ACTIVITY OF NEW FORMULATIONS OF METHOPRENE AGAINST MIDGES (DIPTERA: CHIRONOMIDAE) IN EXPERIMENTAL PONDS

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ABSTRACT. The IGR, methoprene, in 3 solid (Altosid® Pellet, Altosid® XR Briquet and a granular) and a liquid formulation (A.L.L.) was evaluated against chironomid midges in experimental ponds. The A.L.L. was applied at 0.293 liters/ha (0.015 kg AI/ha) and at 5.86 liters/ha (0.28 kg AI/ha). The granules, pellets and briquets were applied at 13 kg/ha (0.17 kg AI/ha), 5.6 kg/ha (0.22 kg AI/ha) and one briquet/ 8 m^2 (0.82 kg AI/ha), respectively. The low rate of A.L.L. was ineffective, but the high rate produced 84–100% control of Tanytarsini and 30–100% of Chironomini during 2 wk posttreatment. The granular formulation gave 61–87% control of total midges in 2 wk posttreatment. Altosid Pellets gave initial and prolonged good control of Tanytarsini (64–99% for 7 wk), Chironomini (79–94% for 5 wk) and total midges (64–98% for 7 wk). The briquets at almost 4× the rate of pellets, yielded 38–98% control of midges for 7 wk posttreatment. Altosid Pellets have an excellent potential for midge control.

INTRODUCTION

In recent years, numerous natural or man-made lentic and lotic habitats in urban and suburban areas exposed to intensive human use (residential, recreational, agricultural, etc.) in different parts of the world are becoming increasingly eutrophic. Many of these habitats also receive discharges from point and nonpoint sources. As a consequence, macrofaunal species diversity in these habitats is gradually decreasing and results in the survival and profuse breeding of more pollution-tolerant type of organisms, such as some species of Chironomidae which constitute a major component of the macroinvertebrates (Ali 1991). Man-made lakes developed more recently for residential and recreational purposes, in the sunbelt region of the southern United States, are particularly well suited for midges and support dense larval populations (Mulla 1974, Ali and Mulla 1977, Ali et al. 1978). Adult midges frequently emerge in large numbers, causing a variety of nuisance, economic and occasionally medical (allergies) problems for humans residing or working near the midge breeding sources. Ali (1991) has provided a detailed review of the variety of problems posed by adult midges.

The organophosphate (OP) larvicide, temephos, is the only chemical registered for aquatic midge control in the USA. The benzoylphenylurea insect growth regulator (IGR), diflubenzuron, is also registered for midge control, but only in California under a special local need (24c). At present, there is an urgency to increase the number of available options for midge control in the USA. In many situations, midge larvae have developed tolerance to temephos. There is also evidence of cross-resistance to the OP insecticides (Pelsue and McFarland 1971, Mulla et al. 1971, Ali and Mulla 1978, Johnson and Mulla 1981).

Methoprene, a juvenile hormone analogue, was effective against midges in the laboratory and field (Mulla et al. 1974, 1976). Methoprene may have good potential for midge control, particularly against OP-resistant midges, but until recently there has been little interest by the industry to develop this IGR for midge control. This may have been due to the lack of practical and cost-effective formulations of methoprene, particularly suited for the control of benthic midges. Recently, three solid formulations of methoprene were developed by Zoecon Corporation, Dallas, TX, and made available for testing against midges. These formulations, along with an existing liquid formulation of the IGR, were evaluated for their efficacy against natural midge populations in experimental ponds in Florida.

MATERIALS AND METHODS

The ponds employed in this study are located at the University of Florida's Central Florida Research and Education Center at Sanford. Each artificial earthen pond is 6 × 4 m and is filled with water to a depth of 45–50 cm. The water supply to each pond is from an underground artesian source, with desired water depth maintained by a float valve.

On April 27, 1990, Altosid® Liquid Larvicide (A.L.L.), Altosid® Pellets, Altosid® XR (extended residual) Briquets and an experimental granular formulation of methoprene (SAN 810 I 1.3 GR) were applied to the ponds. Each solid formulation was applied at one rate to 3 ponds (replicates). The A.L.L. was applied at 2 rates with 3 ponds receiving each rate. Three ponds were left untreated as controls. Thus, a total of

18 ponds were utilized in this experiment. The ponds were treated in a randomized block design. To apply A.L.L., the required amounts were mixed with water in 6 separate 0.5 liter squeeze bottles, each containing 300 ml water, and applied evenly to the pond surface. The amount of granules needed in each pond were mixed with 0.5 kg of sterile, clean sand, and the mixture was dispersed evenly over the pond surface. Similarly, the pellets for each pond were mixed with 0.5 kg of blank pellets (no active ingredient) and evenly dispersed over the pond. Three XR Briquets were placed along the long axis of each pond, 1, 2 and 3 m from the bank. The test formulations, percentage of active ingredient (AI), application rates and AI equivalents/ha are summarized in Table 1. All formulations contained the active isomer, (S)-methoprene, of methoprene.

Immediately prior to the treatments and at weekly or twice weekly intervals after treatments, one night's emergence of adult chironomids from the treated and control ponds was assessed. The adult emergence from each pond was sampled with a 30-cm high, metal-cone, submerged emergence trap (Ali 1980) covering 0.25 m^2 of the pond bottom. Two cones were employed in each pond. The water temperature was measured daily during the experiment by using a maximum-minimum thermometer placed permanently in the middle of one pond.

The trapped adults were identified and counted in the laboratory. Suppression or inhibition of midge emergence due to the treatments was calculated by the formula given in Mulla et al. (1971). This formula has provisions for adjusting reductions in the treated areas in relation to any simultaneous increases or decreases of populations in the controls. The pre- and posttreatment midge population data were compared by analysis of variance. The data were transformed to $y' = \log(y + 1)$ (Elliott 1977) prior to analysis, because their frequency distribution was highly skewed to the left, reflecting numerous zero counts.

RESULTS AND DISCUSSION

The experimental ponds generally supported populations of Tanytarsini and Chironomini midges. Species of Tanytarsini were predominant but specific identifications could not be made due to the lack of taxonomic keys. Among Chironomini, *Chironomus decorus* Johannsen, *Chironomus stigmaterus* Say, *Goeldichironomus holoprasinus* (Goeldi), *Polypedilum parvum* Townes and *Apedilum elachistus* Townes were recognized, but most of these species occurred in numbers too small to assess effectiveness of methoprene against individual species; therefore, they were all combined under the tribe, Chironomini. Species of Tanypodinae, *Ablabesmyia mallochi* (Walley), *Coelotanypus concinnus* (Coquillett) and *Tanypus neopunctipennis* Sublette were collected in negligible numbers in a few samples, forming <1–2% of the total midges collected on any sampling occasion.

The effects of different formulations and/or treatment rates of methoprene on chironomid emergence from the ponds can be elucidated from the pretreatment and the periodic posttreatment data on Tanytarsini, Chironomini and total midges presented in Table 2. The low rate of A.L.L. (0.015 kg AI/ha) was ineffective but at the high rate of 0.28 kg AI/ha, A.L.L. induced complete inhibition of emergence of Tanytarsini and Chironomini within 3 and 7 days of posttreatment, respectively. Overall, A.L.L. at the high rate suppressed emergence of adult Tanytarsini, Chironomini, and total midges by 84–100%, 30–100% and 74–99%, respectively, during the 2 wk posttreatment period (Fig. 1). Emergence returned to pretreatment levels or higher in the 3rd wk after treatment. The granular formulation of methoprene at 0.17 kg AI/ha produced 45–87%, 73–100% and 61–87% control of Tanytarsini, Chironomini and total midges, respectively, during 2 wk after treatment.

The effectiveness of granular formulation was lost in the 3rd wk after treatment. Altosid pellets

Table 1. List of test formulations, application rates and percent active ingredient of methoprene applied to experimental ponds, Sanford, FL (April 27, 1990).

Formulations	%(S)-methoprene	Application rate	AI[1] equivalent
A.L.L.[2]	5.0	0.293 liter/ha	0.015 kg/ha
A.L.L.	5.0	5.86 liter/ha	0.28 kg/ha
SAN 810 I 1.3 GR	1.3	13.0 kg/ha	0.17 kg/ha
Altosid pellet	4.0	5.6 kg/ha	0.22 kg/ha
Altosid XR briquet	1.8	1 briquet/8 m^2	0.82kg/ha

[1] AI = Active ingredient.
[2] A.L.L. = Altosid Liquid Larvicide.

Table 2. Effects of the IGR, methoprene (different formulations and/or rates) on chironomid midge emergence from experimental ponds[1] at Sanford, FL (1990).

Tribe	Mean no. (±SD) adult emergence/m² pre- and posttreatment (days)								
	Pretreatment	3	7	14	21	28	35	42	49
				Altosid Liquid Larvicide (0.015 kg AI/ha)					
Tanytarsini	75 ± 70	319 ± 363	411 ± 478	133 ± 154	117 ± 113	175 ± 162	61 ± 49	67 ± 58	176 ± 204
Chironomini	45 ± 32	26 ± 36	13 ± 12	18 ± 7	21 ± 22	52 ± 46	9 ± 8	11 ± 16	5 ± 12
Total	120 ± 98	345 ± 399	425 ± 489	151 ± 159	137 ± 129	227 ± 205	71 ± 53	78 ± 65	181 ± 203
				Altosid Liquid Larvicide (0.28 kg AI/ha)					
Tanytarsini	47 ± 29	0 ± 0	21 ± 22	14 ± 7	222 ± 285	44 ± 22	72 ± 88	113 ± 135	89 ± 72
Chironomini	16 ± 7	1 ± 2	0 ± 0	12 ± 5	19 ± 19	9 ± 12	21 ± 17	7 ± 11	7 ± 15
Total	63 ± 24	1 ± 2	21 ± 22	26 ± 8	241 ± 298	53 ± 30	93 ± 103	119 ± 134	96 ± 82
				Granular Methoprene (San 810 I 1.3 GR) (0.17 kg AI/ha)					
Tanytarsini	53 ± 43	31 ± 35	97 ± 67	53 ± 62	40 ± 42	37 ± 43	57 ± 83	55 ± 68	89 ± 91
Chironomini	38 ± 34	6 ± 4	0 ± 0	3 ± 2	5 ± 9	10 ± 19	8 ± 7	5 ± 8	7 ± 11
Total	92 ± 43	37 ± 34	94 ± 67	56 ± 62	45 ± 50	47 ± 61	65 ± 90	61 ± 67	95 ± 88
				Altosid Pellets (0.22 kg AI/ha)					
Tanytarsini	50 ± 65	3 ± 3	29 ± 25	15 ± 18	6 ± 8	9 ± 10	11 ± 15	8 ± 7	12 ± 18
Chironomini	30 ± 25	2 ± 2	3 ± 4	2 ± 3	3 ± 3	1 ± 1	2 ± 2	3 ± 3	1 ± 2
Total	80 ± 59	5 ± 4	32 ± 23	17 ± 18	9 ± 8	10 ± 9	13 ± 14	11 ± 8	13 ± 18
				Altosid XR Briquets (0.82 kg AI/ha)					
Tanytarsini	53 ± 61	75 ± 140	8 ± 9	5 ± 7	2 ± 3	9 ± 12	15 ± 26	29 ± 35	17 ± 23
Chironomini	60 ± 30	5 ± 10	3 ± 6	3 ± 4	9 ± 11	3 ± 3	5 ± 9	4 ± 7	3 ± 4
Total	113 ± 81	81 ± 150	11 ± 10	8 ± 7	11 ± 12	12 ± 13	20 ± 35	33 ± 41	20 ± 27
				Control					
Tanytarsini	87 ± 93	393 ± 785	484 ± 495	159 ± 106	71 ± 90	67 ± 60	53 ± 19	56 ± 53	59 ± 56
Chironomini	43 ± 41	25 ± 21	34 ± 20	45 ± 31	10 ± 9	18 ± 13	13 ± 11	5 ± 7	1 ± 2
Total	130 ± 132	418 ± 800	518 ± 509	205 ± 122	81 ± 96	85 ± 64	67 ± 26	61 ± 53	60 ± 57

[1] Ambient water temperatures: 19–33°C.

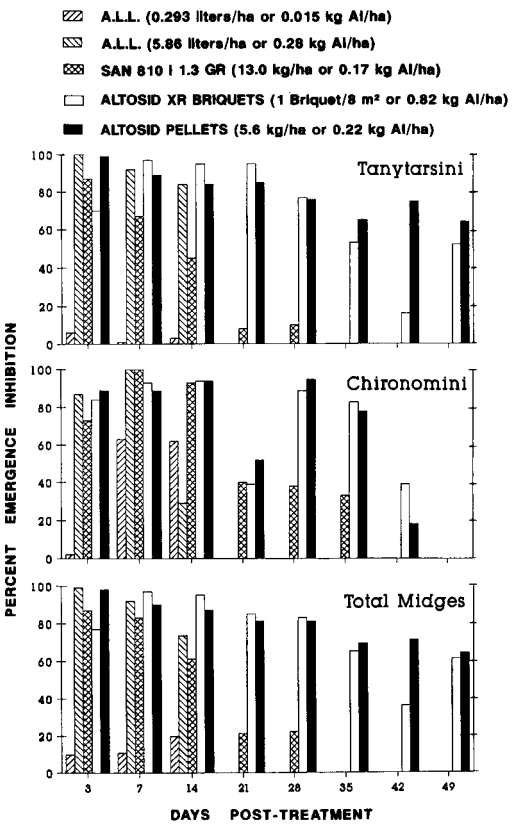

Fig. 1. Percent inhibition of emergence of Tanytarsini, Chironomini and total midge adults due to treatments with different formulations and rates of the IGR methoprene (Altosid) to experimental ponds at the University of Florida's Central Florida Research and Education Center, Sanford.

at 0.22 kg AI/ha gave initial and prolonged good control of Tanytarsini (64–99% for 7 wk), Chironomini (79–94% for 5 wk), and total midges (64–98% for 7 wk). Altosid XR briquet formulation was also effective yielding 53–97% control of Tanytarsini for 5 wk, 39–96% control of Chironomini for 6 wk and 38–98% control of total midges for 7 wk posttreatment. Although the rate of application (0.82 kg AI/ha) of the briquet formulation was almost 4× higher than that of the pellet formulation, the latter formulation gave better midge control.

Analysis of variance indicated that differences in suppression of adult midge emergence between methoprene formulations and times posttreatment were both highly significant ($P < 0.01$). Interaction between these 2 factors was insignificant ($P > 0.1$). Multiple comparisons revealed that the pellets and briquets were the only formulations which significantly reduced midge emergence compared with the controls ($P < 0.01$), and reduced it for longer periods of time than the other formulations tested. The high rate of A.L.L. (0.28 kg AI/ha) gave excellent initial control, but provided limited residual activity. The granular formulation also resulted in relatively short-lived residual activity. This formulation at 13.0 kg/ha (or 0.17 kg AI/ha) did not sustain and deliver sufficient active ingredient for effective, long-term midge control. The more "efficient" performance of the pellets than the briquets may be attributable to more uniform coverage (0.22 m^2/pellet vs. 8 m^2/briquet) and the difference in rate of release of the active ingredient from the 2 formulations. The latter phenomenon can be influenced by the formulation's hardness, its size and the surface area to volume ratio of the particles.

There are limited reports on the field use of methoprene against midges. Mulla and Darwazeh (1975) reported marginal control of *Cricotopus*, *Tanytarsus* and *Paralauterborniella* midges in experimental ponds with 2 slow-release (SR) Altosid liquid formulations, SR-10 and SR-10F, each applied at the rate of 0.11 kg AI/ha. Mulla et al. (1974) evaluated an emulsifiable and 2 encapsulated SR flowable formulations (a 5% AI sinking type and a 10% AI floating type) of Altosid (ZR-515) in small outdoor box plots, in experimental ponds and in a man-made residential-recreational lake. In box plots and ponds, emergence of Chironominae and Tanypodinae was suppressed for 1–3 wk with methoprene at concentrations of 0.1–0.2 ppm. The SR formulations proved superior to the emulsifiable formulations in terms of suppression of adult emergence and residual activity. In the lake, both SR formulations at 0.28 kg AI/ha, produced similar results, inducing inhibition of *Chironomus*, *Tanytarsus* and *Procladius* midges for 2 wk. Repeated treatments of the lake with Altosid SR-10 gave 1–3 wk of midge control, with the duration of control becoming shorter on successive treatments (Mulla et al. 1976); the SR-10 and SR-10F formulations at 0.28 kg AI/ha were almost equally effective.

The results of Mulla et al. (1974) in the lake are comparable to the magnitude and duration of midge control (74–99% for 2 wk posttreatment) produced by A.L.L. applied at 0.28 kg AI/ha in the present study. The limited residual activity of the liquid formulations used previously (Mulla et al. 1974, 1976) and in this study is due to the relatively short half-life (ca. 2 h) of methoprene in water (Schaefer and Dupras 1973). The gradual release of this compound in water for prolonged residual activity has been

achieved through formulation improvement as shown in the present study where the pellets on a lower AI basis than A.L.L. (0.22 kg AI/ha vs. 0.28 kg AI/ha) produced 64–98% control of midges for 7 wk posttreatment.

New solid formulations of methoprene have displayed superior biological and prolonged residual activity against chironomids. This compound is relatively safe to nontarget organisms in the aquatic environment (Miura and Takahashi 1973, Mulla et al. 1979). These attributes make some formulations of the IGR, methoprene, potentially an excellent additional tool for midge control.

ACKNOWLEDGMENTS

This is Florida Agricultural Experiment Stations Journal Series No. R-01565. The assistance of M. L. Kok-Yokomi during the course of this study is acknowledged.

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