ARTICLES

FIELD STUDIES WITH WATER-SOLUBLE INSECTICIDES FOR THE CONTROL OF MOSQUITO LARVAE IN CALIFORNIA PASTURES[1]

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In laboratory studies Bayer L 13/59 (*O,O*-dimethyl 2,2,2-trichloro-l-hydroxyethylphosphonate) was found to be outstanding among various mosquito larvicides tested in water solutions (Gahan *et al.* 1955b). It is completely effective against fourth-instar larvae of *Anopheles quadrimaculatus* Say at about 0.5 p.p.m. It is more soluble in water than most insecticides, and 4 gallons of a saturated solution contain enough insecticide to treat 1,000,000 gallons of water. Indoor storage for 20 weeks and outdoor exposure to sunlight 5 days each week for 4 weeks had no deleterious effect on the toxicity of the compound in solution in distilled water. Since this information was published, Shell OS 2046 (dimethyl 1-carbomethoxy-1-propen-2-yl phosphate) has been found to be slightly more toxic than Bayer L 13/59, and it is completely miscible in water.

In April and May of 1955 field studies were made in California in the vicinity of Visalia and Tulare, to evaluate these two compounds as mosquito larvicides in irrigated pastures. As the rainfall in this section of the State is insufficient to keep pasture grass alive, the fields are flooded every 10 days or 2 weeks with water from wells or large irrigation ditches. The water is introduced at the highest level and gradually works its way through the vegetation to the lower end of the field. In some pastures the excess water flows into a ditch that removes it from the premises, but in others no provision is made for disposing of this surplus, which stands until it is absorbed or evaporates. As the soil is heavy and does not readily absorb water, portions of some fields remain covered for more than a week.

These conditions create excellent habitats for tremendous populations of mosquitoes. Ecological studies conducted by S. Davis and R. C. Husbands[2] in pasture areas of this type have demonstrated that 80 to 90 percent of the mosquitoes are *Aedes nigromaculis* (Ludl.), generally about 5 percent are *Aedes dorsalis* (Meig.), and the remainder are largely *Culex tarsalis* Coq., its density depending upon the age and condition of the pasture. According to W. Donald Murray and Marvin C. Kramer (personal communication), the infestations normally present in the fields used for these studies were at least 95 percent *A. nigromaculis*.

EXPERIMENTAL PROCEDURE. Pastures on five farms were used in these studies. Farmers in this part of California usually divide their pastures into sections 25 to 50 feet wide by constructing longitudinal levees, or borders, the full length of the

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[1] This work was conducted in part under funds allotted by the Department of the Army to the Entomology Research Branch. W. Donald Murray and Marvin C. Kramer, of the Delta and Tulare Mosquito Abatement Districts, respectively, and R. C. Husbands, of the Bureau of Vector Control, assisted in these studies. The Chemagro Corporation supplied the Bayer L 13/59 and the Shell Development Company the Shell OS 2046.

[2] Progress report on irrigation practices and mosquito production 1954. Cooperative study by U.S.D.A., Soil and Water Conservation Research Branch; California Department of Public Health, Bureau of Vector Control; and California Mosquito Control Association, Inc.

fields. These sections are commonly called checks, and each plot used for treatment consisted of a single check. Since there were from 6 to 20 checks in a field, obtaining untreated plots for comparative purposes was no problem.

To insure adequate water to support mosquito breeding, an unusually large quantity was introduced into all the plots. In practical mosquito-control operations less chemical would be needed than was used in these tests.

It was necessary to know the rate of water flow while the irrigation was in progress. If the pump was calibrated, no additional measurement was made, but if its capacity was not known, a circular dam, 6 to 8 inches high, was built around the water-line opening and the water entered the plots through a Parshall flume set in the wall of the dam (Fig. 1). If this apparatus was maintained in a level position, the water flow could be determined from the head pressure behind the throat of the flume. The flow rate was controlled by valves in the water line.

The chemicals were added to the water with the automatic applicator described by Gahan *et al.* (1955a). This device, attached to a 55-gallon drum, was set up at the point of greatest turbulence where the water entered the field. In the fields flooded from wells, the insecticides were introduced as the water bubbled from the valve or collected in the pool formed by the circular dam. In the field flooded from an irrigation ditch, they were applied near the point where the water entered a flume. Because of the range in the rates of water flow and the rates of application of the insecticide, the concentration of the solution dispensed from the reservoir ranged from 0.028 to 2.6 percent.

In large-scale operations this applicator

Fig. 1. Introducing water-soluble insecticides into irrigation water that enters a pasture through a Parshall flume.

would probably be located at the irrigation pump and discharge into the large standpipe, if one is used, or directly ahead of the discharge pipe to treat all the water delivered to the fields. Where ditch irrigation is employed, the apparatus could be located at a large Parshall flume, or weir, that would be needed in the main ditch to measure the rate of flow. In this way large areas could be treated from a single source, and advantage could be taken of the turbulence that occurs at such places to get good agitation.

Initial applications were made on the Simoes farm with Bayer L 13/59 in three concentrations in each of two pastures that consistently had been heavy breeders. The plots were 250 to 400 feet long and 40 feet wide. Because the porosity of the soil was not uniform, the amount of water introduced in the different plots ranged between 78,500 and 131,200 gallons per acre. From 0.112 to 0.118 pound of L 13/59 was applied per acre to give 0.1 p.p.m., from 0.73 to 0.88 pound to give 1 p.p.m., and 3.08 to 3.18 pounds to give 3 p.p.m.

To determine whether a soluble insecticide would remain effective after the treated water had traveled a long distance through the fields, on two farms a plot approximately a half-mile long was treated with L 13/59 at 1 p.p.m. On the Grant farm 825,200 gallons of water were applied, which gave a dosage of 2 pounds of the insecticide per acre, and on the Gray farm 162,000 gallons of water, which gave 0.86 pound of insecticide per acre.

On two farms Shell OS 2046 was used to give a concentration of 1 p.p.m. A plot 320 by 30 feet on the Jennings farm and one 720 by 27 feet on the Canada farm were treated with 0.71 and 1.2 pounds per acre, respectively. On the Canada farm an irrigation ditch was used as the source of water. For this test the Parshall flume was set in the bank of the ditch and the measured water flowed into the field through a funnel-like, constricted area made with two dirt walls 4 to 6 inches high. With this arrangement the hydrostatic pressure was very difficult to control, and the flow did not remain constant for more than 15 or 20 minutes. It is believed that the amount of chemical that this plot actually received was somewhat greater than 1 p.p.m.

The effectiveness of the treatments was determined by dipping for larvae in the treated and nearby untreated areas. The number of dips ranged from 20 to 150 per plot, according to the time available and the amount of water present. Counts were made on the first and second days after flooding, and sometimes also on the third day. A percentage control figure was obtained on the supposition that the larval densities in treated and untreated areas would have been identical had no insecticide been applied. In addition to these field observations, two 1-quart samples of water were removed from the lower end of each treated and untreated plot, and partially grown *Aedes* larvae collected from other fields were exposed in them to determine the knockdown and 24-hour mortality.

RESULTS. Counts of Larvae Obtained by Dipping. As shown in table 1, all but two of the treated plots were completely free of mosquito larvae. In one of the plots treated with L 13/59 at 1 p.p.m., 3 larvae were found in 40 dips on the following day, but since the same number of dips on each of the next 2 days produced no larvae, it is probable that this application also eventually gave 100 percent control. Larvae were never found in the other three plots receiving this concentration, including those a half-mile long. Some control was indicated with L 13/59 at 0.1 p.p.m., but this concentration was definitely inferior to the others.

At the Simoes farm the infestations in the untreated plots were sufficiently high to demonstrate clearly that the insecticide applications were successful. On all the other farms the larval density was low and the reduction in numbers in the treated plots, though complete, was less impressive. The unusually rainy and cold weather during the 2 weeks prior to these tests may explain in part the low populations encountered.

TABLE 1.—Control of *Aedes* larvae in pastures treated with Bayer L 13/59 and Shell OS 2046, as determined by larval counts

Farm	Parts per million of insecticide [1]	Number of dips: Treated plots	Number of dips: Untreated plots	Number of Larvae per dip: Treated plots	Number of Larvae per dip: Untreated plots	Percent control
			Bayer L 13/59			
Simoes	3	220	120	0	70	100
	1	220	120	0.01	10	99.9
	0.1	200	160	5	19	74
Grant	1	200	350	0	0.14	100
Gray	1	200	200	0	.25	100
			Shell OS 2046			
Jennings	1	100	100	0	.09	100
Canada	1	100	100	0	.19	100

[1] Two replicates at each concentration on Simoes farm, one on the others.

Toxicity of Water Samples. The first water samples were removed from the plots on the second day after the insecticide was applied, and larvae were introduced into them immediately. From 44 to 100 larvae were introduced per sample. All treatments caused 100 percent mortality within 24 hours. The knockdown obtained with water from the Grant and Gray farms, collected approximately a half-mile from the point at which L 13/59 was introduced, was as rapid as that with water from the much smaller field on the Simoes farm, being complete in 2–3 hours. These results show that water containing this insecticide in solution can flow considerable distances without losing its toxicity. At 0.1 p.p.m. it was slow in action, as only a small percentage of the insects were down after 10 hours. OS 2046 caused total knockdown in 1 hour in the water from the Canada farm, but more than 16 hours were required in the sample from the Jennings farm.

Lack of Residual Toxicity of Bayer L 13/59. The water samples collected on the Simoes and Grant farms were held until the eighth day, at which time others were taken from the same locations and comparative toxicity tests were run against second- and third-instar *Aedes* larvae. The samples taken on the second day again caused 100 percent mortality, whereas one of those collected on the eighth day caused 34 percent mortality and the others caused none.

After the plots on the Simoes farm had dried, 23 days after the first flooding, they were reflooded with untreated water. Counts made on the first and second days after the fresh water was added showed larvae to be present in all sections of the field and more numerous in the places that previously had been treated with L 13/59. The Delta Mosquito Abatement District had sprayed the untreated plots with parathion at the rate of 0.1 pound per acre when the larvae from the previous brood reached the fourth instar. These observations showed that L 13/59 did not have any residual toxicity. Phosphorus insecticides have been known to be unstable in an alkaline medium, and it is likely the high alkali content of the soil of the these fields had a deleterious effect on the insecticides.

SUMMARY. Field tests were made in the vicinity of Visalia and Tulare, Calif., to evaluate the effectiveness of water solutions of the phosphorus compounds Bayer L 13/59 and Shell OS 2046 as larvicides for the control of mosquitoes in irrigated pastures. An automatic applicator was used to introduce the chemical into the water as it entered the fields.

Bayer L 13/59 at concentrations of 3 and 1 p.p.m. and Shell OS 2046 at 1 p.p.m. gave 99.9 to 100 percent control. Incom-

plete control was obtained with Bayer L 13/59 at 0.1 p.p.m.

Tests with *Aedes* larvae in water samples from the plots showed that the treated water lost none of its toxicity while flowing as much as ½ mile through the fields. Samples taken 2 days after application of Bayer L 13/59 were completely effective, but others collected on the eighth day were ineffective. There was no control in treated plots that were dried and reflooded with untreated water. Lack of residual toxicity may be due to the alkaline soil in the fields that were treated.

References Cited

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AN APPLICATOR FOR ADDING CHEMICALS TO FLOWING WATER AT UNIFORM RATES[1]

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A study of water-soluble insecticides for the control of mosquito larvae in irrigated fields focused attention on the need for an improved applicator for adding chemicals to flowing water.

Wisecup *et al.* (1946) tested various valves, pumps, and siphons for introducing DDT emulsions into rice-field water, but found all needed constant attention for uniform operation. They finally placed primary dependence on drip cans equipped with a metered valve from an oil heating stove, and maintained a constant vigil so the flow could be adjusted as needed.

Knowles and Fisk (1945), who worked concurrently on the same problem, favored a pump ordinarily used for chlorination to transfer water into an airtight bottle and force the displaced air into another airtight bottle that held a DDT emulsion. As the air in the latter bottle increased, the larvicide was ejected through an outlet tube.

Geib and Smith (1949) described a siphon attached to a 50-gallon drum to introduce DDT emulsions into irrigation water in California. The siphon consisted of a small rubber hose and copper tube with a glass metering tip that had an orifice large enough to permit 50 gallons of the emulsion to flow through in 24 hours at about 3 feet of head. The tip was suspended in the irrigation stream. They reported satisfactory operation with this device, but felt that further work was needed on refining the metering tip and on developing an apparatus that would maintain a constant head.

Lt. Comdr. F. R. DuChanois and other U. S. Navy personnel (personal communication) solved the problem of maintaining a constant head by directing the liquid from a reservoir tank into a 5-gallon auxiliary tank in which a steady level was maintained with a float valve similar to those used in toilet flush tanks. The insecticide preparations were released from this auxiliary tank at a uniform rate through a sight needle valve and tube attached near the base of the container.

Maintenance of a constant head is essential to an even discharge from dispensers with a gravity feed, as slight variations in the weight of the water column affect the flow rate. When the water level declines, as it did with some of the dispensers mentioned, the output gradually slows down and may stop completely unless frequent adjustments are made.

The apparatus described in this paper

[1] This work was conducted at the Orlando, Fla., laboratory of the Entomology Research Branch under funds allotted by the Department of the Army.