ARTICLES

RICE FIELD MOSQUITO CONTROL STUDIES WITH LOW VOLUME DURSBAN® SPRAYS IN COLUSA COUNTY, CALIFORNIA. I. INTRODUCTION

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California's annual rice crop is produced on about 350,000 acres, and has a gross value approaching $100,000,000. Approximately three-fourths of the acreage is located in the central Sacramento Valley. Typically, rice fields there are flooded about the first of May. Following flooding and seeding, the water is often lowered or removed to promote early growth. Beginning about the first of June, water is returned and maintained at the season growing depth with a usual maximum of about 10 inches. First drainage occurs around September 1 (depending upon the rice variety) with harvest usually two weeks after the water has been removed.

A mosquito species succession is apparent. On first flooding a hatch of *Aedes melanimon* Dyar often occurs, which can be readily controlled with chemical larvicides. As the field matures and while the newly emerged plants are small, populations of *Culex tarsalis* Coquillett begin to develop in the sparsely shaded warm water. As rice growth progresses, shading and cooling the water, *Anopheles freeborni* Aitken appear and become predominant (Bailey and Gieke 1968). The latter two species, in addition to being serious pests, pose threats to the public health as vectors of arthropod-borne viral encephalitides and malaria.

Modern chemical control attempts began with DDT, with parathion having replaced it over a decade ago. Large scale applications of parathion have been made by aircraft at a dosage rate of 0.1 lb/acre in 0.5 or more gallons of water. The several local mosquito control agencies differ considerably in their criteria as to when, where and how often to treat, and some do not attempt chemical control at all.

Several agencies have relied heavily upon the mosquitofish *Gambusia affinis* (Baird and Girard) either alone or integrated into a chemical control program (Fowler 1964, Russell 1964, Hoy and Reed 1970). The impact of invertebrate predation is under study (Washino 1970).

In spite of research and operational attention directed toward the control of *C. tarsalis* and *A. freeborni* from rice fields, the problem remains one of the most complex facing California's mosquito control agencies. Difficulties in sampling for larvae, in applying chemical larvicides, and in manipulating predators, coupled with the problem that agricultural areas do not yield adequate tax revenues to handle the cost of complete mosquito control with conventional techniques, and further complicated by the fact that the adult mosquitoes are capable of flying great distances (Bailey *et al.* 1965, Bailey and Baerg 1967), all combine to create a set of circumstances that have, more often than not, frustrated control efforts.

Whitesell (1968) reviewed the history of the rice field mosquito problem in Colusa County. Briefly, of the 102,400 acres in the Colusa Mosquito Abatement District, about 20,000 acres are usually planted to rice. An additional 70,000 acres of rice are in the adjacent uncontrolled parts of Colusa County. Rice growing areas in neighboring counties

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are also not completely under mosquito control.

The District was formed in 1958 and has directed most of its control program against *Aedes* spp. from rice fields, duck clubs and pastures. Attempts have been made to utilize parathion to control *C. tarsalis* and *A. freeborni* in rice, based on inspection and treatment of individual fields as deemed necessary. The technique was unsuccessful because of the magnitude of the rice acreage and the difficulty in sampling for larvae in that habitat. Light trap counts show little difference between years when treatment was attempted and years when it was not.

In late 1966, the Department of Agricultural Engineering, University of California at Davis, operating under a 3-year USDA grant to study low-volume insecticide application, applied low-volume Dursban® (then an experimental material) to test plots of noncommercial rice on a federal wildlife refuge in Colusa County. The success of these tests encouraged an outstanding cooperative research project in 1967 in which workers from many agencies and groups participated. The results were summarized in *Down to Earth* (Fall, 1968) as a series of papers by the principals.

The comparative efficacy and nonresistance status of Dursban in the control of *A. freeborni* has since been elucidated by Womeldorf *et al.* (1970). Further work has shown that the differential toxicity against the various instars is significant (Table 1).

Although the results of the 1967 work showed the feasibility of the low volume approach, Dursban was not granted a federal label until the summer of 1968; and then only for noncrop application. Meanwhile, additional plot work was done on the federal refuge to allow collecting rice samples for residue analyses.

On the basis of submitted data, the State of California granted authorization for Dursban to be applied to control mosquitoes in rice at a maximum dosage rate of 0.025 lb/acre with a waiting period of 14 days to harvest. The authorization was received in June, 1969, too late to allow setting up an operational program. However, several tests were made using Dursban M extended with a polypropylene glycol (P 400®), or Dursban ULV (a 2 lb/gal formulation) undiluted or extended with P 400. Two were at a swath width of 132 feet, and three were flown crosswind at a 660-foot swath width utilizing techniques modified from those described by Mulhern (1968). The conditions and results are summarized in Table 2. Both methods of application were shown to be feasible. The importance of allowing 24 or more hours before evaluating field results was also demonstrated.

During the winter of 1969, a meeting

TABLE 1.—Dursban® toxicity against larval *Anopheles freeborni* from uncontrolled areas in the Sacramento Valley, California. Tests performed on field-collected larvae of mixed instars, laboratory-sorted. "First instars" include those less than 2.5 mm long; "second instars" include those 2.5–4.0 mm long.

Date	County	Instar	LC 50	95% Conf. Interval	Slope	LC 90
3–24–70	Placer	2	0.00023	0.00017–0.00030	2.00	0.001
		4 (early)	0.0035	0.0029–0.0043	6.70	0.0055
3–28–70	Tehama	2	0.00028	0.00021–0.00038	6.21	0.00045
		3	0.00071	0.00061–0.00083	4.40	0.0014
		4 (early)	0.0017	0.0013–0.0024	5.72	0.0029
3–28–70	Tehama	1	0.00023	0.00020–0.00028	5.47	0.0004
		2	0.00082	0.0007–0.001	5.22	0.0014
		4	0.014	0.01–0.087	3.80	0.031

Table 2A.—Dursban ® concentrate spray tests: equipment and conditions

Test No.	Date	Acres	Rate: Dosage (lb./A)	Rate: Application (fl. oz./A)	Swath Width (ft.)	Altitude (ft.)	Aircraft	Pressure System	Nozzles: Size	Nozzles: No.	Nozzles: Position	Pressure (psi)	Ground-level Wind (mph)
"Conventional" tests													
1	6–26–69	800	.025	1.6	132	6–10	PA–25–150	CO_2 Unit	80015	3	down & back 45°	15	none detected
2	7–2–69	972	.011	1.4	132	6–10	PA–25–150	Electric gear pump	80015	3	down & back 45°	12–15	5–6
"Crosswind" tests													
3	8–21–69	972	.025	1.6	660	150	PA–25–235	Electric gear pump	D2–25	6	down & forward	22	less than 2 mph, but obviously more at aircraft height
4	8–28–69	740	.025	1.6	660	100	PA–25–150	Wind-driven gear pump	D2–25	4	down & forward 45°	70	ditto above
5	9–4–69	650	.025	1.6	660	100	PA–25–150	Wind-driven gear pump	D2–25	4	down & forward 45°	70	ditto above

TABLE 2B.—Dursban® concentrate spray tests: field results

Test No.	No. Dips	Observ-vation time (hrs)	*Anopheles freeborni*					*Culex tarsalis*				
			1	1	3	4	P	1	2	3	4	P
1	45	Pre	19	3	0	2	1	6	5	0	5	16
		Post 24	0	0	0	0	0	0	0	0	0	0
		Post 108	0	0	0	0	0	1	0	0	0	1
2	60	Pre	3	2	2	0	0	11	7	8	6	2
		Post 24	0	0	0	0	0	0	0	1	0	2
3	260	Pre	Total all instars=29					Total all instars=37				
		Post 12	Total all instars= 8					Total all instars= 6				
4	195	Pre	71	25	16	11	9	3	0	0	0	0
		Post 10	12	5	7	5	7	0	1	0	0	0
		Post 34	3	1	4	3	1	0	0	0	0	0
5	300	Pre	61	33	26	24	6	28	33	14	19	0
		Post 12	0	1	1	1	1	13	23	15	0	1
		Post 36	3	1	0	0	2	6	9	7	0	0

was held for personnel of the University of California, the California Department of Public Health, and several mosquito control agencies to acquaint them with an operational plan outline. Their suggested modifications were incorporated into the final program proposal. A second meeting, some months later, was attended by those who were to participate in the project. The tasks to be included and the variables to be monitored were enumerated, and work assignments were made.

The operational plan as finally developed incorporated the following elements: three applications were to be made, timed to coincide with the expected larval population peaks as confirmed by field population measurements (the first week of June, the third week of July, and the fourth week of August); Dursban would be applied by aircraft as a low-volume formulation at a rate of 1.6 fl oz/acre, and dosage rates of 0.0125, 0.025, and 0.025 lb/acre for the successive treatments, and crosswind swaths of 660 feet width would be used to treat the extensive rice acreage as a block. A second technique would be used to produce a 100-foot-wide swath to dress the edges of individual fields.

Other papers in this series will deal with operational modifications in the 1970 program and those proposed for the future, with the effects upon the mosquito population, and with the results of monitoring environmental and other aspects of the program. The titles of the 5 papers in the series are as follows:

I. Introduction
II. Operational procedures and deposition measurement
III. Effects upon the target organisms
IV. Effects upon aquatic nontarget organisms
V. Effects upon honey bees

The first 3 papers are published in the present issue of Mosquito News, Vol 32 No. 3. The last 2 papers will be published in the next issue (December; Vol 32 No 4.).

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RICE FIELD MOSQUITO CONTROL STUDIES WITH LOW VOLUME DURSBAN® SPRAYS IN COLUSA COUNTY, CALIFORNIA
II. OPERATIONAL PROCEDURES AND DEPOSITION MEASUREMENT

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Mosquito control applications using reduced total applied volumes and finely atomized sprays or coarse aerosols were begun in California several years ago (Burgoyne *et al.,* 1967). Studies were initiated in 1966 under a USDA contract with the University of California at Davis, cooperatively with several mosquito abatement districts, the California Department of Public Health, and other state and federal agencies who aided in setting up extensive low-volume application tests. This work culminated in a large-scale program applying Dursban® and fenthion with both fixed and rotary wing aircraft during the 1967 season in the Colusa Mosquito Abatement District. Several thousand acres of wetlands, planted to rice for waterfowl feed, were sprayed, as were a few hundred acres of rice being grown for seed. Dosage rates were 0.0125 to 0.05 lb/acre for Dursban and 0.075 and 0.1 lb/acre for fenthion. Total volumes varied from 4 to 8 fl oz/acre, with assumed swath widths of 150 ft when using a fixed wing Piper

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