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EFFICACY OF TWO FORMULATIONS OF THE INSECT GROWTH REGULATOR, PYRIPROXYFEN (NYLAR® OR SUMILARV®), AGAINST NUISANCE CHIRONOMIDAE (DIPTERA) IN MAN-MADE PONDS

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ABSTRACT. A juvenoid insect growth regulator, pyriproxyfen (Nylar® or Sumilarv®), in a 10% emulsifiable concentrate (10 EC) and a granular (3% sand granules) formulation was evaluated for efficacy against natural populations of chironomid midges in man-made ponds in central Florida. Both formulations at 0.05 kg AI/ha induced complete suppression of adult midge emergence for 1 wk. At 0.2 kg AI/ha, emergence of adult midges completely ceased for 2 and 5 wk with the EC and the granules, respectively. The EC formulation was not effective beyond 2 wk, but the granules at both treatment rates reduced midge emergence by 81–100% for 9 wk posttreatment. The differences in suppression of adult midge emergence between the 2 formulations and times posttreatment were both highly significant ($P < 0.01$). No significant difference ($P > 0.05$) was found between the posttreatment percent inhibition of midge emergence caused by the lower and the higher rates of the granular formulation. Some reductions of midge larvae occurred in the ponds receiving the higher rate of the 2 formulations, but these reductions were statistically not significant.

INTRODUCTION

Pyriproxyfen, 2-[1-methyl-2-(4-phenoxyphenoxy)ethoxy]pyridine, is a newly discovered insect growth regulator (IGR) known under the trade names of Nylar® and Sumilarv®. This IGR is a juvenile hormone mimic and is highly active against a wide variety of insects of public health importance including fleas (Palma and Meola 1990), tsetse flies (Langley et al. 1990), houseflies (Kawada et al. 1987), cockroaches (Koehler and Patterson 1991) and mosquitoes (Schaefer et al. 1988, Mulla et al. 1989). Preliminary observations of Sinegre et al. (1990) and Schaefer and Miura (1990) indicated that pyriproxyfen was also effective against aquatic chironomid midges. At present, the long-term effects of the IGR and the formulation effects in reducing larval and adult midge populations remain unknown, although unpublished results of some field evaluations of pyriproxyfen against chironomids are available.[1,2] The increasing nuisance and economic problems posed by adult chironomids in recent years on a global basis (Ali 1991a), and their worldwide association with human allergies (Marcer et al. 1990), establishes the importance of chironomids as urban pests of serious concern. Reported here is the efficacy of 2 formulations of pyriproxyfen against natural populations of chironomids in man-made ponds.

MATERIALS AND METHODS

The ponds employed 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 July 7, 1992, pyriproxyfen was applied to the ponds as a 3% sand granule and a 10% emulsifiable concentrate (10 EC) supplied by McLaughlin Gormley King Co., Minneapolis, MN. Each formulation was applied at 0.05 and 0.2 kg AI/ha, with 3 replicates (ponds) for each rate of treatment. Six ponds were left untreated as controls. Thus, a total of 18 ponds was utilized in this experiment. The ponds were treated in a randomized block design. The required amount of EC for each of the 6 treatment ponds was 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 treatment pond was mixed with 0.5 kg of sterile, clean sand, and the mixture was dispersed evenly over the pond surface.

Immediately prior to the treatments, and 1, 3 and 7 days posttreatment and subsequently at

[1] Davis, J. A., A. M. Pinder, K. M. Trayler and S. A. Harrington. 1990. Towards more effective control of nuisance chironomids (midges) in metropolitan wetlands, Perth, Western Australia. Unpublished report. Murdoch University, Australia.

[2] Pinder, A. M., K. M. Trayler and J. A. Davis. 1991. Chironomid control in Perth wetlands. Final report and recommendations. Unpublished report. School of Biol. Environ. Sci., Murdoch University, Australia.

weekly intervals, 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. Population densities of chironomid larvae were also assessed in each pond. The larval samples were collected following the adult sampling regime. On each sampling date, 3 separate mud samples were randomly collected from each pond with a 15 × 8-cm scoop sampler and composited. The water temperature was measured daily by using a maximum–minimum thermometer placed permanently in the middle of one pond.

In the laboratory, each mud sample was washed through a 400-μm pore sieve to recover midge larvae. The larval and adult samples from each pond were examined for identification and counting. Reductions of midge larvae and adults due to the treatments were calculated by the formula given in Mulla et al. (1971). This formula has provisions for adjusting population reductions caused by the treatments in relation to any simultaneous natural increases or decreases of populations. The pre- and posttreatment larval and adult midge population data were compared by analysis of variance. A $\log(n + 1)$ transformation was used on the adult data prior to analysis, because their frequency distribution was highly skewed to the left, reflecting numerous zero counts.

RESULTS AND DISCUSSION

The ponds supported populations of Chironomini and Tanytarsini midges. Among Chironomini, *Polypedilum parvum* Townes and *Apedilum elachistus* Townes were the most prevalent; species of *Chironomus* also occurred consistently, but in low numbers. Species of Tanytarsini were present in all the ponds at population levels much lower than those of Chironomini. Specific identifications of Tanytarsini could not be made due to the lack of taxonomic keys. In a few samples, adult Tanypodinae, *Ablabesmyia mallochi* (Walley), *Coelotanypus concinnus* (Coq.) and *Tanypus neopunctipennis* Sublette were recognized and composed <1% of the total adults collected on any sampling occasion. Because of the low numbers of some Chironomini species in some samples, the adult chironomine data were combined under the tribe Chironomini to elucidate the efficacy of pyriproxyfen and its formulations. In this midge tribe, a few Tanypodinae that occurred sporadically were included.

Data on the effects of both formulations of the IGR at 0.05 and 0.2 kg AI/ha on adult emergence of Chironomini, Tanytarsini and total midges are summarized in Table 1. Posttreatment data for days 1, 28, 42, 56, 70 and 84 are not included, but are available. Each rate of both formulations of pyriproxyfen initially caused complete inhibition of emergence of Chironomini, Tanytarsini and total midges, but the magnitude and duration of control varied with the rate of treatment and formulation (Fig. 1). The EC formulation at 0.05 and 0.2 kg AI/ha caused complete inhibition of midge emergence for 1 and 2 wk posttreatment, respectively. The granular formulation at the same rates was far superior in activity, causing 50–100, 51–100 and 51–100% reductions of adult Chironomini, Tanytarsini and total midges, respectively, for 11 wk posttreatment at 0.05 kg AI/ha. Overall, the lower rate of the granular formulation suppressed 81–100% emergence of adult midges for more than 2 months. The higher rate of the granular formulation produced 90–100, 54–100 and 81–100% reductions of adult Chironomini, Tanytarsini, and total midges for 9 wk posttreatment, with complete inhibition of total midge emergence lasting for at least 5 wk posttreatment. In general, the duration of midge control achieved by the 2 application rates of the granular formulation was very similar but the magnitude of control resulting from the higher rate of treatment was apparently greater, as indicated by complete inhibition of adult emergence for 5 wk posttreatment achieved by the higher rate compared to 1 wk posttreatment at the lower rate.

The differences in suppression of adult midge emergence between the 2 pyriproxyfen formulations and times posttreatment were both highly significant ($P < 0.01$). Multiple comparisons revealed that the effectiveness of the granular formulation in suppressing adult midge emergence was higher than the EC formulation, compared with the controls ($P < 0.01$). However, no significant difference ($P > 0.05$) was found between the posttreatment percent inhibition of midge emergence caused by the lower and the higher rates of the granular formulation.

Table 2 presents data on midge larval densities in the treated and control ponds. The lower rate of both formulations caused no reductions of midge larvae, but the higher rate of EC apparently caused reductions up to 66% (range 0–66%) and the granules at 0.2 kg AI/ha caused reductions up to 69% (range 0–69%) of larval populations during 6 wk posttreatment. These reductions, however, were statistically not significant ($P > 0.05$).

The results of the present study are in complete agreement with those reported from Australia,[1] showing >80% inhibition of chironomid (predominantly *Polypedilum nubifer* Skuse) adult

Table 1. Effects of 2 formulations (10 EC and 3% G) of the juvenoid IGR pyriproxyfen (Nylar® or Sumilarv®), at rates of 0.05 and 0.2 kg AI/ha, on chironomid adult emergence from man-made ponds[1] at the aquatic research facility of the University of Florida's Central Florida Research and Education Center, Sanford, FL (July–September 1992).

Tribe	Rate (kg AI/ha)	Mean no. (±SD) adult emergence/m² pre- and posttreatment (days)									
		Pretreatment	3	7	14	21	35	49	63	77	91
Emulsifiable concentrate (10 EC)											
Chironomini	0.05	14 ± 12	0 ± 0	0 ± 0	15 ± 24	12 ± 18	28 ± 35	36 ± 59	52 ± 67	141 ± 240	195 ± 234
Tanytarsini		7 ± 11	0 ± 0	0 ± 0	0 ± 0	1 ± 2	2 ± 2	3 ± 2	2 ± 3	1 ± 1	33 ± 58
Total		21 ± 8	0 ± 0	0 ± 0	15 ± 24	12 ± 21	30 ± 37	39 ± 60	54 ± 69	142 ± 242	228 ± 291
Chironomini	0.2	52 ± 76	0 ± 0	0 ± 0	0 ± 0	45 ± 56	78 ± 110	70 ± 89	30 ± 26	32 ± 42	83 ± 80
Tanytarsini		7 ± 4	0 ± 0	0 ± 0	0 ± 0	11 ± 5	9 ± 9	33 ± 34	10 ± 9	23 ± 25	23 ± 22
Total		59 ± 79	0 ± 0	0 ± 0	0 ± 0	55 ± 60	87 ± 111	103 ± 105	40 ± 33	55 ± 67	106 ± 95
Sand granules (3% G)											
Chironomini	0.05	198 ± 90	0 ± 0	0 ± 0	3 ± 6	3 ± 3	11 ± 12	17 ± 29	27 ± 31	59 ± 70	206 ± 287
Tanytarsini		15 ± 12	0 ± 0	0 ± 0	0 ± 0	0 ± 0	9 ± 8	5 ± 6	20 ± 18	7 ± 8	13 ± 12
Total		213 ± 71	0 ± 0	0 ± 0	3 ± 6	3 ± 0	20 ± 16	21 ± 35	47 ± 48	65 ± 69	219 ± 290
Chironomini	0.2	125 ± 84	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	5 ± 8	13 ± 18	31 ± 54	88 ± 139
Tanytarsini		5 ± 3	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	9 ± 12	5 ± 8	15 ± 16	7 ± 8
Total		130 ± 82	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	13 ± 20	17 ± 27	46 ± 69	95 ± 146
Control											
Chironomini		195 ± 150	104 ± 95	156 ± 87	129 ± 186	153 ± 150	137 ± 134	72 ± 53	205 ± 266	115 ± 114	148 ± 191
Tanytarsini		9 ± 6	6 ± 5	6 ± 6	3 ± 3	33 ± 24	11 ± 5	35 ± 45	35 ± 25	13 ± 10	14 ± 12
Total		204 ± 140	110 ± 98	163 ± 90	132 ± 186	186 ± 168	148 ± 135	107 ± 69	140 ± 272	127 ± 113	162 ± 212

[1] Ambient water temperatures: 24–39°C.

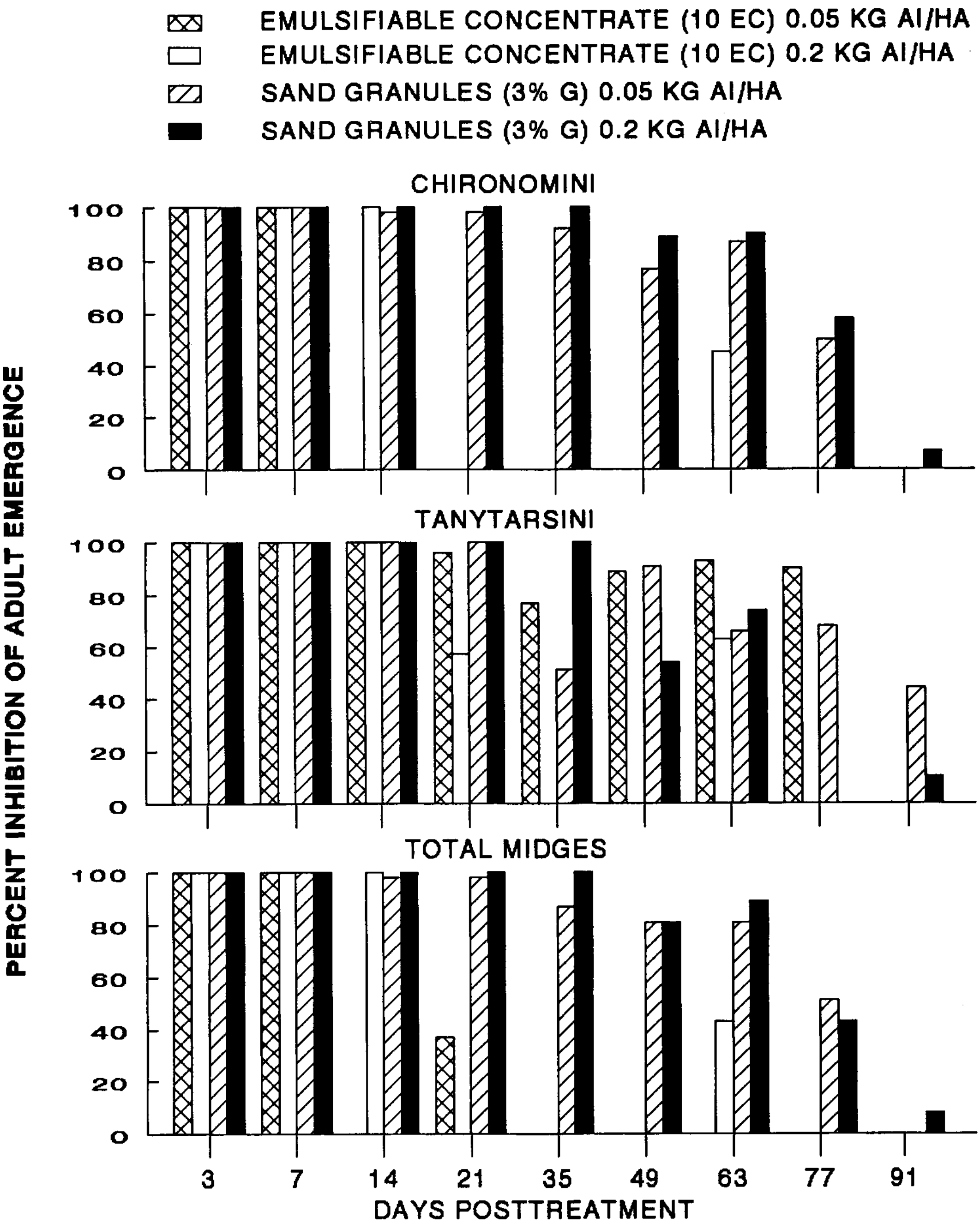

Fig. 1. Percent inhibition of emergence of adult Chironomini, Tanytarsini and total midges due to treatments with 2 formulations of the IGR pyriproxyfen, each applied at 2 rates to man-made ponds at the University of Florida's Central Florida Research and Education Center, Sanford.

emergence for 3 wk and no reductions of midge larvae by Sumilarv® application at 0.05 kg AI/ha to metropolitan wetlands in Perth.

In the past 2 decades, numerous IGRs, including benzoylphenylureas, which interfere with chitin synthesis in insects, and juvenile hormone analogs have been evaluated against chironomids under laboratory and field conditions, as reviewed by Ali (1993). Among the benzoylphenylureas, diflubenzuron, Bay SIR-8514, UC-

Table 2. Effects of 2 formulations (10 EC and 3% G) of the juvenoid IGR pyriproxyfen (Nylar® or Sumilarv®), at rates of 0.05 and 0.2 kg AI/ha, on chironomid[1] larval populations in man-made ponds[2] at the University of Florida's Central Florida Research and Education Center, Sanford, FL (July–August 1992).

Treatment rate (kg AI/ha)	Mean no. (±SD) larvae/sample pre- and posttreatment (days)							
	Pretreatment	3	7	14	21	28	35	42
	Emulsifiable concentrate (10 EC)							
0.05	289 ± 86	140 ± 84	93 ± 59	299 ± 144	149 ± 44	93 ± 91	65 ± 17	140 ± 74
0.2	616 ± 316	233 ± 155	131 ± 99	317 ± 225	65 ± 17	84 ± 84	121 ± 107	177 ± 127
	Sand granules (3% G)							
0.05	383 ± 42	196 ± 219	448 ± 728	289 ± 265	112 ± 101	168 ± 101	168 ± 170	75 ± 107
0.2	812 ± 884	140 ± 128	65 ± 20	233 ± 91	84 ± 48	299 ± 180	224 ± 267	205 ± 133
	Control							
	499 ± 382	271 ± 254	107 ± 55	415 ± 411	107 ± 72	112 ± 95	285 ± 402	84 ± 56

[1] 99% Chironomini and Tanytarsini midges.
[2] Ambient water temperatures: 24–39°C.

62644 and UC-84572 were the most effective in various chironomid control studies, yielding >90% suppression of adult midge emergence for up to 5 or 6 wk posttreatment in some situations at rates ranging from 0.025 to 0.25 kg AI/ha. Among the juvenile hormone analogs, methoprene is the most studied IGR for chironomid control. A more recent evaluation of methoprene in different formulations against chironomids in the ponds utilized in the present study showed the superiority of sustained release methoprene formulations, such as a granular and Altosid® XR briquets and pellets over Altosid® Liquid Larvicide at comparable rates of treatment (Ali 1991b). The briquet formulation at 0.82 kg AI/ha reduced adult midge emergence by 38–98% for 7 wk, and the pellet formulation at 0.22 kg AI/ha suppressed emergence of midges by 64–98% for 7 wk. The present study showed that pyriproxyfen was far superior in activity to methoprene against chironomids as evidenced by 81–100% suppression of adult midge emergence for 9 wk posttreatment by the granules applied at a rate as low as 0.05 kg AI/ha.

The longer control of chironomids achieved by the granular formulation of pyriproxyfen at 0.05 kg AI/ha (or 11 ppb) as compared to the liquid formulation is largely attributable to the better ability of granules to reach and remain in or near the larval biomass (benthos) where the active ingredient is gradually released to prolong control. More regulated release of the active ingredient of this IGR through formulations such as pellets and briquets may provide even longer residual activity against chironomids. The adsorption of pyriproxyfen onto organic matter in the mosquito larval environment and gradual availability of the compound through larval feeding (Schaefer et al. 1991) is another reason for the prolonged activity displayed by this IGR against mosquitoes and midges in the aquatic environments. The half-life of pyriproxyfen on organic matter in a dairy lagoon was 7.47 d when applied at 0.11 kg AI/ha; the compound readily adsorbed onto organic matter where it persisted for more than 2 months, during which time the concentration decayed at an exponential rate (Schaefer et al. 1991). The adsorption property of pyriproxyfen onto organic matter is particularly advantageous for chironomid control. This is because high densities of midge larvae are generally encountered in polluted habitats rich in organic matter and also because of the benthic nature of most chironomid larvae, remaining in or under organic matter accumulated at the habitat bottom.

Pyriproxyfen is environmentally and biologically compatible in the aquatic mosquito and midge environments. When applied at 0.11 kg

AI/ha, pyriproxyfen had no detectable residues (<0.05 ppb) after 2 d in treated water (Schaefer and Miura 1990). The compound had low and limited stability in soil and did not rapidly displace from the upper soil strata by leaching, therefore making it unlikely to build up in soil or penetrate to ground water (Schaefer et al. 1991). At 0.11 kg AI/ha, pyriproxyfen had no residues (<0.005 ppm) after 3 d in the fish *Lepomis macrochirus* (Schaefer and Miura 1990), and was also safe to a variety of aquatic nontarget organisms (Schaefer et al. 1988, Schaefer and Miura 1990). These attributes and the prolonged activity of pyriproxyfen against chironomids warrant further investigations of this IGR (especially formulation research) for chironomid control. An IGR such as pyriproxyfen that has minimal or no decimating effects on midge larvae, an important component of the aquatic food chain, is highly desirable in aquatic midge control programs.

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