FIELD EVALUATION OF ALIPHATIC AMINES AGAINST IMMATURE MOSQUITOES

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ABSTRACT. Ground application of 0.5 lb/A of Alamine 11 [oleyl (primary) amine], Armeen L-15 [Beta-RNH_2 primary beta amine (15 carbons)], and Duomeen L-15 [Beta RNH $(CH_2)_3$ NH_2 (Beta-diamine) 15 carbons] yielded good control of larvae and pupae of the mosquito *Culex tarsalis* Coquillett and *C. peus* Speiser in experimental ponds and seepage breeding sources. The same rate of Alamine 11 controlled larvae and pupae of *Aedes nigromaculis* Ludlow, while Duomeen L-15 and Armeen L-15 suppressed the larvae completely and caused 83 and 90 percent reduction in pupae, respectively. At a higher rate (1.0 lb/A) the 3 materials were highly active against both larvae and pupae. Aerial application of aliphatic amine formulations applied as low volume in petroleum oils failed to produce satisfactory control of *A. nigromaculis* Ludlow larvae in irrigated pastures at the rate of 1.0 lb/A.

INTRODUCTION

In earlier studies, several aliphatic amines showed good activity against larvae and pupae of *Culex pipiens quinquefasciatus* Say in the laboratory (Mulla 1967a, 1967b). In further laboratory evaluation, these materials also showed good activity against larvae and pupae of *Anopheles albimanus* Wiedemann, *Aedes aegypti* Linnaeus and *Ae. nigromaculis* Ludlow. The most promising materials were some of the quaternary ammonium salts, primary alkyl amines, diamines, beta amines and beta diamines (Mulla et al. 1970).

An. albimanus larvae, fully resistant to dieldrin and moderately resistant to DDT, showed little tolerance to aliphatic amines. One insecticide resistant strain of *C. p. quinquefasciatus* showed a low level of cross-tolerance to certain groups of the amines due to vigor tolerance (Georghiou et al. 1969). There was no cross-tolerance to aliphatic amines in the organo-phosphorus resistant strains of *Ae. nigromaculis* (Georghiou et al. 1969, Mulla et al. 1970).

Preliminary field evaluation of some of the aliphatic amine formulations in petroleum oils was promising. Excellent results were obtained with Duomeen L-15 (5%) in petroleum oil (Toxisol FLC), at 0.5 lb/A applied to experimental ponds; however, Armeen L-15 (24%) in the same solvent applied at 0.5 lb/A failed to control larvae of *Culex tarsalis* Coquillett (Mulla and Darwazeh 1971). In preliminary field evaluations, solvents and surfactants were found to play an important role in influencing the toxic effects of the amine formulations against mosquito larvae and pupae.

The studies reported here were initiated to determine the most suitable formulations of promising aliphatic amines and to determine satisfactory rates of application.

MATERIALS AND METHODS

Technical grade materials were formulated in petroleum oils at 25–50% concentration plus 1% surfactant such as Polytergent B-200 (Olin Mathieson Chem. Corp.), AG-1256 (Atlas Chem. Industries, Inc.), Triton N-101 (Rohm and Haas Co.), and AG3-30 (Witco Chem. Co.). Petroleum oils utilized in the formulations included Toxisol FLC, Toxisol TB, Toxisol JA (Atlantic Richfield Co.), Sunland Automotive Diesel and Skelly B. Aliphatic amines tested were: Adogen-462 (Dimethyl dicoco ammonium chloride), Alamine 11 [Oleyl (primary) amine], Alamine 21 (N-Coco-1, 3-propylene diamine), Aliquat 204 (Dimethyl dilauryl ammonium chloride), Aliquat 221 (Dimethyl dicoco ammonium chloride), Aliquat 336 (Methyl tricapryl ammonium chloride), Armeen L-15 (Beta-RNH_2 primary beta-amine 15 carbons), Diam 21 (N-Coco-1,

3-propylene diamine), Duomeen L-15 [Beta $RNH(CH_2)_3 NH_2$ (Beta diamine) 15 carbons], Isothan DL-1 (Dimethyl dialkyl ammonium bromide).

Some of these materials were evaluated against larvae and/or pupae of various species and in a wide range of habitats. Locations and methods of application were as follows:

EXPERIMENTAL PONDS. Detailed descriptions of these facilities in Kern County were given by Hurlbert et al. 1970. Prevailing mosquitoes were *Culex tarsalis*. The required amount of toxicant formulation was mixed with 1000 ml of water and applied with a ½-gal handsprayer. Each rate was replicated twice, and 4 ponds were used as checks. Experience has shown that the solvents used in these amounts do not cause reduction in larvae and pupae. Two of the checks were left untreated, and the other two were treated with the solvent utilized in the aliphatic amine formulations. Ten dips were taken per pond prior to and 24 hours after treatment for larval and pupal assessment.

FIELD PLOTS. Natural mosquito breeding areas were divided into plots, ranging in size from 1/32 to 1/16 A. Mosquito species and a description of the type of location utilized are included in Tables 1–5. The formulated materials were mixed with (500–1000 ml) of water and applied with a ½-gal handsprayer. Ten to 15 dips per plot were taken prior to and 24 hours after treatment for larval and pupal assessment. Each rate was replicated twice, and 2 plots (check) in each test were treated with the solvent utilized in the formulation.

AERIAL APPLICATION. Tests were conducted in Rancho Santa Maria (Smith Pasture) in Kern County California. Materials were applied with a CalAir A-9B plane at the rate of 16 and 32 oz/A of 50% aliphatic amine concentrates in petroleum oils.

Three flagmen, one in the middle and one at each end of the plot, were used to insure line of flight. One plot was used for each rate, and the check plot was treated with the solvent alone at the high-

Table 1. Effectiveness of aliphatic amines dissolved in Toxisol TB plus Polytergent-B200 surfactant (1%) against larvae of *Culex tarsalis* in experimental impoundments (Kern County).

Material (%)	Rate lb/A	No. of larvae/10 dips		(%) reduction
		Pretreat	Post-treat	
Duomeen L-15 (25)	0.25	47	5	91
	0.50	29	0	100
	1.00	20	0	100
Armeen L-15 (25)	0.25	42	20	52
	0.50	20	0	100
	1.00	120	5	96
Diam-21 (50)	0.25	12	23	0
	0.50	50	11	78
	1.00	66	13	80
Aliquat-204 (50)	0.25	54	44	19
	0.50	25	13	49
	1.00	43	18	63
Isothan DL-1 (50)	0.25	34	30	12
	0.50	65	38	42
	1.00	44	20	55
Aliquat-336 (50)	0.25	45	24	47
	0.50	27	3	89
	1.00	30	3	90
Check	..	32	54	0

est rate used (32 oz/A). The mosquito population consisted of fourth-stage larvae (no pupae) of *Aedes nigromaculis*. Fifty dips were taken per plot before and 24 hours after treatment.

In all tests the average numbers of organisms (larvae and/or pupae if present) per dip or 10 dips are presented. Percent reductions were calculated from the post- and pretreatment counts in each treatment. Where pupae were present their numbers were combined with larvae for computation. Figures were rounded, but the % reduction was calculated on the original numbers. The extent of reduction in larvae and pupae can be seen from the pre- and post-treatment figures in the tables for each treatment and the check. Pupal populations will increase with the progression of development.

RESULTS AND DISCUSSION

Duomeen L-15 and Armeen L-15 in Toxisol TB controlled larvae of *Culex tarsalis* in experimental ponds at the rate of 0.5 lb/A active within 24 hours (Table 1). Diam-21, Aliquat-204, Isothan DL-1 produced incomplete control at the rate of 1.0 lb/A, while Aliquat-336 produced 90 percent reduction of larvae.

The above formulations of Duomeen L-15 and Armeen L-15 tested in another area proved less effective against larvae and pupae of *C. tarsalis* in 1/32 acre field plots (Table 2). Failure of these materials to yield complete control is attributed to poor coverage. Mosquito larvae and pupae were concentrated in puddles under dense vegetative growth which hindered penetration. As indicated in previous studies, these materials performed well against larvae of the same species of mosquitoes in plots where water was continuous.

Both formulations of Armeen L-15 in Toxisol TB and Toxisol FLC were equally effective against fourth-stage larvae of *C. peus* Speiser at the rate of 1.0 lb/A (Table 3). Poor results, however, were obtained with Duomeen L-15 in Toxisol FLC. The Duomeen L-15 plots were adjacent to the untreated area (check); therefore, water movement created by wind may have caused some of the material to drift beyond the test plot, leaving an insufficient amount of toxicant for complete larval control.

Complete control of larvae of *Aedes nigromaculis* was not achieved with Duomeen L-15 and Armeen L-15 formulated in Toxisol JA and applied at the rate of 1.0 lb/A. Toxisol JA appears to elicit

Table 2. Effectiveness of aliphatic amines (25%) in Toxisol TB plus Polytergent B-200 surfactant (1%) against larvae and pupae of *Culex tarsalis* in seepage water[a] (Arvin, Calif.).

Material	Rate lb/A	No. larvae and pupae/10 dips				(%) reduction
		Pretreat		Post-treat		
		L	P	L	P	
Alamine-11	0.25	35	17	16	9	51
	0.5	61	30	21	17	58
Duomeen L-15	0.25	96	22	50	16	31
	0.50	32	16	2	3	90
	1.00	7	15	0	0	100
Armeen L-15[b]	0.25	7	12	0	1	95
	0.50	52	22	10	7	77
	1.00	14	17	2	6	74
Check	..	12	5	11	6	0

[a] Test conducted in (1/32) acre plots.
[b] Erratic results due to inadequate coverage. Plots consisted of puddles of water. Water in other plots continuous.

Table 3. Effectiveness of aliphatic amines (25%) in petroleum oils plus Polytergent B-200 surfactant (1%) against larvae of *Culex peus* in seepage water[a] (Corona, Calif.).

Material	Solvent	Rate lb/A	No. larvae/dip		(%) reduction
			Pretreat	Post-treat	
Duomeen L-15	FLC	0.5	42	8	81
		1.0	21	7	67
Armeen L-15	FLC	0.5	26	1	97
		1.0	21	0	100
Armeen L-15	TB	0.5	4	1	75
		1.0	11	0	100
Check	...	...	7	9	0

[a] Plots size 1/32 acre.

better performance to Armeen L-15 than to Duomeen L-15 (Table 4). Armeen L-15 produced 94 percent mortality at 1.0 lb/A, compared with 60 percent obtained with Duomeen L-15. Other materials showing poor performance against larvae and pupae of *A. nigromaculis* at 1.0 lb/A were: Aliquat 204 in Toxisol TB and Diam-21 in Skelly B. These formulations were evaluated in the Fresno Municipal Farm System, where sewage water was used for irrigation (data not presented).

Alamine-11 in Toxisol TB produced complete larval and pupal mortality of *A. nigromaculis* at the rate of 0.5 lb/A (Table 5). At the same rate, Duomeen L-15 and Armeen L-15 in the same solvent produced high mortality of larvae and pupae. These three materials were highly effective against larvae and pupae at the rate of 1.0 lb/A. At this high rate, Alamine-11, Isothan DL-1, Duomeen L-15, and Diam-21 formulated in Sunland Automotive Diesel produced 92, 89, 87, and 75 percent mortality, respectively.

Aerial applications of various aliphatic amines formulated in Toxisol TB and Toxisol JA (applied as low volume treatments) failed to control larvae of *A. nigromaculis* in irrigated pastures when applied at the rate of 16 oz and 32 oz of (50%) concentrates per acre (Table 6). Concentrates (25% active and 1% Triton N-101) of Diam-21, Adogen 462 and Aliquat 204 in Toxisol JA and applied at the rate of 64 oz volume per acre did not control larvae of *A. nigromaculis* (data not presented).

It is apparent that some of these materials such as Duomeen L-15, Armeen L-15 and Alamine-11 formulated in Toxisol TB, although performing well elsewhere, gave poor control of *A. nigromaculis* by aerial application at the rate of 1.0 lb/A

Table 4. Effectiveness of aliphatic amines (25%) in Toxisol JA plus Polytergent B-200 surfactant (1% against larvae of *Aedes nigromaculis* in irrigated pastures.[a]

Material (%)	Rate lb/A	No. of larvae/10 dips		(%) reduction
		Pretreat	Post-treat	
Duomeen L-15	0.25	70	47	33
	0.50	80	90	0
	1.00	60	24	60
Armeen L-15	0.25	48	13	73
	0.50	50	5	90
	1.00	45	3	94
Check	..	66	70	0

[a] Plots size 1/32 acre. Applied by hand sprayers.

Table 5. Effectiveness of aliphatic amines in petroleum oils plus Polytergent B-200 surfactant (1%) against larvae and pupae of *Aedes nigromaculis* in irrigated pasture[a] (Rancho Santa Maria, Kern County, Calif.)

Material	Conc. (%)	Solvent	Rate lb/A	Avg. no larvae and pupae/dip: Pretreat L	Pretreat P	Post-treat L	Post-treat P	(%) reduction
Diam-21	50	Sunland	0.50	5	0	4	2	0
		Diesel	1.00	43	0	8	4	75
Duomeen L-15	50	"	0.50	58	0	7	5	80
			1.00	29	1	2	2	87
Alamine-11	50	"	0.50	13	0	3	3	54
		"	1.00	97	0	5	3	92
Isothan DL-1	50	"	0.50	20	1	4	6	51
			1.00	62	0	8	4	89
Armeen L-15	25	Toxisol	0.25	58	100	2	56	64
		TB	0.50	24	48	0	5	94
			1.00	17	112	0	0	100
Duomeen L-15	25	"	0.25	24	49	1	12	83
			0.50	13	36	0	6	88
			1.00	20	27	0	0	100
Alamine-11	25	"	0.50	6	18	0	0	100
			1.00	10	14	0	0	100
Check	..	..	..	5	0	2	4	0

[a] Test conducted in 1/16 acre field plots.

Table 6. Aerial application of aliphatic amines (50%) in Toxisol TB containing (1%) surfactant (Polytergent B-200) for the control of larvae of *Aedes nigromaculis* in pasture (Rancho Santa Maria, Kern County, Calif.).

Material	Rate/acre (oz)	Rate/acre lb/A	No. of larvae/10 dips: Pretreat	Post-treat	(%) reduction
Armeen L-15	16	0.5	100	46	54
	32	1.0	227	41	82
Alamine-11	16	0.5	217	54	75
	32	1.0	223	57	74
Alamine-21	16	0.5	69	17	75
	32	1.0	73	47	36
Aliquat-336	16	0.5	127	46	64
	32	1.0	148	43	71
Duomeen L-15	16	0.5	125	46	63
	32	1.0	173	72	58
Aliquat-221	16	0.5	47	40	15
	32	1.0	87	36	59
Check	64	...	10	11	0

active. Failure of these materials to yield adequate control of larvae by aerial application may be attributed to poor coverage and lack of penetration. It was also noted that the concentrate formulation after reaching water jelled, producing curdy precipitations in the water. Also, the formulations applied by air did not reach larval pockets beneath grass clumps.

The aliphatic amines, with their unique mode of action (Mulla 1967b) and novel chemical structure, offer additional new tools for the control of resistant and susceptible mosquitoes. Further studies to develop effective and practical formulations for larval and pupal control should be rewarding.

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NOTICE

The VIIIth congress of the German Society of Tropical Medicine will be held in Hamburg from October 8th to October 11th, 1975, in connection with the 75th anniversary of the "Bernhard-Nocht-Institut für Schiffs- und Tropenkrankheiten".

Main subjects of the Congress:

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