Journal of the American Mosquito Control Association, 13(4):311–314, 1997

FIELD TRIAL EFFICACY OF TWO FORMULATIONS OF PERMANONE® AGAINST *CULEX QUINQUEFASCIATUS* AND *ANOPHELES QUADRIMACULATUS*[1]

M. V. MEISCH,[2] C. L. MEEK,[3] J. R. BROWN[4] AND R. D. NUNEZ[5]

ABSTRACT. Tests were conducted during the summer of 1996 to evaluate the effectiveness of different formulations of permethrin, Permanone 31–66® and Aquareslin®, against *Anopheles quadrimaculatus* and *Culex quinquefasciatus*. Tests of both formulations were conducted at rates of 2.019 and 3.926 g AI/h with each formulation/rate replicated 3 times. Results indicate significantly greater control of both pest species at the higher application rate for both formulations. The high rate of Permanone 31–66 proved more effective than that of Aquareslin. Exposure at the low rate for both formulations provided inadequate adult control that was particularly pronounced against *Cx. quinquefasciatus*. Regardless, negligible recovery of exposed adults was observed at any formulation/rate. No significant differences in mortality were noted for any formulation/rate relative to distance downwind. However, volume median diameter and droplets/cm^2 were significantly affected by distance downwind. Furthermore, volume median diameter and droplets/cm^2 were both determined to significantly affect mortality in both mosquito species ($P \leq 0.05$). Overall, results indicate that Permanone 31–66 and Aquareslin applied at a rate of 3.926 g AI/h were effective.

INTRODUCTION

Synthetic pyrethroids are essential insecticides for abatement programs to control adult mosquito populations in Arkansas (Groves et al. 1994). Benefits of this class of insecticides include their suitability for ULV application, dramatic reduction in dosage rates, and cost effectiveness. While synthetic pyrethroids have traditionally been used in conjunction with oil dilutents, environmental concerns have heightened interest in other, less ecologically impacting, formulations. As shown by Weathersbee et al. (1986) and Effird et al. (1991), pyrethroids alone provide effective control of mosquitoes associated with the rice-growing region of Arkansas. However, additional investigations are warranted as new formulations are developed. To this end, studies were conducted to: 1) compare the effectiveness of oil and aqueous formulations of permethrin at different application rates and distances from spray path against *Anopheles quadrimaculatus* Say and *Culex quinquefasciatus* Say and 2) evaluate droplets/cm^2 and volume median diameter as related to distance and mortality.

MATERIALS AND METHODS

Trials were conducted in a fallow field at the Rice Research and Extension Center, Stuttgart, AR, on July 23 and 24, 1996. Insecticides were applied using a truck-mounted LECO 1600® ULV fog generator with an 8663 spray head and nozzle. Adulticide was applied at a ground speed of 10 mph (16.1 km/h), with a nozzle pressure of 22.2 N/m^2 and a flow rate of 278 ml/min. Plots consisted of 3 rows of 3 stakes. Rows were separated by a distance of 30.5 m, with stakes within each row located 30.5, 60.9, and 91.4 m downwind and perpendicular to the spray path.

Tests were conducted against *An. quadrimaculatus* and *Cx. quinquefasciatus* using both Permanone 31–66® (permethrin 31% and piperonyl butoxide 66%) and Aquareslin® (permethrin 20% and piperonyl butoxide 20%). Each formulation was evaluated at rates of 2.019 and 3.926 g/ha and replicated 3 times. Tests were conducted on July 23 and 24, respectively, with the application sequence on both dates as follows. The compounds were tested alternately at low and high dosages. After each application, the equipment was flushed and recalibrated. Treatments on July 23 and 24 occurred between 2030 and 2300 h and between 2017 and 2155 h, respectively. Wind during application was less than 1.6 km/h, and relative humidity was 78 to 80% on both dates.

Adult *An. quadrimaculatus* for these tests were collected from a livestock barn in Arkansas County, AR, using a battery-powered backpack aspirator equipped with screened holding cups. Adult *Cx. quinquefasciatus* were collected from septic ditches in East Baton Rouge, LA. Collected mosquitoes were immediately placed in ice chests and transported to the laboratory. Mosquitoes were then anesthetized using CO_2 and transferred to 5.2 × 8.6-cm cylindrical screened treatment cages (Sandoski et al. 1983). Approximately 20 adults were

[1] The opinions and assertations contained herein are the private ones of the writers and are not to be construed as official or reflecting the views of the University of Arkansas, Louisiana State University, the Navy Department and the Naval Service at large, or the city of Stuttgart, AR. Approved for publication by the Director of the Arkansas Agricultural Experiment Station.

[2] Department of Entomology, University of Arkansas, Fayetteville, AR 72701.

[3] Department of Entomology, Louisiana State University, Baton Rouge, LA 70803.

[4] Navy Disease Vector Ecology and Control Center, P. O. Box 43 NAS, Jacksonville, FL 32212-0043.

[5] Director, City of Stuttgart Mosquito Control, 6th and Buerkle City Lot, Stuttgart, AR 72160.

Table 1. Comparison of mortality for 2 permethrin-formulated compounds against *Anopheles quadrimaculatus* applied via ground ULV at 2 application rates in Stuttgart, AR.

Posttreatment time (h)	Formulation	Application rate (g AI/h)	Mean % mortality[1] (distance downwind, m)		
			30.5	60.9	91.4
1	Permanone 31-66	2.019	45.5 aB	55.2 aB	31.8 aC
	Aquareslin	2.019	39.0 aB	18.8 aC	27.6 aC
	Permanone 31-66	3.926	96.1 aA	88.7 aA	88.4 aA
	Aquareslin	3.926	72.1 aA	79.0 aAB	67.2 aB
	Control	—	2.5	7.2	4.2
12	Permanone 31-66	2.019	72.4 aB	63.9 aB	39.3 aC
	Aquareslin	2.019	66.3 aB	33.7 bC	42.9 abBC
	Permanone 31-66	3.926	97.4 aA	90.3 aA	97.4 aA
	Aquareslin	3.926	80.9 aAB	89.0 aAB	72.7 aB
	Control	—	5.7	10.8	6.0
24	Permanone 31-66	2.019	73.8 aB	67.1 aB	42.4 aC
	Aquareslin	2.019	66.6 aB	35.7 bC	44.2 abBC
	Permanone 31-66	3.926	99.2 aA	91.8 aA	96.9 aA
	Aquareslin	3.926	83.0 aAB	87.3 aAB	74.1 aB
	Control	—	5.6	10.6	7.1

[1] Means for each time period not followed by the same letter within rows (lowercase) and columns (uppercase) are significantly different ($P \leq 0.05$) for distance and formulation/rate, respectively.

placed in each treatment cage. Treatment cages were held at room temperature (22°C) and 40% relative humidity in insulated ice chests until just prior to adulticide application.

Control treatment cages were placed on stakes at a height of 1.5 m within the test plot and allowed to stand for 10 min, with subsequent removal to the laboratory prior to ULV applications. Immediately prior to each spray replicate, 1 treatment cage of *An. quadrimaculatus* and 1 cage of *Cx. quinquefasciatus* were hung from each stake in the test plot at a height of 1.5 m above the ground. In addition, slide spinners (John W. Hock Co., P. O. Box 12582, Gainesville, FL 32604) were used to monitor the spray cloud during low-rate tests on July 23. Slide spinners were placed on each stake in the test plot. Prior to each insecticide application, each spinner was equipped with a Teflon® slide for use with Permanone 31–66 (0.69 spread factor) or a MgO_2-coated slide for use with Aquareslin (0.81 spread factor). Approximately 10 min after each application, treatment cages and slides were collected from the test plot and transported to the laboratory. The number of droplets/cm^2 and volume median diameter (VMD) were determined for each slide in the manner described by Brown et al. (1993).

Control and exposed adults were again anesthetized with CO_2 and transferred to labeled clean holding cages (237-ml paper cups with screened lids). Each screened lid was provided with a cotton pad containing 10% sucrose solution for adult maintenance. Mortality for control and exposed adults was observed at 1, 12, and 24 h posttreatment. Mean mortality data were then corrected by Abbott's formula (Abbott 1925), where applicable, and arcsine transformed for subsequent analysis of variance using GLM (SAS Institute 1985). Mean separation and correlation, where appropriate, were determined using LSD and CORR (SAS Institute 1985).

RESULTS AND DISCUSSION

Statistical analysis indicated significantly ($P \leq 0.05$) different permethrin mortality responses for the 2 mosquito species, with greatest mortality observed for *An. quadrimaculatus*. Significant differences in mortality ($P \leq 0.05$) were also observed for each species in relation to permethrin formulation, application rate, and distance from spray path. Reading time was only significant ($P \leq 0.05$) in relation to *An. quadrimaculatus* mortality. In addition, analysis of mortality data for each species indicated a significant ($P \leq 0.05$) 3-way interaction between formulation, application rate, and distance downwind from the spray path.

Permanone 31–66 and Aquareslin application at the high rate was significantly ($P \leq 0.05$) more effective against *An. quadrimaculatus* than application at the low rate for all reading periods (Table 1). This contrasts with the findings of Effird et al. (1991), who noted no significant difference in mortality between high and low rates of Permanone 31–66 at 1 h following exposure. Furthermore, only at a distance of 91.4 m was the high rate of Permanone 31–66 significantly ($P \leq 0.05$) more effective than the high rate of Aquareslin. In addition, the low rate of Permanone 31–66 provided significantly greater mortality than the low rate of Aquareslin at a distance of 60.9 m downwind for all times posttreatment. However, no significant difference in mortality was observed for these low rates at either 30.5 or 91.4 m during any time posttreatment. Significant difference in mortality related to distance

Table 2. Comparison of mortality for 2 permethrin-formulated compounds against *Culex quinquefasciatus* applied via ground ULV at 2 application rates in Stuttgart, AR.

Posttreatment time (hrs)	Formulation	Application rate (g AI/h)	Mean % mortality[1] (distance downwind, m) 30.5	60.9	91.4
1	Permanone 31-66	2.019	25.6 aC	20.5 aB	7.0 aC
	Aquareslin	2.019	33.9 aC	7.9 bB	18.0 abBC
	Permanone 31-66	3.926	97.4 aA	82.0 aA	85.0 aA
	Aquareslin	3.926	71.2 aB	72.8 aA	51.6 aB
	Control	—	0.6	1.4	0.0
12	Permanone 31-66	2.019	43.1 aC	28.0 aB	16.3 aC
	Aquareslin	2.019	33.0 aC	7.9 bB	22.9 abC
	Permanone 31-66	3.926	96.8 aA	83.8 aA	91.6 aA
	Aquareslin	3.926	74.6 aB	78.9 aA	61.2 aB
	Control	—	0.6	2.2	0.0
24	Permanone 31-66	2.019	43.5 aBC	27.0 aB	13.8 aC
	Aquareslin	2.019	28.9 aC	5.8 bB	16.2 abC
	Permanone 31-66	3.926	94.1 aA	80.4 aA	84.6 aA
	Aquareslin	3.926	71.4 aB	70.4 aA	56.6 aB
	Control	—	0.6	3.0	0.0

[1] Means for each time period not followed by the same letter within rows (lowercase) and columns (uppercase) are significantly different ($P \leq 0.05$) for distance and formulation/rate, respectively.

was only observed for the low rate of Aquareslin at 12 and 24 h posttreatment, with the highest mortality observed at 30.5 m downwind. Similar lack of distance effect for low and high rates of Permanone 31–66 was noted by Groves et al. (1994).

Significant differences in mortality ($P \leq 0.05$) were observed among the formulation/rates tested against *Cx. quinquefasciatus* (Table 2). At 1, 12, and 24 h posttreatment, Permanone 31–66 was significantly ($P \leq 0.05$) more effective than all other treatments against *Cx. quinquefasciatus* at distances of 30.5 and 91.4 m downwind. In contrast, Permanone 31–66 and Aquareslin at the high rate were equally effective at a distance of 60.9 m downwind. Results do suggest that the observed significant difference in mosquito species mortality response was a result of the ineffectiveness of low-rate applications of both formulations against *Cx. quinquefasciatus*. During all times posttreatment, only Aquareslin at the low rate caused a significant difference in *Cx. quinquefasciatus* mortality related to distance. In all instances, the highest mortality was observed at 30.5 m downwind from the spray path.

A significant 2-way interaction ($P \leq 0.05$) was determined for mean drops/cm^2 relative to adulticide formulation and distance downwind from the spray path. Additional statistical analysis indicated a negative correlation of Permanone 31–66 and Aquareslin to distance, $\chi^2 = -0.92$ and -0.72, respectively. Permanone 31–66 resulted in significantly more drops/cm^2 than did Aquareslin at distances of 30.5 and 91.4 m downwind, with no statistical difference observed at 60.9 m (Table 3). Significantly more droplets/cm^2 were observed for Permanone 31–66 at a distance of 30.5 m than at either 60.9 or 91.4 m. In contrast, significantly more droplets/cm^2 were determined at both 30.5 and 60.9 m for Aquareslin. Overall, Permanone 31–66 resulted in more drops/cm^2 (127.9) than did Aquareslin (84.7).

Volume median diameter of droplets was observed to significantly vary in relation to both permethrin formulation and distance downwind from the spray path. Volume median diameter of droplets was determined to positively correlate to distance only for Permanone 31–66 ($\chi^2 = 0.72$), with negligible correlation for Aquareslin ($\chi^2 = 0.19$). Permanone 31–66 droplets were significantly larger at a distance of 91.4 m than at distances of 30.5 and 60.9 m. Results of analysis for Aquareslin droplets indicate significantly larger drops at distances of 30.5 and 91.4 m than at 60.9 m. Nevertheless, at all distances, significantly larger droplets were noted for Aquareslin than for Permanone. Curtis and Beidler (1996) determined that 15-μm droplets were significantly more effective than larger or

Table 3. Comparison of volume mean diameter and droplets/cm^2 for 2 permethrin formulations applied at a rate of 2.019 g AI/h at increasing distances downwind from the spray path.

Distance (meters)	Volume median diameter (μm) Permanone	Aquareslin	Droplets/cm^2 Permanone	Aquareslin
30.5	15.7 bB[1]	29.2 aA	150.9 aA	89.8 bA
60.9	15.1 bB	27.3 aB	108.6 aB	100.4 aA
91.4	17.5 bA	29.6 aA	104.8 aB	56.7 bB

[1] Means for volume mean diameter and droplets/cm^2 not followed by the same letter within rows (lowercase) and columns (uppercase) are significantly different ($P \leq 0.05$) for formulation and distance, respectively.

smaller droplets against *Aedes taeniorhynchus* (Weiderman). Our investigation appears to confirm these findings for both *An. quadrimaculatus* and *Cx. quinquefasciatus*. Therefore, the reduced control of both mosquito species observed from Aquareslin exposure may be largely an effect of droplet size rather than an effect of insecticide formulation. However, additional investigations ensuring consistent drop size for all test formulations would be necessary to confirm this hypothesis. Nevertheless, VMD and droplets/cm^2 were both determined to significantly affect mortality in both mosquito species ($P \leq 0.05$).

Overall, results indicate effectiveness of Permanone 31–66 and Aquareslin against both mosquito species when applied at the high rate. Neither formulation applied at the low rate provided adequate control and, in particular, exhibited poor control of the *Culex* species. Results do indicate that formulation, rate, distance, VMD, and drops/cm^2 are all contributing factors influencing mortality and deserve additional investigation.

ACKNOWLEDGMENT

This research was supported in part by a grant-in-aid from AgrEvo Corporation.

REFERENCES CITED

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

Brown, J. R., V. Chew and R. D. Melson. 1993. Temperature and flow rate effects on mass median diameters of thermally generated malathion and naled fogs. J. Am. Mosq. Control Assoc. 9:232–234.

Curtis, G. A. and E. J. Beidler. 1996. Influence of ground ULV droplet spectra on adulticide efficacy for *Aedes taeniorhynchus*. J. Am. Mosq. Control Assoc. 12:368–371.

Effird, 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.

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.

Sandoski, C. A., W. B. Kottkamp, W. C. Yearian and M. V. Meisch. 1983. Efficacy of resmethrin alone and in combination with piperonyl butoxide against native riceland *Anopheles quadrimaculatus* (Diptera: Culicidae). J. Econ. Entomol. 76:646–648.

SAS Institute. 1985. SAS® user's guide: statistics, version 5 ed. SAS Institute, Inc., Cary, NC.

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.