SPRAY PLANE APPLICATIONS OF LARVICIDES FOR CONTROL OF *AEDES* IN FLOODED PASTURES IN CALIFORNIA [1]

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There were three problems arising from the 1947 mosquito control operations in California which suggested further investigation. First, the airplane studies in Kern Mosquito Abatement District conducted that year (Geib, 1948; Magy, 1948; Magy, Dahl, Geib & Kirkwood, 1949) indicated that DDT-xylene water emulsion applied with a spray plane at the rate of one gallon of 5% solution (0.4 pounds DDT) per acre resulted in effective control of *Aedes dorsalis* (Meigen) and *Aedes nigromaculis* (Ludlow) larvae in flooded pastures. From an economic point of view it would be of considerable importance to increase the pay-load of the plane by reducing the volume of the spray material to be applied. Second, several districts were using DDT-diesel oil spray solutions for *Aedes* control in flooded pastures, and were reporting adequate results, whereas, in Kern County during the 1946 and 1947 seasons, this material frequently failed to result in satisfactory control. Third, Rhothane (TDE) water emulsion was being used by several districts with varying results.

In 1948 the Bureau of Vector Control, California State Department of Public Health, in cooperation with the Merced County Mosquito Abatement District and the Kern Mosquito Abatement District planned and conducted a series of studies in each of the districts with the view of obtaining a solution to the above three problems.

The objectives of these spray plane studies for the control of *A. dorsalis* and *A. nigromaculis* larvae were therefore to determine: (1) The difference in effectiveness of a large volume of spray solution containing a small amount of DDT compared with a more concentrated spray solution; (2) the comparative effectiveness of DDT water emulsion and DDT in diesel oil; and (3) the relative toxicity of DDT versus Rhothane (TDE) larvicidal sprays.

Procedure, Equipment, Techniques, and Materials

The same types of spray plane studies were repeated in both the Kern and the Merced County Mosquito Abatement Districts. The Kern Mosquito Abatement District used a 220 horsepower PT-17 Stearman airplane flown at 90 miles per hour. The Merced County Mosquito Abatement District used an Aeronca Champion plane with an 85 horse power motor flown at 80 miles per hour. Both planes were equipped with a spray boom mounted below the wings with Chicago Spray Systems Whirljet nozzles attached to the booms and with wind operated pumps. The flight intervals, the number of nozzles, and the rates of discharge varied according to the dosages desired, but in each study 0.4 pound of DDT or Rhothane was dispersed per acre.

Five formulations prepared in the same manner were tested in each district. Braun-Knecht-Heimann (BKH) DDT water emulsible concentrate, Series E, was used in the DDT mixtures as it appeared to be a representative proprietary emulsible. The formulations included: Five and 10% DDT water emulsions; 5 and 10% DDT in diesel oil; and 5% Rhothane water emulsion. In each case 0.4 pound of insecticide was applied per acre.

[1] This report is one of a series on continuing mosquito control operational and biological studies begun in 1946 by the Bureau of Vector Control, Division of Environmental Sanitation, California State Department of Public Health in cooperation with various mosquito abatement agencies.

Meteorological and biological variables were measured for each study.

As a basis for sampling larval populations, sixty dips were taken two to four hours before treatment and the same number of dips 24 hours after treatment. Areas with numerous pupae were avoided due to the apparent resistance of pupae to DDT. Because the first and second instar larvae were easily killed, they were omitted in the computation of toxicity rates of the various solutions, although counts were taken. Results were based upon the percentage of third and fourth instar larval reduction between pre- and post-treatment counts.

Attempts were made to set up untreated control plots. It was very difficult to find fields large enough for plane-spraying purposes, and to include both treated and untreated portions and at the same time to have ideal conditions necessary for satisfactory experimental controls. Only six studies in the Merced County District had suitable areas to allow controlled experiments.

A. dorsalis and *A. nigromaculis* were present in the studies in both districts. *A. dorsalis* predominated in Kern County, while in Merced County the reverse was true with *A. nigromaculis* predominating.

Results and Discussion

The toxicity of the various materials used is presented in Table 1. Combined averages of third and fourth instar larval reductions are listed for each material in each area, consideration being given to the type of vegetative conditions. Most of the studies were conducted under favorable vegetative conditions, that is, the vegetation was of light or medium density and 75% or less of the water surface was covered with vegetation. If the vegetation was of heavy density and/or the water area completely covered with vegetation, the vegetative conditions were considered to be adverse.

The results indicate that 5% DDT-water emulsion at one-gallon per acre and 10% DDT-water emulsion at one-half gallon per acre gave above 94% larval reduction in both Kern and Merced Counties. With the DDT-diesel oil and

TABLE 1.—Toxicity of Larvicides Applied with Spray Planes @ 0.4 lb. Larvicide per Acre

Larvicides	MERCED COUNTY M.A.D.				KERN M.A.D.			
	Adverse & Favorable Vegetative Conditions		Favorable Vegetative Conditions		Adverse & Favorable Vegetative Conditions		Favorable Vegetative Conditions	
	No. of Studies	Percent Reduction	No. of Studies	Percent Reduction	No. of Studies	Percent Mortality	No. of Studies	Percent Reduction
5% B.K.H. DDT-Water Emulsion at at 1 gallon/acre	4*	96.9	4	96.9	7	99.9	6	100
10% B.K.H. DDT-Water Emulsion at ½ gallon/acre	5**	94.5	5	94.5	7	95.1	6	99.7
5% DDT in Diesel Oil at 1 gallon per acre	5*	83.2	4	97.0	7	50.5	6	44.9
10% DDT in Diesel Oil at ½ gallon per acre	5	94.2	5	94.3	6	45.3	5	36.4
5% Rhothane-Water Emulsion at 1 gallon per acre	5**	76.2	4	95.2	6	24.8	6	24.8
Untreated controls	6	15	4	2.3	–	–	–	–

* 2 plots
** 1 plot

Rhothane-water emulsion the Merced County studies had larval reduction rates generally above 90% except under adverse vegetative conditions, but in Kern County the larval reduction rates were generally below 50% under all types of vegetative conditions.

If those studies done under adverse vegetative conditions were omitted the average larval reduction for the Merced County studies was above 94% for all of the materials used. However, in Kern County this was not the case for the diesel oil studies as the average reduction rates dropped. There were probably other factors that caused these failures in Kern County.

It is of interest to note that in the untreated controls in the Merced County studies there was no natural reduction in five out of six studies. The larval count was usually a little larger 24 hours after the first count.

By eliminating those studies conducted under unfavorable vegetative conditions, correlation of the effect of other measurable variable factors with mortality has been possible. This was done by assuming that all of the materials used were potentially equally effective. Variable factors and their component units of values (variable increments) are listed in Table 2. The average mortality within

TABLE 2.—Analysis of Variables of Airplane Studies in Merced County and Kern Mosquito Abatement Districts.

Variable Factors	*Variable Increments*	*Number of Studies*	*Average % Reduction*
Flight Air Temp. °F	64–73	10	95
	74–83	11	91
	84–93	22	67
	94–103	7	54
Water Temperature °F	58–72	14	85
	73–86	22	87
	87–100	14	51
Daily Mean Air Temp. °F	70–75	14	86
	76–80	21	76
	81–85	13	65
	86–90	2	50
Conversion and Inversion	Conversion	21	70
	Inversion	3	95
	No Difference	26	70
Time of day	Before 10 a.m.	24	88
	After 10 a.m.	26	69
Relative Humidity	26–42%	21	73
	43–59%	19	75
	60–76%	7	93
Wind Velocity MPH	1	7	91
	2	15	61
	3	18	73
	4	3	99
	5	8	82
	7½	2	99
pH of water	5	2	99
	6	18	83
	7	26	73
	8	4	57
Water Depth	4"	42	74
	8"	8	83

each increment range is given. It should be emphasized that these averages may give mortality "trends," not necessarily mortality correlations.

In reference to Table 2, the following mortality "trends" are indicated:

(1) *Temperature:* There was strong evidence indicating that several temperature variables affect mortality. As the flight air temperature increased the average mortality dropped, and as the flight air temperature decreased the mortality increased. This inverse trend is also true for the daily mean temperature and to a lesser extent for the water temperature. The higher mortality before 10 a.m. with the prevailing lower temperature is significant.

The reduction in control as the water and daily mean temperature rise may be more closely related to the operational difficulty of obtaining an adequate dispersal by airplanes as the result of the evaporation of the larvicides, rising air currents, and shifting winds, than may be due to biological factors. There is also the possibility that DDT may be more readily inactivated at higher water temperatures.

(2) *Conversion and Inversion Air Currents:* There was not much correlation of conversion (rising) or inversion (downward) air currents with the control of larvae as only three studies were run under inversion air current conditions. Nevertheless, of the three studies under inversion the average larval reduction was 95% and under conversion it was 70%.

(3) *Relative Humidity:* There was a trend toward a higher degree of control as the humidity increased. Under high humidity there would probably be less evaporation of the spray as it drops through the air to the ground.

(4) *Wind Velocity:* No clear-cut trend was indicated in regard to the increase or decrease of the wind velocity.

(5) *pH of Water:* The results seemed to indicate that the mortality dropped as the pH increased.

(6) *Water Depth:* Studies conducted in areas with deeper waters apparently had a greater larval reduction than those with lower water depths. The theory is offered that as deeper waters are cooler than shallower waters when exposed to the same surface temperatures, a higher larval reduction following treatment would be expected in water of greater depth.

In retrospect it appears that the possible reasons for the larger number of successful studies with all of the materials in Merced County were due to their having been conducted under more favorable temperature conditions than those in Kern County. The studies in Kern County were usually started late in the morning or early in the afternoon. This was especially the case for the studies involving diesel oil and rhothane.

The B.K.H. water emulsible materials were equally effective in both Merced and Kern Counties. This material appeared to have the faculty of overcoming adverse conditions. Of a total of 14 studies in Kern County with the 5% and 10% B.K.H. solutions, eight were done under temperature conditions that would be considered unfavorable to give adequate control, but, nevertheless gave almost complete kill.

The difference in the preponderance of *A. dorsalis* over *A. nigromaculis* in Kern County and the reverse preponderance in Merced County may have had some bearing on the results. It is possible that *A. dorsalis* is more resistant to DDT and TDE than *A. nigromaculis.*

Summary and Conclusions

1. For the control of *Aedes dorsalis* and *Aedes nigromaculis* larvae in intermittently flooded pastures with spray planes, DDT water emulsion was more consistently effective than DDT in diesel oil, and Rhothane (TDE) water emulsion. DDT water emulsion seemed to have the faculty of overcoming adverse temperature conditions to give effective control, whereas the latter two materials did not seem to have this faculty.

2. One-half gallon of 10% DDT mosquito larvicide solutions was equally as effective as one-gallon of 5% DDT larvicides when applied by a spray plane for the control of *A. dorsalis* and *A. nigromaculis* larvae.

3. At a constant rate of application of 0.4 pound of insecticide per acre, mortality to these mosquito larvae tended to decrease when water temperature, daily mean temperature, air temperature and pH of the water increased. Spray plane applications before 10 a.m. gave higher larval reduction rates than those applied after 10 a.m. Mortality tended to increase under high relative humidity conditions, and increased water depths up to 8 inches.

4. It appears that the studies in Merced County were conducted under more favorable temperature conditions than those in Kern County, which may be the reason for the consistently favorable results obtained in Merced County compared to the less satisfactory results for all the materials in Kern County.

5. The difference in the results in these two districts may have been due to the fact that *A. dorsalis,* predominating in Kern County, may possibly be more resistant to DDT and TDE than *A. nigromaculis,* which predominated in Merced.

ACKNOWLEDGMENTS

The authors wish to thank the following individuals for their helpful assistance on this project: S. I. Kirkwood, Tetsuo Hayashida, Grafton Campbell, Thor A. Holm, and William J. Buchanan of the Bureau of Vector Control; Edgar A. Smith, Manager, who assisted in planning the study and Edward Kotes, pilot of the Merced County Mosquito Abatement District; Dale F. Knopf, pilot of the Kern Mosquito Abatement District; and Dr. W. M. Hoskins, University of California, who contributed certain statistical evaluative information.

Literature Cited

GEIB, A. J. 1948. Experiences in the use of airplanes in the Kern Mosquito Abatement District. Proc. 16th Ann. Conf. Calif. Mosq. Cont. Assoc. 63–66.

MAGY, H. I. 1948. A comparison of the use of thermal exhaust aerosol plane and the spray plane in mosquito larvae control in Kern County and the Sutter-Yuba Mosquito Abatement District. Proc. of 16th Ann. Conf. Calif. Mosq. Cont. Assoc. 69–71.

MAGY, H. I., DAHL, A. H., GEIB, A. F., AND KIRKWOOD, S. J. 1949. DDT larvicides dispersed by spray and thermal aerosol planes for the control of *Aedes dorsalis* (Meigen) and *Aedes nigromaculis* (Ludlow). *Mosquito News* 9(4):153–161.