NEW INSECT GROWTH REGULATORS AGAINST FLOOD AND STAGNANT WATER MOSQUITOES-EFFECTS ON NONTARGET ORGANISMS

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ABSTRACT. Six insect growth regulators (IGRs) were screened in the laboratory against 4th instar larvae of *Culex quinquefasciatus* and *Culiseta incidens*. Two of the urea type IGRs Bay SIR–6874 and SIR–8514 showed high activity (LC_{90} about 1–7 ppb) against both species, the former being about 3–4 times as active as the latter. However, since further development of the former was stopped, the latter was studied in the field. The JH type IGRs MV-678 and CGA-19255 were less active, the LC_{90} of MV-678 in the range of 5–70 ppb and that of CGA about 1 ppm. The latter species was the most susceptible. Pupae were not susceptible to these materials.

EC, WP and G (granular) formulations of Bay SIR–8514 and EC and flowable formulations of MV–678 were evaluated in the field against flood- and stagnant-water mosquitoes. *Psorophora columbiae* was the most susceptible, *Aedes nigromaculis* next in susceptibility while *Cx. tarsalis* required the highest rate of application for effective control. Bay SIR–8514 and MV–678 were equally effective in the range of 0.01-0.025 lb/A against *Ps. columbiae*. Against *Ae. nigromaculis* the former compound was effective at 0.01, but MV-678 was effective in the range of 0.05-0.1 lb/A. These same rates of both materials were also needed for effective control of *Cx. tarsalis*. MV-678 produced excellent control for 1 week only, while Bay SIR-8514 prevented adult emergence for more than 2 weeks.

INTRODUCTION

In recent years, the intensity and extent of resistance in mosquitoes to various larvicides in California have been increasing noticeably. In the past 2–3 years, the ubiquitous irrigated pasture mosquito has practically become immune to all registered organophosphate larvicides. The discovery and development of juvenile hormone (JH) and insect growth regulator (IGR) types of compounds have raised new hopes to overcome these difficulties by providing substitute materials against multi-resistant strains (Schaefer et al. 1974). A large number of the IGR type materials were evaluated and found to be highly active against several species of stagnant and flood-water mosquitoes (Jacob and Schoof 1971, Mulla et al. 1974, Mulla and Darwazeh 1976, Schaefer and Wilder 1972, Sharma et al. 1977, Steelman et al. 1975).

From among the many IGRs studied, only methoprene (Altosid®) has gone through registration and has become available for use in mosquito control programs since 1974. Diflurobenzuron or Dimilin® is another very effective IGR against a wide range of mosquito species (Mulla and Darwazeh 1976, and others) but it is still under consideration for registration.

Georghiou et al. (1974) reported that mosquito larvae can metabolize methoprene in the laboratory, a feature which potentially can lead to mosquito tolerance. In addition, standard formulations (EC and SR) of methoprene were found to be short-lived, producing control of asynchronous species of mosquitoes for only 2–4 days (Mulla and Darwazeh 1975).

The present studies were conducted to evaluate several formulations of new experimental IGRs, and to determine their effectiveness against susceptible as well as resistant strains of flood-water and stagnant water mosquitoes in the laboratory and under field conditions, and to assess their impact on the most common nontarget organisms.

METHODS AND MATERIALS

LABORATORY. Six materials were evaluated in the laboratory against larvae and pupae of a laboratory colony of *Culex quinquefasciatus* (Say), and *Culiseta incidens* (Thomson). Technical grade materials of Bay SIR-6874 [1 - (3, 5 - dichloro - 4)4 - nitrophenoxyphenyl) - 3 - (2)chlorobenzoly)-urea], Bay SIR-8514[1 - (4-trifluoromethoxyphenyl) - 3 - (2)chlorobenzoyl) - urea], CGA-19255 (6-azido-N-cyclopropyl - N' - ethyl - 1, 3, 5-triazine, 4-diamine) and Stauffer MV-678[2-methyl-9 - (*p* - isopropylphenyl - 2,6 - dimethylnonane] were utilized to prepare (1%) stock solutions in acetone, and serial dilutions were prepared as needed. For bioassay, twenty 4th stage larvae or pupae were placed in disposable styrofoam bowls (Amoco China foam No. 612) containing 200 ml of tap water, and the required amount of toxicant was added (0.2-1.0 ml of the acetone solution) to yield the desired concentrations in ppb. Larvae were fed ground lab chow mixed with brewer's yeast at 3:1 ratio immediately after treatment and then at 2- to 3-day intervals. Food was provided after dead larvae, pupae and adults were counted and removed with a disposable eye dropper, until complete mortality was achieved or surviving larvae pupated and emerged as adults. Each concentration and check were run in duplicates, utilizing 3–4 concentrations per material. Each material was tested on 2–3 different occasions to account for day to day variations. LC_{50} and LC_{90} estimates in ppb were obtained from dosage response lines on a probit log paper based on mean mortality values versus log concentrations.

FIELD. Those IGRs which showed high biological activity in the laboratory were evaluated further under field conditions. Field trials were conducted against OP resistant *Aedes nigromaculis* (Ludlow) in Tulare County, and *Psorophora columbiae* (Dyer and Knab) in the Palo Verde Valley of southern California and *Cx. tarsalis* Coquillett at the Aquatic Research Facility of the University of California, Riverside, located in the Coachella Valley of southern California.

In the Palo Verde Valley, tests were conducted in tail water of alfalfa fields located on C and D Blvd., half-mile south of 10th Ave., north of the City of Blythe. In Tulare County, the studies were conducted in Kings County Truck Line pastures located on Ave. 120 and Road 88, and in Toste pastures located on Ave. 160 and Road 80. All test plots were 1/32 acre in size, utilizing 2 plots per application rate, and 2 plots were left untreated as checks in each location. The materials tested were formulated by the suppliers as WP, EC, granules, encapsulated or flowable concentrates. The required amount of WP, EC and flowable formulations were mixed with 500 ml of tap water, and applied with ½ gal stainless steel hand sprayer in 4 swaths for complete coverage. In order to apply the granular formulation evenly, a 3 oz. (capacity 90 g) salt shaker was filled to capacity with blank Coachella Valley sand, and several dry runs were made, and number of swaths and speed required were determined. The needed amount of granules then was placed in the shaker and blank sand was added to fill the shaker. After mixing thoroughly, the entire amount was applied in 6 swaths, covering the entire plot. At the time of treatment, mosquito larval population consisted of 2–3 stages.

Larval counts in Tulare County were taken prior to treatment and 24, 48 and 72 hrs after treatment, although data for all these intervals may not be reported. In addition to larval assessment, surviving 4th stage larvae and pupae were removed 24 and 48 hrs after treatment respectively from the treated plots and checks. The larvae and pupae were isolated in 4-oz dixie cups at Tulare Mosquito Abatement District. Ten larvae or pupae were placed per cup (2 cups/plot) each containing 100 ml of the field water which was collected from each plot. Mortality of larvae, pupae and adults in each treatment was assessed and the percent inhibititon of emergence (% EI) was determined after all organisms either died or reached the adult stage. However, in the Palo Verde Valley, due to rapid development of *Ps. columbiae*, larval assessment was monitored more frequently and at closer intervals, by taking 10 dips per plot prior to treatment and 12, 24, 36 and 48 hrs after treatment. Also 18 and 24 hrs after treatment, 4th stage larvae and pupae respectively were collected from treated and untreated plots. They were isolated in field water of each plot and monitored as described above. Larval and pupal isolates were placed in the shade, on a table under a tree, outdoors.

The same materials and formulations were also evaluated against *Cx. tarsalis* population at the Aquatic Research Facility of the University of California, Riverside, in Coachella Valley (Mulla and Darwazeh 1975). In brief, this facility consists of 64 ponds, 18 x 18 ft in size, and water level (12 in) in the ponds was maintained by float valves. The granular formulation was applied as described above, while the needed toxicant of EC, WP and flowable formulations were mixed with 100 ml of water and sprayed onto the water surface with a polyethylene squeeze bottle.

Effectiveness of the IGRs tested and their impact on nontarget organisms was determined in the manner reported earlier (Mulla et al. 1975). In brief, mosquito larvae and nontarget organisms present were sampled by taking 5 dips per pond prior to and 3, 7, 14 and 21 days after treatment. The 5 dips were combined and concentrated in a measuring cup provided with 150 mesh stainless steel cloth, then transferred in water into a vial and preserved by the addition of (95%) ethyl alcohol. Organisms present in the sample were identified and counted under stereoscopic microscope in the laboratory.

Inhibition of emergence of mosquitoes was assessed by placing 20 4th-instar *Cx. tarsalis* larvae in each of 2 floating isolation units per pond (Mulla et al. 1974). The floating isolation units were set up 3, 7, and 14 days after treatment, depending on availability of 4th stage larvae in the ponds as well as persistence of materials evaluated.

The isolated individuals were followed until emergence. Mortality in each stage was determined and the final inhibition of emergence was calculated by the formula:

$$\% \text{ inhibition of emergence (EI)} = 100 - \frac{T}{C}\, 100,$$

where T = emergence or survival in treatments, and C = emergence or survival of isolated individuals in untreated ponds (checks). The % reduction in the population of immature stages (3–4th stage larvae and pupae which was assessed by dipping) was calculated by the formula:

$$\% \text{ reduction } (\%R) = 100 - \frac{\text{Posttreatment}}{\text{Pretreatment}}\, 100.$$

RESULTS AND DISCUSSION

LABORATORY. Bay SIR-6874 was the most effective urea type IGR tested producing 90% inhibition of emergence at 0.6 ppb against 4th stage larvae of *Cs. incidens* (Table 1). This material and Dimilin® (diflurobenzuron) however, were almost equally effective against *Culex quinquefasciatus* with an LC_{90} in the range of 1.5-1.8 ppb. Bay SIR-8514 was less effective than its analog Bay SIR-6874 against larvae, but was far more effective against the pupae. Both Dimilin and Bay SIR-8514 were equally effective against the *Culex* pupae, causing 90 percent mortality at 120 ppb (Table 1). In general, none of the materials are considered to have sufficient activity against the pupae at practical rates.

Methoprene (Altosid) and Stauffer MV-678 were less effective than the urea type IGRs, but both materials were active against both mosquito species tested with an LC_{90} in the range of 50–70 ppb against *Culex* and 5–10 ppb against *Culiseta* lar-

Table 1. Susceptibility of mosquito larvae and pupae to various (IGRs) in the laboratory.

	LC_{50}–LC_{90} ppb		
	Cx. quinquefasciatus		*Cs. incidens*
IGRs	Larvae	Pupae	Larvae
diflubenzuron	0.5–1.5	60–120	0.3–0.8
Bay SIR-6874	0.7–1.8	1000–5000+	0.2–0.6
Bay SIR-8514	2.0–6.8	60–120	0.8–1.5
methoprene	10.0–50.0	4000–5000+	3.0–10.0
MV-678	17.0–70.0	5000+ —	2.5–5.0
CGA-19255	350.0–1000.0	—	— —

vae. The azidotriazine type IGR CGA-19255 (considered as antimetabolite) was the least effective requiring 1 ppm to achieve 90 percent mortality (Table 1).

FIELD. The IGRs produce various degrees of mortality in the various stages of the immature individuals developing from the treated cohorts. Some IGRs such as the JH type induce most of the mortality in the pupal stage with some mortality occurring in the larval and adult stages. The urea type IGRs, for example diflurobenzuron, induce most of the mortality in the larval instars with some mortality also occurring in the pupal stage and the adults. To determine stage related mortality, both larval assessment techniques of the aquatic stages by dipping and isolation of surviving larvae and pupae were employed. It should be noted that low to mediocre reduction in the larval and pupal populations in the treated plots does not provide a sound basis for determining efficacy of IGRs. This assessment has to be supplemented by gathering data on the development and mortality of the surviving individuals by isolating them and observing their development up to the point of adult emergence from the treated population isolated.

In the field, the 2 formulations of Bay SIR-8514 (EC 6.5% and 25 WP) produced different results when assessing the abundance of larvae and pupae of *Ps. columbiae* in the plots (Table 2). The EC formulation for example produced little or no reduction in the surviving larvae and pupae. In contrast the WP formulation yielded a relatively higher level of reduction. There is a good deal of variability in the various treatments, and this is to be expected, as the level of development of this species is so rapid that slight variation in developmental stages and the effects of formulations can lead to variable data as shown in Table 2. The results of the isolation units as discussed later will lend support to the similarity of the 2 formulations. MV-678 (EC) at both rates evaluated yielded similar results. Similar results were also obtained with the flowable formulation of this compound, but at the highest rate the % reduction was markedly lower and this is probably due to the slow rate of development of larvae in this treatment. It is possible that the high rate caused delay in larval development, while the lower rates allowed larvae to reach the 4th and pupal stages, where bulk of the mortality occurred. Further studies, however, are needed to confirm these findings.

Bay SIR-8514 (25 WP) caused complete inhibition of emergence in the larval isolates, and in the higher rate no pupae survived for isolation, while 94% EI was obtained at the lower rate (0.005 lb/A) in the pupal isolates (Table 3). The EC formulation of this material caused 58, 92 and 100% inhibition of emergence in the larval isolates, and 28, 89 and 100% in the pupal isolates at the rate of 0.0025, 0.005 and 0.1 lb/A respectively. From the combined evidence presented in Tables 2 and 3, it is apparent that the EC and WP for-

Table 2. Evaluation of various IGRs against *Ps. columbiae* in tail water of alfalfa fields in the Palo Verde Valley of southern Calif. (Blyth, 1978).

Material and formulation	Rate lb/A	Avg no of larvae and pupae/10 dips pre & posttreat (hr)							
		Pretreat		24			48		
		L	P	L	P	(%R)	L	P	(%P)
SIR-8514	0.0025	47	0	0	215	0	Dried up[a]		
EC (6.5%)	0.0050	133	0	101	51	0	120	135	0[ab]
	0.0100	813	0	850	0	0	520	0	36[a]
SIR-8514	0.005	370	0	30	8	90	10	6	96[a]
25 WP	0.010	411	0	50	7	0	152	4	62[a]
MV-678 EC 4	0.050	187	0	59	33	51	18	5	88[a]
	0.100	348	0	92	32	64	24	20	87[a]
MV-678[c] 1.5 S	0.025	62	0	109	28	0	4	6	84[b]
	0.050	118	0	31	77	8	5	2	94[b]
	0.100	420	0	828	13	0	165	185	17[b]
Check	—	419	0	502	215	0	469	174	0

[a] No pupal skins or newly emerging adults observed on water surface 48 hrs posttreatment while the checks had these, thus indicating delay in development.

[b] Many dead adults and pupal skins observed on water surface. Some teneral adults observed in plots.

[c] Formulation hard to mix with water.

mulations are equally effective against this species.

When the surviving immatures were isolated, complete mortality occurred in the larval and pupal isolates collected from test plots treated with MV-678 EC 4 (Table 3). The flowable formulation (1.5/S) also caused complete mortality in the larval isolates, while 72–73% inhibition of emergence in the pupal isolate was obtained at the rates of 0.025-0.1 lb/A. The EC formulation of MV-678 seems to be better than the flowable formulation.

Against *Ae. nigromaculis,* all 3 formulations of Bay SIR-8514 produced high but similar mortality in the immature stages

Table 3. Evaluation of various IGRs against *Ps. columbiae* in alfalfa fields in Palo Verde Valley of Calif.[a] (Blyth, 1978).

Material and formulation	Rate lb/A	Avg (%) cumulative mort in isolation units						
		4th stage larvae				Pupae		
		L	P	A	(% EI)	P	A	(% EI)
SIR-8514	0.0025	30	25	10	58	25	15	28
EC (6.5%)	0.0050	34	39	20	92	52	39	89
	0.0100	87	13	0	100	No Pupae		100
SIR-8514	0.005	72	28	0	100	67	28	94
25 WP	0.010	75	25	0	100	No Pupae		100
MV-678	0.05	75	25	0	100	100	0	100
EC 4	0.10	85	15	0	100	100	0	100
MV-678	0.025	60	40	0	100	78	0	73
1.5 S	0.050	95	5	0	100	63	15	73
	0.100	60	40	0	100	50	27	72
Check	—	7	8	1	16	8	9	17

[a] Air temp. during experiment 80°F min.–104°F max.

(Table 4). In general, the reduction in the immature population was nil to low at the 0.005 lb/A but almost complete at the 0.025 lb/A. This is to be noted from the fact that there were no pupae in the plots treated with the high rate of Bay SIR-8514, after 72 hrs. The 0.01 lb/A rate also produced a very high level of mortality. The 2 formulations of MV-678 yielded mortalities of the immature stages in the mid range at the 2 higher rates. However, since this material induces high mortality in the late pupae or during eclosion of the adults, 100% inhibition of emergence was obtained at the highest rate (see Table 5). Pupal density in MV-678 treated plots and checks was high suggesting that most of the mortality is occurring in the larval instars during transformation to the pupae in plots treated with Bay SIR-8514 (Table 4). On the other hand, it was noted that most of the mortality occurred in the pupal stage in plots treated with MV-678.

In assessing the delayed effects by isolating surviving larvae and pupae, all formulations of Bay SIR-8514 were equally effective at the rates of 0.01 and 0.025 lb/A in producing 93-100% inhibition of emergence in the larval and pupal isolates of surviving populations (Table 5). At the lowest rate (0.005 lb/A), a somewhat lower level of inhibition of emergence was obtained with the EC formulation, but the same rate of the 25 WP and 0.5 G were more effective, causing 73-80% inhibition of emergence (Table 5).

After evaluation of the urea type IGR Bay SIR-8514 and the terpenoid type IGR MV-678 against floodwater mosquitoes, they were then studied against the stagnant-water mosquito *Cx. tarsalis* in natural ponds. The former IGR, in general, produced marked reduction in the immature stages at the 2 higher rates of 0.05 and 0.10 lb/A (Table 6). It is important to note that marked reduction in the density of 1–2 instars (not shown in the table) and pupae occurred with all 3 formulations applied at these 2 higher rates, when compared to the pretreatment and check populations. The overall reductions (based on 3–4 instars and pupae

Table 4. Evaluation of various IGRs and their formulations against larvae of *Ae. nigromaculus* in irrigated pastures of Tulare County[a] (1978).

Material and formulations	Rate lb/A	Avg no of larvae and pupae/10 dips pre & posttreat (hr)							
		Pretreat		48			72		
		L	P	L	P	(%R)	L	P	(%P)
SIR-8514	0.005	212	0	193	239	0	7	220	0
EC (6.5%)	0.010	295	0	119	47	44	0	20	93
	0.025	268	0	69	35	61	0	0	100
SIR-8514	0.005	97	0	80	121	0	—	—	—
25 WP	0.010	66	0	17	16	50	—	—	—
	0.025	116	0	7	9	87	—	—	—
SIR-8514	0.005	109	0	134	106	0	2	74	30
0.5 G	0.010	394	0	70	59	67	1	39	90
	0.025	397	0	23	1	94	0	0	100
MV-678	0.010	140	0	63	77	0	—	—	—
EC 4	0.025	104	0	15	34	53	—	—	—
	0.050	77	0	16	23	50	—	—	—
MV-678	0.010	152	0	120	109	0	1	139	8
1.5 S	0.025	323	0	81	199	13	5	161	47
	0.050	659	0	163	184	47	2	180	72
Check	—	301	0	252	162	0	5	407	0

[a] Air temp. during experiment 68°F min.–100°F max.

Table 5. Evaluation of various IGRs and their formulations against larvae of *Ae. nigromaculis* in irrigated pastures of Tulare Co. (1978).

Material and formulations	Rate lb/A	Avg (%) cumul mort in isolation units: Larval isolates L	P	A	(% EI)	Pupal isolates P	A	(%
SIR-8514	0.005	35	0	5	38	5	10	15
EC (6.5%)	0.010	97	0	3	100	45	55	100
	0.025	100	0	0	100	No Pupae		100
SIR-8514	0.005	29	14	31	73	dried		
25 WP	0.010	85	15	0	100	dried		
	0.025	94	6	0	100	dried		
SIR-8514	0.005	68	0	13	80	28	45	73
0.5 G	0.010	90	0	5	95	35	58	93
	0.025	100	0	0	100	No Pupae		100
MV-678	0.010	61	6	15	81	dried		
EC 4	0.025	40	14	29	82	dried		
	0.050	40	28	23	91	dried		
MV-678	0.010	30	5	10	43	5	3	8
1.5 S	0.025	18	5	0	21	3	7	10
	0.050	65	10	15	90	33	58	91
Check	0	0	0	3	3	0	0	0

only) were noticeable up to 14 days posttreatment when the experiment was terminated.

To assess the delayed effects of Bay SIR-8514, cohorts of surviving larvae were isolated for detailed observations (Table 7). At the 2 lower rates (data for 0.01 not included), inhibition of emergence during the 2-week period ranged from 0–67% in plots treated with the 3 formulations. It is therefore concluded that these rates are not adequate for desired control of *Cx. tarsalis*. The 2 higher rates (0.05 and 0.1 lb/A) produced very high to complete inhibition of emergence in the isolated cohorts when

Table 6. Evaluation of various formulations of the IGR Bay SIR-8514 against *Cx. tarsalis* in experimental ponds[a] (Coachella Valley, 1978).

Formulation	Rate lb/A	Avg no of larvae and pupae/5 dips pre & posttreat (days): Pretreat 3-4	Pretreat P	7: 3-4	7: P	7: (%R)	14: 3-4	14: P	14: (%P)
EC (6.5%)	0.010	50	33	35	48	0	65	6	14
	0.025	81	19	11	5	84	37	1	62
	0.050	36	1	18	1	49	2	1	92
	0.100	17	5	10	1	50	0	0	100
25 WP	0.010	50	17	9	13	67	32	2	49
	0.025	69	20	15	19	62	21	3	73
	0.050	17	0	3	0	82	1	1	88
	0.100	30	4	33	4	0	3	0	91
0.5 G	0.010	60	26	51	20	17	80	4	2
	0.025	47	4	8	11	63	9	2	78
	0.050	15	10	6	4	60	0	2	92
	0.100	18	4	11	2	41	1	0	91
Check	—	78	19	70	27	0	50	17	31

[a] Water temp. 42°F min.–60F max.

Table 7. Mortality and inhibition of emergence of *Cx. tarsalis* from isolated larvae in ponds treated with the IGR SIR-8514 formulations (Coachella Valley, 1978).

Formulations	Posttreat (days)	Avg (%) cumeul. mortality in isolates at rates (lb/A) 0.025 L	P	(% EI)	0.05 L	P	(% EI)	0.10 L	P	(% EI)
EC (6.5%)	3	38	33	67	79	16	94	70	29	99
	7	23	35	44	41	41	76	34	65	99
	14	[a]	—	—	NL	—	100	NL	—	100
25 WP	3	20	44	59	54	40	93	78	22	100
	7	18	29	29	58	30	84	51	49	100
	14	[a]	—	—	NL	—	100	NL	—	100
0.5 G	3	29	29	52	49	51	100	68	32	100
	7	9	13	0	26	74	100	55	45	100
	14	[a]	—	—	NL	—	100	NL	—	100
Check	3	8	4	12	8	4	12	8	4	12
	7	15	10	25	15	10	25	15	10	25
	14	6	5	11	6	5	11	6	5	11

[a] Experiment discontinued due to lack of activity.
NL: No larvae present.

corrected for the check. These rates of application were effective for the entire duration (14 days) of the experiment, suggesting the longevity of these rates to be prevailing beyond 14 days posttreatment. From these data, it appears that the granular treatments were somewhat more effective than the EC and WP formulations. It should also be noted that mortality occurred in both the larvae and pupae. The rate of application needed for *Cx. tarsalis* seems to be 5 times as high as that for *Ae. nigromaculis* (Table 5) and 10 times as high as for *Ps. columbiae* (Table 3).

The 2 formulations of MV-678 evaluated against *Cx. tarsalis* produced similar results in causing reduction in the immature mosquitoes (Table 8). The reduction in density was slight if and when corrected for the changes in the populations in the check.

In studying the delayed effects of MV-678, both rates of application of both formulations resulted in very high to

Table 8. Evaluation of various formulations of the IGR MV-678 against *Cx. tarsalis* in experimental ponds[a] (Coachella Valley, 1978).

Formulations	Posttreat (days)	Avg no of larvae and pupae/5 dips, (%) reduction at rates (lb/A) 0.05 3-4	P	(% R)	0.10 3-4	P	(% R)	Check 3-4	P	(% R)
EC4	Pretreat	18	2	—	30	7	—	78	19	—
	3	21	4	0	29	15	0	93	26	0
	7	6	1	65	35	6	0	70	27	0
	14	5	0	75	6	5	70	50	17	31
	21	12	1	35	4	5	76	28	22	67
1.5 S	Pretreat	34	1	—	29	9	—	—	—	—
	3	24	4	20	18	13	18	—	—	—
	7	28	2	14	18	6	37	—	—	—
	14	12	1	63	4	4	79	—	—	—
	21	17	0	51	12	1	66	—	—	—

[a] Water temp. 42°F min.–60°F max.

Table 9. Mortality and inhibition of emergence of *Cx. tarsalis* from isolated larvae in ponds treated with the IGR MV-678 formulations (Coachella Valley, 1978).

Formulations	Posttreat (days)	Avg (%) cumul. mortality at indicated at rates (lb/A)								
		0.05			0.10			Check		
		L	P	(% EI)	L	P	(% EI)	L	P	(% EI)
EC 4	3	46	49	94	61	39	100	8	4	12
	7	73	21	92	46	54	100	15	10	25
	14	55	13	64	8	14	12	6	5	11
1.5 S	3	100	—	100	23	77	100	8	4	12
	7	74	26	100	9	91	100	15	10	25
	14[a]	45	5	43	14	5	9	6	5	11

[a] Larvae and pupae slowly developing due to cold weather. Experiment discontinued while 4th stage larvae remained alive in isolation units for almost 3 weeks without pupation.

complete inhibition of emergence of adults (Table 9). The inhibition of emergence at both rates lasted for 1 week posttreatment. There was little or no difference in the performance of the 2 formulations. It seems that the effective rates of application of MV-678 are in the range of 0.05–0.1 lb/A, rates similar to those found effective against *Ae. nigromaculis* (Table 5), but somewhat higher than those found for *Ps. columbiae* (Table 3).

Along with the studies on the efficacy of the two IGRs and their formulations against *Cx. tarsalis* in the field, population trends of those organisms sampled by the dipper method were also assessed. Members of the genus *Baetis* mayflies were abundant in the ponds. There was a marked but not complete reduction in the numbers of mayfly naiads only at the highest rate (0.1 lb/A) of Bay SIR-8514 (Table 10). The other rates produced some but not significant reduction. MV-678 at the rates applied (0.05, 0.1 lb/A) produced no reduction in the naiads of this mayfly.

Other nektonic organisms recovered in the dippers in noticeable numbers were dragonfly naiads and diving beetle larvae and adults. None of these organisms was affected adversely by any of the rates or formulations of the two IGRs. It can be said that Bay SIR-8514 and MV-678 at mosquito larvicidal rates have little or no short-term effects on the most sensitive groups of invertebrates such as mayflies.

Table 10. Effect of various IGRs and their formulations against mayfly naiads in experimental ponds (Coachella Valley, 1978).

Material and formulation	Rate lb/A	Avg no per 5 dips pre and posttreat (days)			
		Pre	3	7	14
SIR-8514	0.010	66	96	90	82
EC (6.5%)	0.025	136	58	12	23
	0.050	14	12	21	17
	0.100	13	27	8	5
SIR-8514	0.010	40	90	76	103
25 WP	0.025	141	186	96	70
	0.050	4	1	2	6
	0.100	167	6	6	3
SIR-8514	0.010	55	89	140	144
0.5 G	0.025	67	94	130	111
	0.050	50	92	43	30
	0.100	59	75	17	3
MV-678	0.050	33	57	49	56
EC 4	0.100	20	60	25	24
MV-678	0.050	33	37	30	46
1.5 S	0.100	15	14	13	12
Check	—	186	174	160	187

These materials are effective against mosquitoes at rates lower than those affecting mayfly populations.

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References Cited

Georghiou, G. P., Chi S. Lin and M. E. Pasternak. 1974. Assessment of potentiality of *Culex tarsalis* for development of resistance to carbamate insecticides and insect growth regulators. Proc. Calif. Mosq. and Vect. Cont. Asso. 42:117–8.

Jacob, W. L. and H. F. Schoof. 1971. Studies with juvenile hormone-type compounds against mosquito larvae. Mosq. News 31: 541–53.

Mulla, M. S. and H. A. Darwazeh. 1975. Activity and longevity of insect growth regulators against mosquitoes. J. Econ. Entomol. 68:791–94.

Mulla, M. S. and H. A. Darwazeh. 1976. The IGR Dimilin® and its formulations against mosquitoes. J. Econ. Entomol. 69: 309–12.

Mulla, M. S., H. A. Darwazeh and R. L. Norland. 1974. Insect growth regulators: Evaluation procedures and activity against mosquitoes. J. Econ. Entomol. 67:329–32.

Mulla, M. S., G. Majori and H. A. Darwazeh. 1975. Effects of the insect growth regulator Dimilin® or TH-6040 on mosquitoes and nontarget organisms. Mosq. News 35: 211–16.

Schaefer, C. N., W. H. Wilder, F. S. Mulligan, III and E. F. Dupras, Jr. 1974. Insect development inhibitors: Effects of Altosid®, TH-6040 and H-24108 against mosquitoes (Diptera:Culicidae). Proc. Calif. Mosq. & Vect. Cont. Asso. 42:137–39.

Schaefer, C. H. and W. H. Wilder. 1972. A practical evaluation of insect developmental inhibitors as mosquito control agents. J. Econ. Entomol. 65:1066–71.

Sharma, V. P., Batra, C. P. and Brooks, G. D. 1977. Control of *Culex pipiens fatigans* Wied. in drains using a growth regulating compound, OMS-1390. J. Com. Dis. 9:136–38.

Steelman, C. D., J. E. Farlow, T. P. Breaud and P. E. Schilling. 1975. Effects of growth regulators on *Psorophora columbiae* (Dyar and Knab) and nontarget aquatic insects species in rice fields. Mosq. News 35:67–75.