal dosage increase upon adult mortality.

MATERIALS AND METHODS

Adult *An. quadrimaculatus* were collected using a backpack aspirator (U.S. Department of Agriculture, Medical and Veterinary Entomology Research Laboratory, Gainesville, FL) from a livestock barn approximately 9 mi. (14.5 km) south of the city of Stuttgart, AR. A biting collection of adult *Ps. columbiae* was made using backpack and hand-held aspirators at the RREC. Both species were then transported to the laboratory. Mosquitoes were anesthetized using CO_2 and transferred to cylindrical screened cages (5.2 × 8.6 cm) (Sandoski et al. 1983). The test cages of adult *An. quadrimaculatus* contained approximately 20 individuals and the cages of adult *Ps. columbiae* contained approximately 10 individuals. All test cages containing adult mosquitoes were then held at room temperature (22°C) and a relative humidity of 40% until just prior to conducting the test.

A single test plot consisting of 3 rows of 3 stakes/row was placed over low, vegetated terrain on the RREC. Rows were separated by approximately 500 ft. and each of the 3 stakes within the rows were 100, 200, 300 ft. downwind from and perpendicular to the spray path. One cage each of adult *An. quadrimaculatus* and *Ps. columbiae* were suspended from each stake within the test plot approximately 5 ft. above ground. Ground ULV applications of 1:1 and 1:5 mixtures of technical permethrin and piperonyl butoxide at 0.00075 lb AI/acre were replicated 3 times on the evenings of August 2 and 3, 1994, between 1900 and 2100 h. An additional test of

[1] This study was completed a part of USDA, CSRS Southern Regional Project S-230 on Riceland Mosquitoes and is approved for publication by the Direction of the Arkansas Agricultural Experiment Station.

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3 replications of technical permethrin and piperonyl butoxide at a slightly higher rate (0.001 lb AI/acre) was conducted on the evening of August 9, 1994.

Chemicals applied on the evenings of August 2 and 3 were mixed 1:49 with mineral oil. Flow rate was calibrated as 9.25 oz./min and mean droplet size was measured as 16.0 μm. Chemicals applied on the evening of August 9 were mixed 1:63 with mineral oil. Flow rate was calibrated as 13.25 oz./min and mean droplet size was measured as 16.0 μm. During all tests conducted on the evenings of August 2 and 3, temperature ranged from 79 to 80°F and wind speed averaged approximately 2 mph and wind direction changed from 160 to 180° azimuth. During tests conducted on the evening of August 9, temperatures ranged from 77 to 80°F and wind speed varied from 2 to 4 mph and wind direction changed from 160 to 180° azimuth. Applications were conducted using an 18-hp Vectec Grizzly® model cold aerosol generator driven at 15 mph with a nozzle pressure of 6 psi for all replications.

Separate treatment cages containing both species of adult mosquitoes were placed 2/stake as described above in the test plots just prior to exposure and allowed to remain for 10 min posttreatment. Control cages were also placed within the test plots and allowed to stand for approximately 10 min and subsequently removed prior to all ULV applications.

After each replication, exposed cages were immediately transported to a holding facility at the RREC where the mosquitoes were anesthetized with CO_2 and transferred to 237-ml paper cups with screen lids. A solution of 10% sugar water was offered in cotton pads placed on the surface of each screen lid. Percent mortality was observed at 1 and 24 h posttreatment.

Percent mortality data were subjected to an arcsine, square root (%/100) transformation and a subsequent analysis of variance (GLM). Means were corrected by Abbott's formula (Abbott 1925) and mean separation was subsequently conducted using Duncan's multiple range test (SAS Institute 1985).

RESULTS AND DISCUSSION

No significant difference ($P \leq 0.05$) in mortality was observed between the 1:1 and 1:5 formulations tested at 0.00075 lb AI/acre against both *Ps. columbiae* and *An. quadrimaculatus* nor were any significant differences observed among distances tested. Against *Ps. columbiae* at both 1 and 24 h posttreatment, mortalities due to the 1:1 and 1:5 formulations were significantly greater than the control, but simi-

Table 1. Two formulations of technical permethrin/piperonyl butoxide (PBO) tested at 3 distances against *Anopheles quadrimaculatus* and *Psorophora columbiae* during August 1994 at the Rice Research and Extension Center.

Date	Species	Time interval (h)	Chemical	Application (lb (AI)/acre)	Control	100 ft.	200 ft.	300 ft.
August 2 and 3	*Ps. columbiae*	1	1:1 Permethrin/PBO	0.00075/0.00075	8.1 b	53.6 a	58.2 a	59.7 a
			1:5 Permethrin/PBO	0.00075/0.00375	8.1 b	68.6 a	59.6 a	45.1 a
August 2 and 3	*Ps. columbiae*	24	1:1 Permethrin/PBO	0.00075/0.00075	18.9 b	85.7 a	98.8 a	97.4 a
			1:5 Permethrin/PBO	0.00075/0.00375	18.9 b	97.3 a	100.0 a	100.0 a
August 2 and 3	*An. quadrimaculatus*	1	1:1 Permethrin/PBO	0.00075/0.00075	3.3 b	48.8 a	42.3 a	44.3 a
			1:5 Permethrin/PBO	0.00075/0.00375	3.3 b	62.4 a	61.6 a	53.7 a
August 2 and 3	*An. quadrimaculatus*	24	1:1 Permethrin/PBO	0.00075/0.00075	3.8 b	63.4 a	63.5 a	76.3 a
			1:5 Permethrin/PBO	0.00075/0.00375	3.8 b	78.8 a	70.9 a	72.6 a
August 9	*An. quadrimaculatus*	1	1:1 Permethrin/PBO	0.001/0.001	1.1 b	83.8 a	76.6 a	77.0 a
August 9	*An. quadrimaculatus*	24	1:1 Permethrin/PBO	0.001/0.001	2.0 b	88.7 a	87.3 a	82.1 a

[1] Means reported from retransformed data analyzed by General Linear Models (GLM). Means not followed by the same letter within rows are significantly different ($\alpha = 0.05$) by Duncan's multiple range test. Within column comparisons for the same time intervals were not significant. Means have been corrected for control mortality according to Abbott (1925).

Table 2. Comparison of 1- and 24-h mortality between *Anopheles quadrimaculatus* and *Psorophora columbiae* at the Rice Research and Extension Center, August 2 and 3, 1994.

Species	Time (h)	Chemical (Permethrin/PBO)	Application rate (lb AI/acre)	Mean percentage mortality[1] (distances downwind)			
				Control	100 ft.	200 ft.	300 ft.
An. quadrimaculatus	1	1:1	0.00075/0.00075	3.3 b	48.8 a	42.3 a	44.3 a
		1:5	0.00075/0.00375	3.3 b	62.4 a	61.6 a	53.7 a
P. columbiae	1	1:1	0.00075/0.00075	8.1 b	53.6 a	58.2 a	59.7 a
		1:5	0.00075/0.00375	8.1 b	68.6 a	59.6 a	45.1 a
An. quadrimaculatus	24	1:1	0.00075/0.00075	3.8 aB	63.4 aA	63.5 aA	76.3 aA
		1:5	0.00075/0.00375	3.8 aB	78.8 bA	70.9 aA	72.6 aA
P. columbiae	24	1:1	0.00075/0.00075	18.9 bB	85.7 bA	98.8 bA	97.4 bA
		1:5	0.00075/0.00375	18.9 bB	97.3 bA	100.0 bA	100.0 bA

[1] Means reported from retransformed data analyzed by GLM. Means not followed by the same letter within columns (lower case) and within rows (upper case) are significantly different ($\alpha = 0.05$) by Duncan's multiple range test. Data were not analyzed across double line. Means have been corrected for control mortality according to Abbott (1925).

lar at all distances tested and between formulations (Table 1). Mortality increases for *Ps. columbiae* at 1 and 24 h between the 1:1 and 1:5 formulations were computed to be 0.6 and 5.1%, respectively (Table 1). Similar results were obtained against *An. quadrimaculatus* where mortality due to the 1:1 and 1:5 formulations was significantly greater than controls, but similar at all distances and between formulations (Table 1). An overall mean increase in percent mortality for *An. quadrimaculatus* from the 1:1 to 1:5 formulations was computed to be 22.6% at 1 h posttreatment, but dropped to 8.6% at 24 h posttreatment.

The additional test against *An. quadrimaculatus* at a higher dosage (0.001 lb AI/acre) yielded no significant difference ($P \leq 0.05$) in mortality between the 2 formulations or at any distance tested (Table 1). However, mean mortalities did increase 34% at 1 h posttreatment and 26.8% at 24 h posttreatment when percent mortalities were compared.

Comparison of mortalities between the 2 species tested during the same time exposure revealed significant differences ($P \leq 0.05$) between species at 24 h posttreatment (Table 2). The primary difference was evident when comparing mortality between species at 24 hours posttreatment. With one exception (100 ft., 1:5 formulation) all mortalities were significantly different between the 2 species tested. No significant differences ($P \leq 0.05$) were observed between the 2 species at 1 h posttreatment. Overall, it would appear that *An. quadrimaculatus* was less susceptible to the permethrin/piperonyl butoxide mixtures than was *Ps. columbiae.*

These tests were conducted at considerably lower dosages than are typically applied in abatement programs in an attempt to determine the efficacy of the 2 permethrin/piperonyl butoxide formulations. Overall, the results imply no significant differences between formulations of technical permethrin and piperonyl butoxide at 1 and 24 h posttreatment. Furthermore, an increase (33.3%) in permethrin (0.00025 lb AI/acre) against *An. quadrimaculatus* resulted in an overall mortality increase (30.4%). In comparison, a 400% increase in piperonyl butoxide only against *An. quadrimaculatus* resulted in a lower overall mortality (8.6%). In addition, *An. quadrimaculatus* appeared to be significantly more tolerant to both chemical formulations tested. Finally, no significant differences were observed among distances in any of the tests conducted. However, control mortalities were always significantly different from all dosage mortalities at all distances tested in all bioassays. Therefore, from a purely economic standpoint, this marginal increase in mortality may not justify the increased cost of using the 1:5 formulation.

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