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FIELD TRIAL EFFICACY OF ANVIL 10+10® AND BIOMIST 31:66® AGAINST *OCHLEROTATUS SOLLICITANS* IN DELAWARE

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ABSTRACT. Anvil 10+10® (hereafter Anvil) and Biomist 31:66® (hereafter Biomist) were applied by ground ultra-low volume (ULV) methods to determine the effectiveness of each formulation against *Ochlerotatus sollicitans*. Each formulation was tested at 50, 67, and 100% of respective maximum label dosage rates. Mosquitoes were exposed in cages on a 3 × 3 grid at distances of 30.5, 60.9, and 91.4 m. Mortality data were collected at intervals of 1, 4, and 12 h after treatment. No significant differences ($P \geq 0.05$) were found among formulations at applications of 100% of the label rate and no significant differences ($P \geq 0.05$) were found between Anvil applied at 100% of the label rate and Biomist applied at 50 and 67% of label rates. Ground ULV applications of Anvil at 100% label rate and Biomist at all tested rates were effective (≥95% mortality) adulticides. Applications of Anvil at 50 and 67% label rates were significantly less effective ($P \leq 0.05$) than applications of Biomist at equal percentages of the maximum label rate. Applications of Anvil at rates of 50 and 67% were not effective.

KEY WORDS Adulticide, synthetic pyrethroid, sumithrin, permethrin, *Ochlerotatus sollicitans*

INTRODUCTION

Adulticiding is 1 of 5 components of an effective and responsible mosquito control integrated pest management program (Axtell 1979). In Delaware, 2 major classes of adulticide chemicals are currently used in operational mosquito control—synthetic pyrethroids and organophosphorous compounds. The organophosphate naled is applied by fixed-wing aircraft and synthetic pyrethroids have recently replaced malathion in the truck-mounted ultra-low volume (ULV) adulticiding program. Synthetic pyrethroids have several desirable characteristics, including high target susceptibility (Elliott et al. 1978), quick knock-down (Amdur et al. 1991), reduction in active ingredient per acre (Meisch et al. 1994), short environmental half-life (Hansen et al. 1983), low mammalian toxicity (Kamrin 1997, Ray 1991), low odor, greater public acceptance, and lack of corrosive activity to paints and ferrous metals.

The objectives of this investigation were to conduct statistically valid research on comparative efficacy of Anvil 10+10® (hereafter Anvil; Clarke Mosquito Control Products, Roselle, IL) and Biomist 31:66® (hereafter Biomist; Clarke Mosquito Control Products) for the control of *Ochlerotatus sollicitans* (Walker), a primary pest and vector species in Delaware; and to determine the cost per hectare of each product that achieves satisfactory control. These 2 pyrethroid formulations were chosen for comparative efficacy testing because each possesses a U.S. Environmental Protection Agency (EPA) "general-use" registration that is viewed more positively by many mosquito control districts (MCDs) as compared to "restricted-use" labels for use in public arenas. Additionally, these 2 pyrethroid formulations were selected based upon the dichotomy in active ingredients (and possibilities of efficacy differences), and EPA registration differences for use in aquatic habitats and pasturelands. In turn, individual MCDs should consider not only efficacy data when deciding upon specific pyrethroid formulations but also consider EPA label restrictions and cost when deciding which formulation is best for the specific environments local to their management area. Finally, it should be noted that Anvil is labeled-approved by the EPA at a maximum application rate of 0.0040 kg active ingredient (AI)/ha (0.0036 lb AI/acre), whereas Biomist is labeled at a maximum application rate of 0.0078 kg AI/ha (0.007 lb AI/acre) or a rate 1.94 times higher than the maximum label rate for Anvil. This research compares each chemical formulation based upon percentage of maximum label rate.

MATERIALS AND METHODS

Between August 9 and September 22, 2000, 16 comparable Anvil and Biomist efficacy trials were conducted in 8 test periods in a fallow agricultural field adjacent to the Delaware Mosquito Control Headquarters in Milford, DE. Three replicate tests were performed at the 50% label rate (Anvil, 0.0020 kg AI/ha; Biomist, 0.0039 kg AI/ha) and 3 replicate tests were performed at the 67% label rate (Anvil, 0.0027 kg AI/ha; Biomist, 0.0052 kg AI/ha) for each insecticide. Two replicate tests were performed at the 100% label rates (Anvil, 0.0040 kg AI/ha; Biomist, 0.0078 kg AI/ha). Comparative tests of each insecticide were performed during the same 30-min test period and under similar environmental conditions.

Anvil was diluted 1:1 with Klearol® (Summit Chemical, Baltimore, MD) as recommended by Clarke to best optimize performance and Biomist was diluted 1:2 with Klearol in an effort to maintain comparable flow rates between formulations. Each formulation was applied using 2 Pro-Mist 25HD™

(Beecomist Systems, Telford, PA) electric-rotary spray systems, each calibrated for flow rate and droplet spectrum. Droplet volume median diameter ranged from 13.2 to 15.1 μm for each insecticide and revolution spray head speed was 29,200–30,500 rpm. Spray applications were made at a truck speed of 16 km/h. At the conclusion of each test period, spray systems were flushed with an alcohol-based solvent and recalibrated for flow rate. Each Pro-Mist spray system was dedicated to the research of this project and was not integrated into the daily and general operations of the mosquito control program.

Test plots were designed on a 3 × 3 grid with caged mosquitoes placed 30.5, 60.9, and 91.4 m perpendicular to and downwind from the spray path. Adjacent rows were approximately 30.5 m apart. Adult *Oc. sollicitans* were collected 4–8 h before testing by battery-powered handheld aspirators (Meek et al. 1985) in rural upland–salt marsh interfaces of Kent County, Delaware. Approximately 20 adults were transferred to holding compartments of modified World Health Organization (WHO) cages (Lesser 2001), transported to the test site in coolers. Twenty minutes before testing, adults were transferred from the WHO-cage holding compartment to a 100-mesh wire screen exposure cage with techniques described by Lesser (2001). Experimental treatment cages were hung on 1-m stainless steel poles at each grid point within the treatment plot immediately before insecticide application. Cages were collected 10 min after treatment, and mosquitoes were transferred from the exposure cage to polyvinyl chloride holding cages where mosquito mortality was recorded at 1-, 4-, and 12-h posttreatment intervals. Mosquitoes tested as experimental controls were collected, handled, and transferred within the WHO cage in a manner exactly the same as for the experimental treatment mosquitoes. Controls were hung on stainless steel posts in the test site for 10 min and then removed from the test site; mortality was measured at the 12-h interval. All mosquitoes were presented a cotton ball soaked with 10% sucrose after treatment. Within each of the 8 test periods, ambient temperature ranged from 15.6 to 27.8°C and local ground-level winds ranged from 1.6 to 8.0 km/h.

Observed treatment mortality data were corrected for control mortality with Abbott's formula (Abbott 1925), arcsine transformed, and subjected to analysis of variance determination with the General Linear Models program (GLM; SAS Institute 2000); mean separation was determined by the Waller–Duncan *K*-ratio *t*-test (SAS Institute 2000).

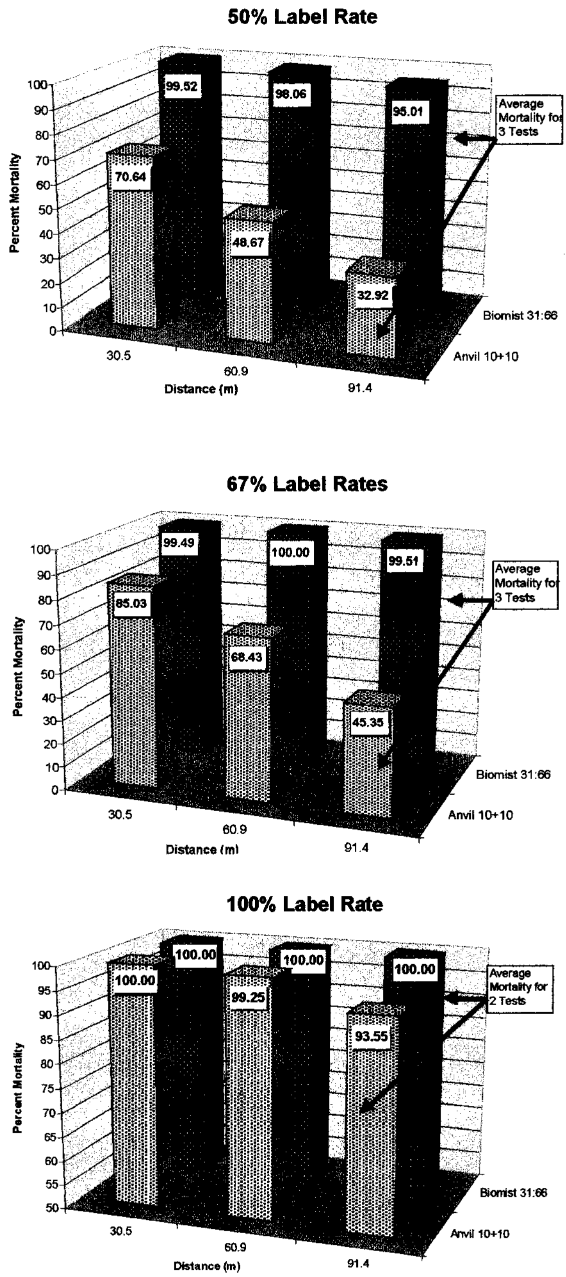

Fig. 1. Spatial efficacy of Anvil 10+10 and Biomist 31:66. Application rates are indicated within the graphics. All mortality data were observed at 12 h after chemical application.

RESULTS AND DISCUSSION

Comparisons among formulations, within and among application rates

Efficacy comparisons between Anvil and Biomist applied at the 100% label rate were not significantly different ($P \geq 0.05$) at 12-h postapplication intervals and only slight differences were found in initial (1- h) knockdown rates (Table 1). No significant differences ($P \geq 0.05$) were found between Anvil applied at 100% label rate and Biomist applied at 50 and 67% label rates at all distances and time intervals. Significant differences ($P \leq 0.05$) were found in 12-h efficacy comparisons of Anvil and

Table 1. Average and comparative percent mortality of 2 synthetic pyrethroids tested at 3 distances in multiple trials[1] on *Ochlerotatus sollicitans* in August–September 2000 by the Delaware Mosquito Control Program.

Post-treatment time (h)	Formulation	Application rate (% of maximum label rate)	Mean % mortality[1] (distance downwind, m)		
			30.5	60.9	91.4
1	Anvil 10+10	100	88.5 aAB	81.9 aAB	76.5 aC
	Biomist 31:66	100	100 aA	99.3 aA	100 aA
4	Anvil 10+10	100	100 aA	99.3 aA	93.6 aABC
	Biomist 31:66	100	100 aA	100 aA	100 aA
12	Anvil 10+10	100	100 aA	99.3 aA	93.5 aABC
	Biomist 31:66	100	100 aA	100 aA	100 aA
	Control[2]	—	4.0	4.0	Na
1	Anvil 10+10	67	45.9 aE	42.7 aE	25.6 aDE
	Biomist 31:66	67	98.0 aAB	97.5 aAB	93.1 aBC
4	Anvil 10+10	67	82.3 aCD	60.5 bCD	43.9 cD
	Biomist 31:66	67	99.5 aAB	100 aA	99.5 aA
12	Anvil 10+10	67	85.0 aC	68.4 bC	45.4 cD
	Biomist 31:66	67	99.5 aAB	100 aA	99.5 aA
	Control[2]	—	2.7	13.3	2.7
1	Anvil 10+10	50	53.9 aE	37.0 aE	22.0 bE
	Biomist 31:66	50	96.1 aB	91.7 aB	88.6 aBC
4	Anvil 10+10	50	71.5 aDE	48.5 bDE	34.4 bDE
	Biomist 31:66	50	99.5 aAB	97.6 aAB	94.1 aAB
12	Anvil 10+10	50	70.6 aE	48.7 abDE	32.9 bDE
	Biomist 31:66	50	99.5 aAB	98.1 aAB	95.0 aBC
	Control[2]		10.7	9.3	4.0

[1] Reported means were retransformed and analyzed by General Linear Models (GLM). Means not followed by the same letter within rows (lowercase) and columns (uppercase) are significantly different (α = 0.05) as determined by the Waller–Duncan *K*-ratio *t*-test. Reported mean experimental mortality is an average of 9 replicates (3 trials with 3 replicates per trial) for tests determining efficacy of each formulation at the 50 and 67% label rates and 6 replicates (2 trials with 3 replicates per test) for tests determining efficacy at respectively 100% label rates.

[2] Reported mean control mortality is an average of 3 replicates per distance.

Biomist when each was applied and tested at the 50 and 67% label rates. These significant efficacy differences were observed between formulations at all test distances and at all time intervals, with Biomist providing significantly greater mortality than Anvil.

Temporal efficacy: Comparisons of Anvil and Biomist found very slight differences ($P \leq 0.05$) in temporal efficacy at 1-, 4-, and 12-h intervals when each was applied at 100% label rates. Significant differences ($P \leq 0.05$) in temporal efficacy were found in comparisons of Anvil and Biomist when each was applied at the 50 and 67% label rates. In these comparisons, mortality due to Biomist was significantly higher in all postapplication time intervals and significant differences ($P \leq 0.05$) were found in the initial 1-h rate. Analysis of the data presented in Table 1 indicates that mortality due to Biomist is generally observed within 1 h of pesticide application, whereas mortality due to Anvil is generally observed at 1–4 h when applied at 50 and 67% of the maximum label rates. Therefore, despite the inherent chemical similarities of Anvil and Biomist active ingredients as well as similarities in mode of action, analyses of these data demonstrate that Biomist is a faster-acting insecticide than Anvil at comparable label rate applications. Similar temporal efficacy results to those reported here have been found in Florida in sumithrin–permethrin comparative tests on *Ochlerotatus taeniorhynchus* (Wiedemann) and *Culex quinquefasciatus* (Say) (Dukes, personal communication).

Spatial efficacy: At 12 h after application, Biomist was found to elicit 95% or greater mosquito control at all application rates and at all test distances, whereas Anvil was found to elicit the same control only at the 100% label-rate application and at 30.5- and 60.9-m test distances (Fig. 1).

Comparisons within formulations, within and among application rates

Anvil: The Delaware Mosquito Control Program considers an adulticide to be an effective control agent when 95% or more of the target mosquito population is killed in field bioassays or highly controlled operational field tests (Meredith, personal communication). By this standard, Anvil applied at 100% of label rate was demonstrated to be an effective adulticide. Conversely, Anvil applied at 50 and 67% of label rate was demonstrated to be ineffective. Results of analyses of mortality vs. distance were not significantly different ($P \geq 0.05$) at 100% rates. However, significant differences in distance-related mortality were found when Anvil was applied at 50 and 67% label rates.

Highest mortality was observed in caged mosquitoes nearest the point of chemical release. Finally, comparisons of 12-h efficacy among all 3 application rates found significant differences ($P \leq 0.05$) in mortality vs. application rate and these efficacies ranged from 32.9 to 100%.

Biomist: Biomist was demonstrated to be an effective mosquito-control adulticide at all 3 rates tested. Within application rates, no significant differences ($P \geq 0.05$) in mortality vs. distance were observed at any of the 3 application rates tested. In addition, comparisons of 12-h efficacy among all 3 application rates tested found very slight differences in mortality vs. application rate (mortality ranged from 95.0 to 100%).

Cost–benefit analysis

Overall, results of this research indicate that Anvil, when applied at the 100% label rate, is an effective adulticide (mortality > 95%) and possesses performance characteristics similar to that of Biomist applied at the 50, 67, and 100% label rates. Additionally, application of Anvil at 50 and 67% of maximum label rates was ineffective for control of *Oc. sollicitans* in Delaware. Performance characteristics of Biomist did not vary significantly with application rate and results indicate that Biomist was an effective adulticide at all 3 test application rates. Therefore, the cost–benefit analysis should compare the application of Anvil at the 100% label rate vs. Biomist at the 50% label rate because mosquito control efficacy is similar. Based on the cost of each product in Delaware in 2000, cost–benefit analysis favors Biomist by a factor of 2.18 times. Additionally, research and cost–benefit analysis performed by Groves et al. (1995) found that 1:1 permethrin and piperonyl butoxide dilution ratios are favorable over higher synergistic dilution ratios. Therefore, analysis of Anvil vs. another mosquito adulticide with a 1:1 permethrin to piperonyl butoxide ratio may show a greater cost–benefit effectiveness of permethrin vs. sumithrin.

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