THIRD AND SECOND SEASON EFFECTIVENESS OF MOSQUITO LARVICIDE RESIDUALS AND FURTHER TRIALS OF GRANULAR DIELDRIN, HEPTACHLOR, AND DDT AT MINIMAL DOSAGES *

V. I. MILES

Field trials were initiated in 1956 at Chinook, Montana to evaluate the effectiveness of single preflood and post-flood applications of selected residual larvicides for controlling irrigation mosquitoes. Dieldrin, heptachlor, and DDT applied to plots early in the summer of 1956 as water emulsions and granular formulations at rates of 1.0, 1.5 and 3.0 pounds of toxicant per acre, respectively, gave essentially complete control of irrigation mosquitoes throughout the season (1). Second-season observations showed effective control throughout the 1957 season on 5 of 6 dieldrin plots, 1 of 3 heptachlor plots, and 1 of 2 DDT plots; and granular dieldrin applied in the spring of 1957 at 0.5 pound toxicant per acre provided complete control throughout the first (1957) season (2). Limited floodings of several of the experimental plots during both seasons and termination of mosquito production in the fall of 1957 precluded determination of the complete duration of larvicidal effectiveness. The present paper concerns observations continued in the 1958 season and further trials of granular dieldrin, heptachlor, and DDT at minimal dosages as preflood and post-flood residual larvicides.

The methods used in larvicide treatments and mosquito evaluations in 1956 and 1957 are given in the two references cited. Observations were made in 1958 on one treated plot that was not flooded during the two previous seasons, 3 plots that previously produced no more than 0.1 mature larvae per dip, and 14 plots on which no mosquito production occurred following treatment. As during previous seasons, both treated and untreated check plots were sampled for mosquito larvae twice each week when flooded. Sampling of treated plots was discontinued when the number of mature larvae and pupae present exceeded that of untreated check plots, indicating that the insecticidal treatments were no longer effective.

The third-season results from plots treated in 1956 are given in Table 1. No mature larvae were found on the single DDT plot during the 1958 season; however, this result is not conclusive in view of the fact very few larvae were found on the untreated check plot for this habitat type. Mature larvae were found on both heptachlor plots during their first floodings in 1958, indicating loss of residual effectiveness. Two of the five dieldrin plots under third-season observations produced mature larvae and pupae in July in numbers exceeding those from associated check plots. One of these two plots, however, showed some residual effectiveness on its first flooding in June. The remaining three dieldrin plots demonstrated considerable third-season effectiveness; some persistence of insecticide residual was evident on two plots during single floodings in May and on one plot flooded 4 times in June and July. Although both heptachlor and dieldrin treatments showed some residual effectiveness during the early part of the 1958 season, neither insecticide provided complete control of irrigation mosquitoes throughout the third season.

All of the 10 plots treated at Chinook in 1957 with granular dieldrin at the rate of 0.5 lb. toxicant per acre produced mature larvae during their first or second floodings in 1958 (Table 1). Although the numbers of larvae produced on the treated plots

* From the Technology Branch, Communicable Disease Center, Bureau of State Services, Public Health Service, U. S. Department of Health, Education and Welfare, Greeley, Colorado.

TABLE 1.—Third-year results of DDT, dieldrin, and heptachlor, and second-year results of granular dieldrin as residual larvicides Chinook, Montana, 1956–1958

Insecticide	Formulation	Pre- or post flood	Location of plot	Date treated 1956	Date treated 1957	Lbs. toxicant per acre	Number of floodings 1956	Number of floodings 1957	Number of floodings 1958	Average number mature larvae and pupae per dip from treated plots and untreated check plots in 1958: May	June	July	Aug.	Sept.
DDT	1.5% Emulsion	Post	Roadside Ditch	5/4	—	2.8	2	2	1	0.0/0.1	0.0/0.0	0.0/0.0	0.0/0.0	0.0/0.0
Dieldrin	10% Granular	Pre	Alfalfa Field	6/4	—	1.0	2	4	2	Dry	1.1/19.5	7.9/5.4	—	—
		Post	Pasture	6/6	—	1.0	1	2	1	0.4/2.9	Dry	Dry	Dry	Dry
	0.5% Emulsion	Pre	Roadside Ditch	5/8	—	0.9	4	5	1	Dry	Dry	1.3/0.0	Dry	Dry
		Pre	Wasteland	5/8	—	1.1	4	4	1	0.0/5.2	Dry	Dry	Dry	Dry
		Post	Wasteland	6/1	—	1.0	3	5	4	Dry	0.0/2.8	0.3/3.3	Dry	Dry
Heptachlor	5% Granular	Pre	Pasture	6/6	—	1.5	0	0	1	Dry	3.1/2.9	—	—	—
	0.75% Emulsion	Post	Roadside Ditch	5/17	—	1.4	3	1	1	0.5/0.1	2.2/0.0	—	—	—
Dieldrin	2.5% Granular	Pre	Bluejoint Mead.	—	5/10	0.5	—	2	1	0.3/4.1	0.0/0.7	Dry	Dry	Dry
			Bluejoint Mead.	—	5/14	0.5	—	1	2	Dry	0.3/15.0	0.1/1.5	Dry	Dry
			Pasture	—	5/13	0.6	—	1	2	Dry	2.3/5.5	1.4/1.1	—	—
			Pasture	—	5/13	0.5	—	2	1	0.1/0.4	Dry	Dry	Dry	Dry
			Wasteland	—	5/14	0.5	—	1	1	Dry	Dry	0.2/3.3	Dry	Dry
		Post	Bluejoint Mead.	—	5/23	0.5	—	2	1	—	0.1/3.0	Dry	Dry	Dry
			Pasture	—	5/18	0.5	—	3	2	1.4/26.0	4.0/10.0	—	—	—
			Roadside Ditch	—	5/18	0.5	—	3	3	1.4/26.0	1.1/10.5	3.1/10.5	Dry	Dry
			Roadside Ditch	—	5/24	0.5	—	1	1	0.2/0.2	0.0/0.0	0.0/0.0	Dry	Dry
			Wasteland	—	5/24	0.5	—	1	2	0.0/5.2	Dry	0.9/8.4	Dry	Dry

compared with untreated check plots indicated some residual effectiveness on most of the plots during early summer, satisfactory control was not obtained throughout the second season on any of the plots.

The species composition of larvae collected in 1958 from plots treated with dieldrin in 1956 and 1957 and from associated check plots is shown in Table 2. Only *Aedes dorsalis* was collected from one plot treated in 1956, suggesting tolerance of this species to the failing residual effectiveness of dieldrin. However, the species composition of larvae collected from the remaining dieldrin plots and from associated check plots was not markedly different, indicating no over-all species tolerance to failing insecticide residuals of dieldrin.

In the further larviciding trials made in 1958, the granular materials used were 8/20 mesh bentonite containing 2.5 percent dieldrin, 15/30 mesh attaclay containing 5 percent heptachlor, and 30/60 mesh attaclay containing 10 percent DDT. Plots ranging in size from 0.1 to 0.69 acre were treated between April 29 and June 7, 1958. Crank-type spreaders were used in applying the granules. To facilitate uniform coverage, operators of the spreaders were guided by flagged stakes placed at 20-foot intervals along two sides of the plots. The stakes also assisted in measuring the areas treated. Granules were applied in amounts to give the following dosages of toxicant per acre: 0.25 and 0.12 pound dieldrin; 0.75 and 0.25 pound heptachlor; and 1.5 and 0.75 pound DDT.

The treated plots were flooded from 1 to 5 times during the season. When flooded, both treated and untreated check plots were sampled for mosquito larvae twice each week as in previous larviciding experiments. Samples of mature larvae, when present, were collected for identification.

The results from individual plots treated with dieldrin, heptachlor, and DDT in 1958 are presented in Tables 3, 4, and 5.

Since mosquito production occurred during the season on the majority of the plots, the average numbers of mature larvae and pupae per dip for treated plots are shown together with the concurrent averages for untreated check plots.

Mosquito production varied widely on replicate plots of different habitat types, particularly on seepage areas as compared with plots representing other habitat types.

TABLE 2.—Species composition of mature larvae from 1956 and 1957 dieldrin larvicidal plots and untreated check plots Chinook, Montana, 1958

Location of plot	Type plots	Number of plots	Number of larvae identified	Percentage for each species by plot location					
				Aedes dorsalis	*Aedes vexans*	*Aedes nigromaculis*	*Culiseta inornata*	*Culex tarsalis*	Other species*
Alfalfa Field	Treated	1	52	100	0	0	0	0	0
	Check	1	109	30	24	46	0	0	0
Pasture	Treated	4	139	35	16	42	1	6	0
	Check	2	132	49	9	29	6	6	1
Bluejoint Meadow	Treated	3	6	17	17	17	16	0	33
	Check	2	67	52	16	6	6	5	15
Roadside Ditch	Treated	3	82	75	7	17	1	0	0
	Check	3	104	48	24	23	0	5	0
Wasteland	Treated	3	7	14	72	14	0	0	0
	Check	2	45	11	11	7	27	40	4
All Plots	Treated	14	286	39	12	44	1	3	1
	Check	10	457	41	17	26	5	8	3
Totals	Both	24	743	40	15	33	4	6	2

* Other species include *Aedes idahoensis, A. spencerí, A. trivittatus* and *Anopheles earlei.*

TABLE 3.—Results of residual larviciding experiments with granular dieldrin applied at 0.25 pound and 0.12 pound toxicant per acre Chinook, Montana, 1958

Pre- or post flood	Location of plot	Date treated	Size of area treated (acre)	Actual dosage lb./acre	Days to first post-treatment flooding	Number of floodings	Average number of mature larvae and pupae per dip on treated plots and untreated check plots				
							May	June	July	August	September
Pre	Bluejoint Meadow	5/7	0.51	0.25	8	2	0.8/5.2	Dry	0.0/0.7	Dry	Dry
	Bluejoint Meadow	5/8	0.41	0.24	7	2	0.1/5.2	0.1/1.6	Dry	Dry	Dry
	Seepage Area	5/8	0.19	0.26	11	3	0.0/53.0	0.0/0.7	0.0/0.2	0.0/0.0	0.0/0.0
Post	Bluejoint Meadow	5/13	0.27	0.23	–	5	0.2/30.0	0.0/1.8	0.0/7.5	2.9/8.4	44.2/49.3
	Pasture	5/27	0.48	0.26	–	2	0.2/15.0	0.0/2.0	0.0/6.1	0.0/1.8	Dry
	Pasture	6/5	0.20	0.25	–	1	—	25.0P/10.5	Dry	Dry	Dry
	Wasteland	6/2	0.10	0.26	–	3	—	4.2P/13.0	0.1/7.4	0.0/48.0	Dry
	Seepage Area	5/29	0.10	0.26	–	3	—	0.0/6.6	0.0/1.4	0.0/0.5	0.1/1.4
Pre	Bluejoint Meadow	5/7	0.45	0.11	8	3	18.7/25.0	0.1/0.4	0.1/0.7	Dry	Dry
	Pasture	5/9	0.22	0.11	31	3	Dry	3.2/7.1	0.6/2.0	Dry	6.7/9.1
	Pasture	5/9	0.41	0.12	26	2	Dry	4.7/11.0	Dry	Dry	0.8/0.2
	Wasteland	5/7	0.51	0.12	19	2	31.8*/21.4	3.9/10.6	Dry	6.3/12.6	Dry
	Seepage Area	5/8	0.10	0.12	13	1	0.0/0.8	0.1/1.6	0.0/0.1	0.0/<0.05	0.0/0.0
Post	Bluejoint Meadow	5/15	0.37	0.10	–	2	0.0/25.0	0.1/1.0	0.0/0.1	Dry	Dry
	Pasture	6/3	0.10	0.12	–	1	—	0.0/1.7	0.0/2.9	Dry	Dry
	Pasture	6/4	0.40	0.12	–	2	—	0.0/60.0	1.1/7.6	Dry	Dry
	Wasteland	5/13	0.41	0.12	–	5	0.0/30.0	0.0/2.0	0.0/7.8	0.6/8.4	0.1/49.3
	Seepage Area	5/29	0.10	0.13	–	3	—	0.0/6.6	0.0/1.44	0.0/0.45	0.0/1.4

P = Pupae only.

* Includes pupae, days after flooded, thus obviously washed into this deep swale.

TABLE 4.—Results of residual larviciding experiments with granular heptachlor applied at 0.75 pound and 0.25 pound toxicant per acre Chinook, Montana, 1958

Pre- or post flood	Location of plot	Date treated	Size of area treated (acre)	Actual dosage lb./acre	Days to first post-treatment flooding	Number of floodings	Average number of mature larvae and pupae per dip on treated plots and untreated check plots				
							May	June	July	August	September
	Bluejoint Meadow	5/6	0.41	0.73	13	3	0.0/9.4	0.0/1.65	0.7/1.2	Dry	Dry
	Pasture	5/6	0.69	0.72	20	3	2.9/15.0	Dry	4.7/28.4	Dry	Dry
Pre	Wasteland	5/5	0.58	0.70	21	5	3.2/15.0	0.0/10.6	2.5/52.4	Dry	Dry
	Wasteland	4/30	0.43	0.82	33	4	Dry	0.1/2.3	0.1/1.2	3.7/6.6	Dry
	Seepage Area	5/1	0.10	0.75	26	2	0.0/53.0	0.0/61.0	0.0/4.6	0.3/1.1	0.0/2.8
	Bluejoint Meadow	5/14	0.26	0.77	–	2	0.0/1.4	0.0/1.2	Dry	Dry	Dry
	Pasture	5/10	0.38	0.79	–	1	0.0/5.5	Dry	Dry	Dry	Dry
Post	Pasture	6/6	0.42	0.72	–	3	—	3.5/94.0	6.2/97.0	9.2/31.0	Dry
	Wasteland	5/10	0.39	0.77	–	2	0.0/7.7	0.0/7.5	Dry	0.0/0.0	Dry
	Seepage Area	5/14	0.10	0.75	–	4	0.0/0.0	0.0/6.0	0.1/8.6	0.1/0.2	0.0/2.8
	Bluejoint Meadow	5/8	0.50	0.25	7	3	0.0/5.2	3.4/1.1	0.0/1.2	Dry	Dry
	Bluejoint Meadow	5/8	0.55	0.24	7	3	0.0/5.2	0.0/0.7	0.0/1.2	Dry	Dry
Pre	Pasture	4/30	0.52	0.24	30	5	0.0/2.0	Dry	11.0/54.0	8.7/7.2	1.4/7.2
	Wasteland	5/1	0.47	0.26	14	4	0.0/0.9	Dry	0.2/0.2	1.8/0.9	Dry
	Seepage Area	5/1	0.10	0.25	26	1	0.1/53.0	0.7/12.0	0.8/2.6	5.3/1.1	3.4/2.8
	Bluejoint Meadow	5/15	0.40	0.25	–	1	0.0/5.2	Dry	Dry	Dry	Dry
	Pasture	5/10	0.20	0.25	–	2	0.0/28.0	0.0/2.9	Dry	3.6/16.4	0.0/0.0
Post	Pasture	6/4	0.18	0.27	–	2	—	0.8/9.5	0.0/5.2	Dry	Dry
	Wasteland	6/4	0.58	0.26	–	2	—	2.6/13.7	0.2/9.0	0.1/0.4	0.1/0.2
	Wasteland	6/7	0.49	0.25	–	1	—	0.0/1.7	0.0/2.9	Dry	Dry
	Seepage Area	6/5	0.30	0.25	–	2	—	0.0/5.9	1.3/17.8	0.3/9.4	Dry
	Seepage Area	6/5	0.10	0.25	–	4	—	0.2/5.8	0.0/17.8	0.0/7.4	Dry

TABLE 5.—Results of residual larviciding experiments with granular DDT applied at 1.5 pounds and 0.75 pound toxicant per acre Chinook, Montana, 1958

Pre- or post flood	Location of plot	Date treated	Size of area treated (acre)	Actual dosage lb./acre	Days to first post-treatment flooding	Number of floodings	Average number of mature larvae and pupae per dip on treated plots and untreated check plots				
							May	June	July	August	September
Pre	Bluejoint Meadow	4/30	0.49	1.52	15	2	2.6/5.2	1.0/510.0	Dry	Dry	Dry
	Bluejoint Meadow	4/29	0.30	1.50	26	2	Dry	39.7/27.0	20.1/25.2	Dry	Dry
	Pasture	5/10	0.41	1.46	107	1	Dry	Dry	Dry	Dry	0.1/2.9
	Wasteland	5/1	0.37	1.90	30	3	Dry	0.6/4.5	0.2/0.7	16.0/8.5	6.6/7.2
Post	Bluejoint Meadow	5/10	0.26	1.50	—	3	0.0/5.2	0.0/5.0	0.0/1.2	Dry	Dry
	Pasture	5/27	0.40	1.50	—	3	5.9*/9.6	0.0/0.9	0.0/8.2	0.0/2.4	—
	Wasteland	5/28	0.27	1.45	—	4	—	0.0/0.1	0.1/2.5	1.2/16.7	Dry
Pre	Bluejoint Meadow	4/30	0.51	0.68	15	1	25.3/25.0	Dry	Dry	Dry	Dry
	Pasture	4/29	0.20	0.73	31	2	Dry	11.0/13.6	89.4/44.0	Dry	Dry
	Pasture	5/9	0.12	0.80	20	4	Dry	1.1/4.5	Dry	0.3/0.8	Dry
	Wasteland	5/3	0.41	0.73	11	3	2.7/4.1	Dry	15.4/48.8	4.1/1.8	Dry
Post	Bluejoint Meadow	5/14	0.27	0.77	—	2	21.0/25.0	0.3/0.35	Dry	Dry	Dry
	Pasture	5/27	0.46	0.76	—	3	0.6*/9.6	0.5/5.1	0.0/8.2	Dry	10.7/43.0
	Wasteland	5/15	0.12	0.81	—	3	0.0/10.8	0.0/19.5	0.1/0.1	Dry	Dry

* Pupae only.

Seepage areas typically were relatively small accumulations of water near major irrigation canals. Entire areas of such isolated seepage water were usually treated. Both dieldrin and heptachlor, even at the lower dosage rates, generally were effective on these small areas of quiet water (Tables 3 and 4). On the other hand, evidence of failure for both these toxicants, even at the higher dosages, occurred on some plots located on bluejoint meadows and pastures. These "on-field" plots usually represented minor portions of relatively large areas which were subject to flooding.

Some of the sites selected for preflood treatment were later found to be in the path of flowing, shallow water during irrigations. Insecticidal failures on these plots suggested that flow through the plots at higher water levels caused dissipation of the insecticidal residues. In addition, some of the indicated failures early in the season may have been partially due to larvae and pupae that were transported into the plots during floodings. This was particularly evident for plots where mosquito production was markedly reduced later in the season when the levels of irrigation water were more stabilized.

Two of the three 1958 post-flood DDT treatments at 1.5 pounds toxicant per acre gave effective control throughout the season (Table 5). The third plot showed considerable evidence of DDT residue during most of the season. All of the other DDT treatments showed little or no residual effectiveness. Mosquito production was persistently high on the plots that received preflood DDT treatments, even at 1.5 pounds toxicant per acre, suggesting that exposure to the elements caused the DDT to deteriorate during the dry periods prior to flooding of the plots.

Both dieldrin and heptachlor treatments were generally more effective than DDT, except for the post-flood applications of DDT at 1.5 pounds per acre as noted above (Tables 3 and 4). Some of the erratic results obtained with dieldrin and heptachlor at the lower dosages may have been partly due to uneven coverage in these scanty applications.

TABLE 6.—Species composition of mature larvae from larvicidal plots and untreated check plots Chinook, Montana, 1958

Insecticide and dosages (lb. toxicant/A)	Plot location	No. of plots	No. of larvae identified	Percentage for each species by plot location					
				Aedes dorsalis	*Aedes vexans*	*Aedes nigromaculis*	*Culiseta inornata*	*Culex tarsalis*	Other species*
Dieldrin 0.5 lb. and 0.25 lb. per acre	Blue joint Meadow	5	154	51	5	43	0	0	1
	Pasture	4	129	23	36	33	1	5	2
	Wasteland	2	134	58	18	1	11	10	2
	Seepage Area	1	5	80	0	0	20	0	0
Heptachlor 0.25 lb. and 0.75 lb. per acre	Bluejoint Meadow	2	17	100	0	0	0	0	0
	Pasture	4	134	64	22	8	1	5	0
	Wasteland	4	156	27	23	46	1	2	1
	Seepage Area	5	354	8	4	0	2	85	1
DDT 0.75 lb. and 1.5 lb. per acre	Bluejoint Meadow	4	156	62	15	1	13	0	9
	Pasture	5	177	64	7	27	1	0	1
	Wasteland	4	167	25	11	20	19	23	2
Untreated Check Plots	Bluejoint Meadow	6	226	39	7	43	0	0	2
	Pasture	15	574	60	17	15	1	5	2
	Wasteland	11	732	35	27	9	6	21	2
	Seepage Area	4	454	44	5	1	17	32	1

* Includes 27 *Aedes idahoensis*, 12 *A. trivittatus*, 9 *A. spenceri*, 4 *A. flavescens*, 1 *A. riparius*, 1 *A. sticticus*, and 11 *Anopheles earlei*.

The species composition of larvae collected from plots treated in 1958 and from untreated check plots is shown in Table 6. Here again, 4 of 5 larvae from a dieldrin plot were *A. dorsalis,* and 17 larvae from a heptachlor plot were exclusively *A. dorsalis*. On the basis of the comparatively small numbers of larvae collected from these two plots, the predominance of *A. dorsalis* suggests a tolerance of this species to residuals of dieldrin and heptachlor. However, the species composition of the considerably larger numbers of larvae from the remaining larvicidal plots was not significantly different from that of untreated check plots. Thus there was no marked evidence of species tolerance to insecticide residuals of dieldrin, heptachlor, or DDT.

In summary, the results of the 1958 larviciding trials indicate that preflood applications of dieldrin at the rate of 0.25 pound toxicant per acre and post-flood applications of DDT at 1.5 pounds per acre provided almost complete control of irrigation mosquitoes for the entire season. Post-flood treatments with dieldrin at 0.25 pound per acre and heptachlor at 0.75 pound per acre provided effective control for about 12 weeks. Heptachlor applied as a preflood treatment at 0.75 pound per acre provided effective mosquito control for at least 9 weeks.

SUMMARY

Single preflood and post-flood applications of dieldrin, heptachlor and DDT as water emulsions and granular formulations at approximately 1.0, 1.5, and 3.0 pounds toxicant per acre, respectively, did not provide satisfactory control of irrigation mosquitoes during the third season after treatment; and granular dieldrin at 0.5 lb./acre did not provide complete control throughout the second season. Preflood applications of granular dieldrin at 0.25 lb./acre and post-flood applications of granular DDT at 1.5 lb./acre gave almost complete control throughout one season. Post-flood dieldrin at 0.25 lb./acre and granular heptachlor at 0.75 lb./acre provided effective control for about 12 weeks. Preflood heptachlor at 0.75 lb./acre was effective for at least 9 weeks.

Dieldrin and heptachlor were more effective on seepage areas of quiet water than on pastures and bluejoint meadows which were subject to repeated floodings by irrigation. On relatively small seepage areas, granular dieldrin at 0.12 lb./acre provided almost complete control throughout one season, and granular heptachlor at 0.25 lb./acre was effective for 7 weeks applied preflood and for 11 weeks applied post-flood.

References Cited

1. SHULTZ, G. R., and MILES, V. I. 1959. Larviciding experiments in the Milk River Valley, 1956. Proceedings 10th and 11th Annual Meetings, Utah Mosquito Abatement Association, pages 1–5.

2. MILES, V. I., and SHULTZ, G. R. 1959. Second season effectiveness of mosquito larvicide residuals and further tests of granular dieldrin as a residual larvicide. *Ibid,* pages 49–52.