developed some of the modifications of the trap chambers. Mr. Paul Steel, manager of the Columbia Wildlife Refuge, U.S.F.W.S., has been most gracious in aiding studies on biting insects within the refuge.

Literature Cited

Dow, R. P. 1959. A method of testing insect traps and attractants, and its application to studies of *Hippelates pusio* and *Culex tarsalis.* Jour. Econ. Ent. 52:496–503.

HAUFE, W. O. and BURGESS, L. 1960. Design and efficiency of mosquito traps based on visual response to patterns. Canad. Entom. 92:124–40.

LUMSDEN, W. H. R. 1958. A trap for insects biting small vertebrates. Nature (London) 181: 819–20.

PRATT, H. D. 1948. Influence of the moon on light trap collections of *Anopheles albimanus* in Puerto Rico. Jour. Natl. Malaria Soc. 7:212–20.

PROVOST, M. W. 1959. The influence of moonlight on light-trap catches of mosquitoes. Ann. Ent. Soc. Amer. 52:261–71.

MOSQUITO CONTROL IN OLIVE VATS [1]

MIR S. MULLA [2]

Department of Entomology, University of California Citrus Experiment Station, Riverside

During the 1960 season a "citizens' committee" to survey the evergrowing problem of *Hippelates* eye gnats and mosquitoes in the Hemet—San Jacinto Valley of Southern California was established. Funds for the survey came from the Board of Supervisors of Riverside County and voluntary contributions by the citizens and organizations of the Hemet—San Jacinto Valley.

The committee requested the State Department of Public Health and the Department of Entomology, University of California at Riverside, to supervise a short-term study to determine the nature and scope of the eye gnat and the mosquito problem in that valley.

During the course of this survey a variety of niches and sources that supported mosquito larval populations were detected. Among them, uncovered olive vats operated by a local packing firm were found to breed large numbers of *Culex p. quinquefasciatus* and, to a lesser degree, *C. peus*. The vats were anywhere from 3 to 8 feet deep and 7 to 15 feet in diameter. There are about 200 vats in this one packing installation and all of them (except those emptied for repair) are kept filled with water from May to October, a period during which they are not used for processing and packing the olives. Since the vats are located in the center of the city of Hemet, and support a fair population of mosquito larvae, they are a constant source of mosquito annoyance.

The olive vats provided an ideal semi-field condition where the effectiveness of granular insecticides in deep bodies of water could be studied. Emulsifiable concentrate formulations were also studied and some were found to be effective at lower concentrations than are necessary to kill susceptible larvae of *C. p. quinquefasciatus* in the laboratory. A plausible explanation for this phenomenon is offered.

METHODS AND MATERIALS

Vats 42 inches deep and 92 inches across were the only ones (Fig. 1) used in these experiments. The pH of the water in the vats was 6; the temperature of the water ranged from 68° to 78° F. during the day

[1] Paper No. 1262, University of California Citrus Experiment Station, Riverside, California.

[2] The able assistance of Harold Axelrod and Ken Calhoun of the University of California at Riverside is duly acknowledged. Mr. Harvey I. Magy of the State Department of Public Health, Los Angeles, also cooperated in this study.

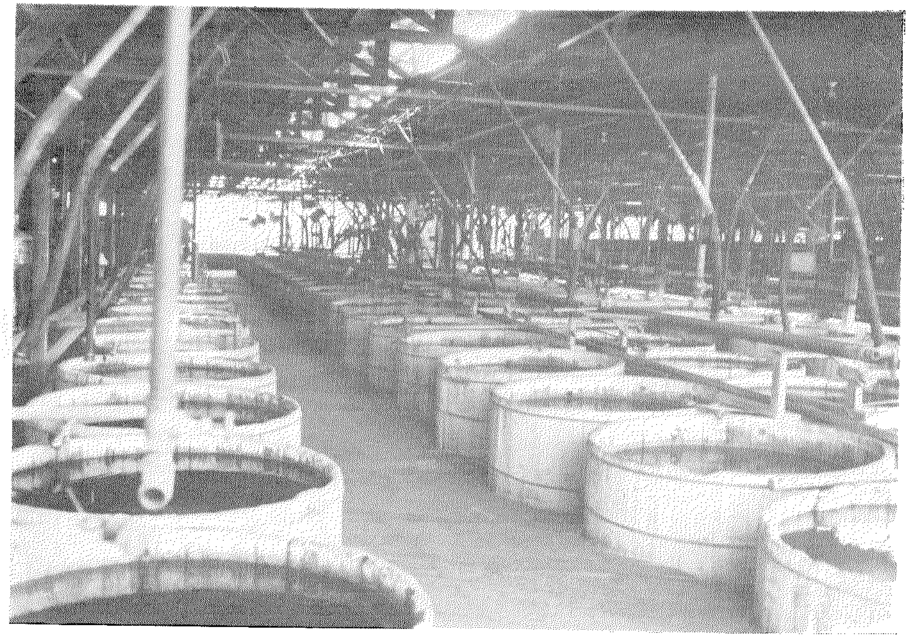

FIG. 1.—Olive vats located within the city limits of Hemet breed *Culex* mosquitoes.

in September when most of the tests were conducted. The emulsifiable concentrate formulations were applied directly to the water in naturally infested vats by pipetting the required amount of the concentrate and pouring it on the surface. No attempt was made to stir or mix the concentrate into the water.

Larval count by dippings was not satisfactory, but the water was clear and most of the larvae could be easily counted. Three to five 30-second counts were taken before and 24 hours after treatment with the liquid toxicant formulations. Only fourth instar larvae were counted.

In order to study the effectiveness of granular insecticides, larvae of *Culex pipiens quinquefasciatus* from a susceptible laboratory colony were caged in the vats shown in Figure 1. The cages were made from 40-mesh plastic screen and two cages containing 25 fourth instar larvae each were placed in each treated vat. Larval mortality was read after 24 hours of exposure. Both laboratory-prepared and commercially available materials were evaluated.

RESULTS AND DISCUSSION

The use of organochlorine insecticides was precluded due to the possibility that they might leave residues in the grain of the wood of the vats. Therefore, less stable materials such as organophosphorus and carbamate insecticides were evaluated. The effectiveness of the toxicants used in the vats was also determined in the laboratory against a susceptible strain of *C. p. quinquefasciatus* (Table 1) (Mulla *et al.*, 1960).

EMULSIFIABLE CONCENTRATES. Emulsifiable concentrate formulations of malathion, parathion, and five experimental insecti-

TABLE 1.—Effectiveness of various insecticides against fourth instar larvae of *Culex p. quinquefasciatus* in the laboratory

Material	LC 50 (P.P.M.)	LC 90 (P.P.M.)
Parathion	0.0045	0.0082
Bayer 29493 (Baytex)	0.011	0.014
Bayer 25198	0.016	0.022
E.N. 18133	0.023	0.031
Bayer 38156	0.027	0.042
Dow K-6882	0.038	0.052
Malathion	0.068	0.120
VC-13	0.150	0.310
Dowco 139	0.580	1.20

cides were evaluated in the olive vats. Parathion was the most effective material of all, followed by Bayer 25198 [*O,O*-dimethyl *O-p*-(methyl sulfinylphenyl) phosphorothioate], Dow K-6882 [*O*-ethyl *O*-(2,4,5-trichlorophenyl) methyl phosphoroamidothioate], and malathion (Table 2). Dowco 139 (4-dimethylamino-3,5-xylol-N-methylcarbamate) was slightly less effective than malathion, but for all practical purposes, the activity of these two materials under the testing conditions is assumed to be essentially the same. In laboratory studies against susceptible fourth instar larvae of *C. p. quinquefasciatus*, however, malathion proved to be approximately 10 times as effective as Dowco 139 (see Table 1).

Compound VC-13 (*O*-2,4-dichlorophenyl *O,O*-diethylphosphorothioate) did not prove too promising; very high rates (over 0.6 p.p.m. or 5 lbs. per acre) were required to obtain good kill of the larvae. This compound, although more effective than Dowco 139 in the laboratory (see Table 1), proved less effective under the testing conditions in the olive vats.

Bayer 38156 was ineffective at the rates applied here to the vats. Under some field-testing conditions this material proved highly effective against fourth instar larvae of *Culex tarsalis* (Mulla *et al.* 1961).

TABLE 2.—Evaluation of larvicides against *Culex pipiens quinquefasciatus* and *C. peus* breeding in olive vats

Insecticide and formulation	Dosage		Avg. No. larvae/count [1]		Percent control
	P.P.M.	Lbs./A	Pretreatment	Posttreatment	
Malathion 80% EC	0.05	0.43	10.3	3.3	67
	0.08	0.69	20.0	0.0	100
	0.10	0.90	6.2	0.3	95
	0.15	1.30	12.0	0.0	100
Parathion 50% EC	0.001	0.009	50.0	38.0	24
	0.002	0.017	45.0	0.0	100
Dowco 139 25% EC	0.04	0.32	19.0	14.0	26
	0.08	0.64	11.0	3.0	73
	0.10	0.77	3.0	0.0	100
Bayer 25198 50% EC	0.002	0.017	48.0	30.0	38
	0.005	0.043	10.3	6.3	39
	0.0075	0.065	10.0	0.0	100
Bayer 38156 50% EC	0.05	0.40	67.0	64.0	5
	0.10	0.80	37.0	30.0	19
VC-13 75% EC	0.2	1.7	5.3	2.8	47
	0.4	3.4	5.1	1.7	66
	0.6	5.1	1.9	0.2	89
Dow K-6882 25% EC	0.005	0.043	63.0	57.0	10
	0.010	0.08	25.0	14.0	43
	0.040	0.24	33.0	2.0	94

[1] Three to five 30-second counts of mosquito larvae were taken per vat. Counts were taken 24 hours after treatment and only fourth instar larvae were counted.

Aside from differences attributable to the occurrence of resistance in the various populations and the nature of the various breeding grounds, no great variations are to be expected in the susceptibility of *Culex p. quinquefasciatus* and *C. tarsalis*. Possibly the emulsifiable concentrate formulation of this material did not emulsify readily in the vats. It is obvious that the concentrations of parathion, Bayer 25198, and Dowco 139 (in parts per million) needed to kill all the larvae in the vats are lower than those required for similar kill in the laboratory (see Table 1). This difference is probably due to the high initial concentration of these insecticides in the upper part of the water where the larvae stay.

Malathion and Dow K-6882 were required at approximately the same concentrations in the vats as those in the laboratory to kill 95 to 100 percent of the larvae. Greater concentrations of VC-13 were required for a given kill in the vats than those required in the laboratory. This suggests that various toxicants follow different courses of distribution in deep bodies of water.

Homogeneous distribution of parathion and malathion took place in glass jars containing water with depths of 2.5 to 15.0 cm. (Rai and Lewallen 1960). In view of the small amount and small depth of water used, even distribution of the toxicants in the absence of any stratification seems plausible. However, these results can not be extended to deeper bodies of water in the field. Many factors such as toxicant solubility in water temperature of the treated water, speed of kill of the toxicant, water movement, larval activity and behavior, and above all, the stability of the toxicant, undoubtedly would influence the effectiveness of a larvicide in deep bodies of water.

It is premature to assume that all toxicants would distribute evenly in deep or shallow bodies of water at the same rate. Bowman *et al.* (1959) showed unequal distribution of DDT in water in test jars and indicated appreciable loss of DDT due to codistillation with water. It is therefore possible that different gradients of concentrations will be maintained by the application of the several toxicants for various periods. Concentration gradients in deep water will be from top to bottom for liquid formulations, and from bottom to top for granular formulations.

It is interesting to note that the dosages administered on the basis of surface area of the water for some of the materials are relatively high and cost-wise prohibitive. This is, of course, due to the greater depth of the water. To maintain effective toxicant concentration, high rates per acre for these materials have to be employed. For maintaining the same toxicant concentration in shallow bodies of water, lower rates per surface area would be needed to result in good kill of the larvae.

Although emulsifiable concentrate formulations of several materials were found to be highly effective, the use of such formulations for the routine control of mosquitoes in the vats was not desirable. Hazard of handling liquid formulations, acquisition of spraying equipment, and the time involved in the spray operation prompted a test of the effectiveness of granular formulations of several insecticides.

Granular Formulations. Granular formulations of parathion, American Cyanamid E.N. 18133 (*O,O*-diethyl *O*-2-pyrazinyl phosphorothioate), and Bayer 29493 [*O,O*-dimethyl *O*(4-[methylthio]-*m*-tolyl) phosphorothioate] were evaluated at fairly high concentrations. These three toxicants were found to be highly effective against mosquito larvae in the San Joaquin Valley (Mulla *et al.* 1960). Two of the parathion formulations were prepared in the laboratory and the remaining formulations were obtained from commercial sources. The objective of this test was to determine the residual activity of the formulations in the vats, but the vats were drained 7 days after treatment. No data, therefore, could be obtained on long-term control of mosquitoes in the vats beyond one week after treatment.

TABLE 3.—Effectiveness of granular insecticides against fourth-instar larvae of *Culex pipiens quinquefasciatus*[1] placed in olive vats

Granular insecticide	Particle size	Dosage (P.P.M.)	Avg. 24-hour percent mortality of mosquito larvae days after treatment		
			2	3	7
2% Parathion[2]	16/30	0.1	96	100	100
2% Parathion[3]	16/30	0.1	100	100	100
2% Parathion-D[4]	18/24	0.1	8	4	98
		0.2	36	4	32
2% Parathion-N[4]	16/22	0.1	2	2	8
		0.2	100	100	100
5% EN 18133[5]	8/40	0.1	100	100	100
		0.2	100	100	100
5% Bayer 29493[6]	30/60	0.1	100	100	100
		0.2	100	100	100
Check		—	0	0	0

[1] From a susceptible laboratory colony.
[2] Parathion impregnated on A-LVM attapulgite granules in the laboratory using AR-60 as solvent.
[3] Parathion impregnated on A-LVM attapulgite granules in the laboratory using Chevron Light Solvent as solvent.
[4] Coated-type granules.
[5] Impregnated on Celite granules, solvent not known, American Cyanamid Company.
[6] Chemagro Corporation, coated-type granules.

Parathion granules prepared in the laboratory proved to be effective at 0.1 p.p.m. and one commercial formulation proved to be effective at the 0.2 p.p.m. concentration (Table 3). No difference between the two laboratory formulations prepared with Chevron Light Solvent and AR-60 could be ascertained at such a high toxicant concentration (0.1 p.p.m.). None of the commercial parathion granules proved effective at 0.1 p.p.m. concentration. But granular formulations of E.N. 18133 and Bayer 29493 were highly effective at the concentrations used.

Small quantities of granular insecticides can be easily dropped into the vats and much lower rates of the effective formulations can be used for initial kill of the larvae. With some granular formulations there is the possibility of stratification of the toxicant released into water having great depths. Effective formulations of parathion, Bayer 29493, E.N. 18133, and other larvicides used at 0.1 to 0.2 p.p.m. probably will control mosquitoes in the vats for a period of 2 to 4 weeks. Stable materials such as E.N. 18133 are liable to result in larval kill for longer periods after treatment.

References

BOWMAN, M. C., ACREE, F., JR., SCHMIDT, C. H., and BEROZA, M. 1959. Fate of DDT in larvicide suspensions. Jour. Econ. Ent. 52(6):1038–42.

MULLA, MIR S., ISAAK, LEWIS W., and AXELROD, HAROLD. 1960. Laboratory and field evaluation of new insecticides against mosquito larvae. Mosq. News 20(3):256–61.

RAI, LALLAN, and LEWALLEN, LAWRENCE L. 1960. Effect of varying depths of water with identical surface area on mosquito larval mortality using commercial malathion and parathion emulsion concentrates. Mosq. News 20(3):271–4.