Supplement to the Journal of Nematology 29(4S):690–694. 1997.

High-pressure Liquid Injection of Isazofos for Management of *Hoplolaimus galeatus* and *Tylenchorhynchus dubius* Infesting Turfgrasses[1]

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Abstract: Three high-pressure liquid injection machines were used to inject isazofos into the root zone of turfgrass plots to evaluate its potential for control of *Hoplolaimus galeatus* and *Tylenchorhynchus dubius.* A Rogers root zone injector delivering isazofos at 2.3 kg a.i./ha through 30° and 60° spray tips at 5,000 psi (3.45×10^7 Pascals) significantly reduced nematode populations at 32 days after a single application and 33 days after a second application. In a second experiment with the Rogers injector at 2.3 kg a.i./ha, *H. galeatus* populations were significantly lower at 16 days after a single application and at 42 and 61 days after a second application with the 60° spray angle tips. An Envirojet turfgrass injector used to inject isazofos at 1.15 kg a.i./ha and 2.88 kg a.i./ha at 3,000 psi (1.38×10^7 Pascals) significantly reduced nematode populations at 7 days after treatment at the low rate and at 63 days after treatment with both application rates. A Landpride material injector applying isazofos at 6.9 and 13.8 kg a.i./ha at 2,000 psi (1.38×10^7 Pascals) significantly reduced nematode populations at 7, 14, and 63 days after treatment at the high rate and at 63 days after the low-rate application. Although suppression of nematodes with isazofos was found, the degree of suppression is probably not enough to warrant recommendation of high-pressure delivery of isazofos for control of *H. galeatus* and *T. dubius* populations infesting turfgrasses.

Key words: Agrostis canina, Agrostis palustris, annual bluegrass, control, creeping bentgrass, high-pressure liquid injection, *Hoplolaimus galeatus,* isazofos, *Lolium perenne,* nematicide, nematode, perennial ryegrass, *Poa annua,* turfgrass, *Tylenchorhynchus dubius,* velvet bentgrass.

Isazofos is an organophosphate insecticide-nematicide that effectively controls many turfgrass pests (Niemczyk and Krueger, 1987). Isazofos has been used for sting (*Belonolaimus* sp.) and lance (*Hoplolaimus* sp.) nematode suppression in turfgrasses in some southern states under Section 2ee of the Federal Insecticide Fungicide and Rodenticide Act. When applied as either 5% or 10% granules, isazofos has provided good control of nematodes infesting bananas (e.g. *Radopholus similis*) and turfgrasses (Hague and Gowan, 1987). Populations of *Pratylenchus* sp. and *Meloidogyne* sp. were reduced by 72% and 88%, respectively, in *Lolium perenne* 'Ellett'' when isazofos was applied at 2 kg a.i./ha (Barker and Watson, 1987).

The relatively short persistence of isazofos in soils (half-life 0.5 to 5.0 weeks) minimizes its leaching hazard. Somasundaram et al. (1993) showed that, in soils not previously exposed to isazofos, more than 90% of the material degraded within 3 weeks of application. When applied to a golf course fairway, downward movement of isazofos into the soil was minimal over a 14-day sampling period due to its rapid degradation and absorption on thatch (Niemczyk and Krueger, 1987). Isazofos applied to turfgrass with a 1.9-cm thatch layer resulted in little leaching of the active ingredient into the top 2.5 cm of soil (Niemczyk and Krueger, 1987). To overcome a thatch barrier, irrigation is recommended to move isazofos through the thatch into the soil (Sears and Chapman, 1979).

Technological advancements have resulted in the development of application techniques that are able to introduce liquid or granular formulations of pesticides beneath the turf surface (Vittum, 1994). High-pressure liquid injection machines are currently being evaluated for their ability to overcome the sorption of chemicals on living plant tissues, thatch, or soil particles

Received for publication 21 May 1997.
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The authors thank G. Perry and D. Silvan for use of their golf courses; D., J., and T. Taylor (ILI Envirojet, Inc.), C. Santopietro (Wilfred MacDonald, Inc.), M. Stelter and K. Beetch (Great Plains) and W. Lemus and C. S. Stroble for technical assistance.

when applied to turf. This technology could be useful to turf managers since it is not always practical to irrigate immediately after pesticide application due to economic, environmental, and (or) logistical constraints (Vittum, 1994). The benefits associated with high-pressure liquid pesticide injection include reduced surface exposure, runoff, drift, and photodegradation, culminating in enhanced efficacy against soil pests (Vittum, 1994).

Hoplolaimus galeatus (Cobb) Thorne causes root swelling and stunts top growth of annual bluegrass, bermudagrass, and zoysiagrass (Vargas, 1994). *Tylenchorhynchus dubius* (Bütschli) Filipjev causes thinning and wilting of top growth as well as root discoloration and stunting of annual bluegrass, Kentucky bluegrass, and creeping bentgrass (Vargas, 1994). Previous experiments with isazofos applied to the surface of greens did not demonstrate effective control of *H. galeatus* and *T. dubius* (Alm, unpubl.). The purpose of this study was to evaluate the efficacy of isazofos applied by three high-pressure liquid injection machines for the control of *H. galeatus* and *T. dubius* infesting turfgrasses.

Materials and Methods

The first experimental site was a golf course fairway composed of 55% annual bluegrass (*Poa annua* L.), 30% creeping bentgrass (*Agrostis palustris* Huds.), and 15% perennial ryegrass (*Lolium perenne* L.) primarily infested with *H. galeatus*. Soil consisted of 58.5% sand, 34.0% silt, 7.5% clay, 3.9% OM, pH 4.7. Isazofos was applied with a Rogers skidmount root-zone injector (Model RZI 4453SM, Rogers Innovative, Saskatoon, SK, Canada) to 6.36-m^2 plots arranged in a randomized complete-block design. A rate of 2.3 kg a.i./ha was applied to each of four replicates on 11 August and again to the same plots on 15 September 1995 through nozzles angled at 30° and 60° from vertical. Liquid placement at 5,000 psi (3.45×10^7 Pascals) was reported to be between 2.5 and 7.5 cm or 1.25 and 5 cm deep with the 30° and 60° nozzles, respectively (Rogers Innovative, technical bulletin). Control plots were not treated since previous experiments had shown no effect of high-pressure injection of water on nematode populations. To evaluate nematode survival, five soil cores (1.9-cm diam. and 8 cm deep) were removed from each plot 20, 32, 42, 62, 70, and 90 days after the first treatment, which corresponded to 7, 33, 41, and 49 days after the second application. Cores from each plot were combined and a 140-cm^3 subsample was used for nematode extraction. Nematodes were extracted by means of sugar flotation-centrifugation (Zuckerman et al., 1990), and the total number of *H. galeatus* in each sample was counted.

In the second experiment, isazofos was applied with the Rogers injector to a Kingstown velvet bentgrass (*Agrostis canina* L.) green infested with *H. galeatus*. Soil consisted of 66.5% sand, 32.0% silt, 1.5% clay; 7.5% OM, pH 4.8. Isazofos and fenamiphos were applied to 6.36-m^2 plots arranged in a

TABLE 1. Evaluation of isazofos applied with a Rogers root-zone injector to a predominantly *Poa annua* fairway for management of *Hoplolaimus galeatus*.

Treatment	Kg a.i. per ha	Spray angle	Mean ± SE live nematodes per 140 cm^3 soil[a]					
			20 datl[b]	32 datl	42 datl, 7 dat2	62 datl, 33 dat2	70 datl, 41 dat2	90 datl, 49 dat2
Isazofos	2.3	30°	528 ± 31	618 ± 33b	585 ± 79	654 ± 94b	649 ± 27	593 ± 51
Isazofos	2.3	60°	640 ± 58	508 ± 76b	528 ± 71	604 ± 55b	613 ± 108	596 ± 13
Control	—	—	525 ± 93	953 ± 57a	771 ± 170	1,124 ± 199a	906 ± 140	798 ± 133
P			0.1	<0.01	0.4	<0.05	0.1	0.2

[a] Data are averages of four replications. Means in the same column followed by the same letter are not significantly different according to an LSD test ($P = 0.05$).
[b] datl = days after treatment one; dat2 = days after treatment two.

TABLE 2. Evaluation of isazofos applied with a Rogers root-zone injector and fenamiphos to a Kingstown velvet bentgrass experimental green for management of *Hoplolaimus galeatus*.

Treatment	Kg a.i. per ha	Spray angle	Mean ± SE live nematodes per 140 cm³ soil[a] 16 datl[b]	30 datl, 14 dat2	43 datl, 27 dat2	58 datl, 42 dat2	77 datl, 61 dat2
Isazofos	2.3	30°	266 ± 57b	236 ± 22	350 ± 121	306 ± 44ab	385 ± 52ab
Isazofos	2.3	60°	299 ± 57b	294 ± 12	124 ± 44	141 ± 40b	326 ± 36ab
Fenamiphos	112.1	—	394 ± 32b	215 ± 35	195 ± 46	169 ± 31ab	268 ± 61b
Control	—	—	660 ± 101a	299 ± 62	250 ± 45	334 ± 77a	549 ± 104a
P			<0.05	0.4	0.3	0.07	0.11

[a] Data are averages of four replications. Means in the same column followed by the same letter are not significantly different according to an LSD test ($P = 0.05$).
[b] datl = days after treatment one; dat2 = days after treatment two of isazofos treatments only.

randomized complete-block design with four replicates. Isazofos was applied at 2.3 kg a.i./ha through 30° and 60° angle nozzles at 5,000 psi (3.45×10^7 Pascals). Fenamiphos was applied manually to the turf surface at the recommended rate of 11.2 kg a.i./ha followed by 1.27-cm irrigation. Control plots were not treated. All applications were made on 26 July 1995, and the isazofos treatments were reapplied on 11 August 1995. Nematode survival was evaluated 16, 30, 43, 58, and 77 days after the first set of isazofos treatments, which corresponded to 14, 27, 42, and 61 days after the second treatments.

The third and fourth experiments were conducted on a practice green (90% annual bluegrass, 10% creeping bentgrass) infested with *T. dubius.* Soil consisted of 74.5% sand, 22.0% silt, 3.5% clay; 7.1% OM, pH 5.7. For the third experiment, isazofos was applied at rates of 1.15 and 2.88 kg a.i./ha at 3,000 psi (2.07×10^7 Pascals) using an Envirojet turfgrass injector (Landscape Model, International Liquid Injection, Hernando, FL). Applications were made on 24 August 1995 to 56-m^2 plots arranged in a randomized complete-block design with four replicates.

The fourth experiment consisted of isazofos treatments of 6.9 and 13.8 kg a.i./ha applied at 2,000 psi (1.38×10^7 Pascals) using a Landpride material injector (21″ Model, Great Plains Manufacturing, Assaria, KS). To evaluate nematode survival in experiments 3 and 4, cores were collected 7, 14, 28, 48, and 63 days after treatment. Data for all experiments were analyzed with ANOVA and means separated with LSD (SAS Institute, Cary, NC).

RESULTS AND DISCUSSION

In the first experiment with the Rogers root-zone injector on a predominantly *P. annua* fairway, isazofos treatments applied through either 30° or 60° nozzles significantly reduced *H. galeatus* populations 32 days after treatment one and 33 days after treatment two (Table 1).

TABLE 3. Evaluation of isazofos applied with an Envirojet turfgrass injector to a predominantly *Poa annua* practice green for management of *Tylenchorhynchus dubius*.

Treatment	Kg a.i. per ha	Mean ± SE live nematodes per 140 cm³ soil[a] 7 dat[b]	14 dat	28 dat	48 dat	63 dat
Isazofos	1.15	414 ± 70b	716 ± 156	528 ± 46	520 ± 70	564 ± 24b
Isazofos	2.88	699 ± 40a	645 ± 42	629 ± 30	520 ± 12	510 ± 37b
Control	—	739 ± 92a	974 ± 242	623 ± 107	614 ± 103	1,128 ± 139a
P		<0.05	0.2	0.5	0.6	<0.01

[a] Data are averages of four replications. Means in the same column followed by the same letter are not significantly different according to an LSD test ($P = 0.05$).
[b] dat = days after treatment.

TABLE 4 Evaluation of isazofos applied with a Landpride injector to a predominantly *Poa annua* practice green for management of *Tylenchorhynchus dubius.*

Treatment	Kg a.i. per ha	Mean ± SE live nematodes per 140 cm^3 soil[a]				
		7 dat[b]	14 dat	28 dat	48 dat	63 dat
Isazofos	6.9	573 ± 66ab	531 ± 70ab	405 ± 78	410 ± 62	343 ± 69b
Isazofos	13.8	505 ± 62b	423 ± 62b	526 ± 54	338 ± 51	295 ± 37b
Control	—	739 ± 92a	974 ± 242a	623 ± 107	614 ± 103	1,128 ± 139a
P		0.05	0.08	0.5	0.1	<0.01

[a] Data are averages of four replications. Means in the same column followed by the same letter are not significantly different according to an LSD test ($P = 0.05$).
[b] dat = days after treatment.

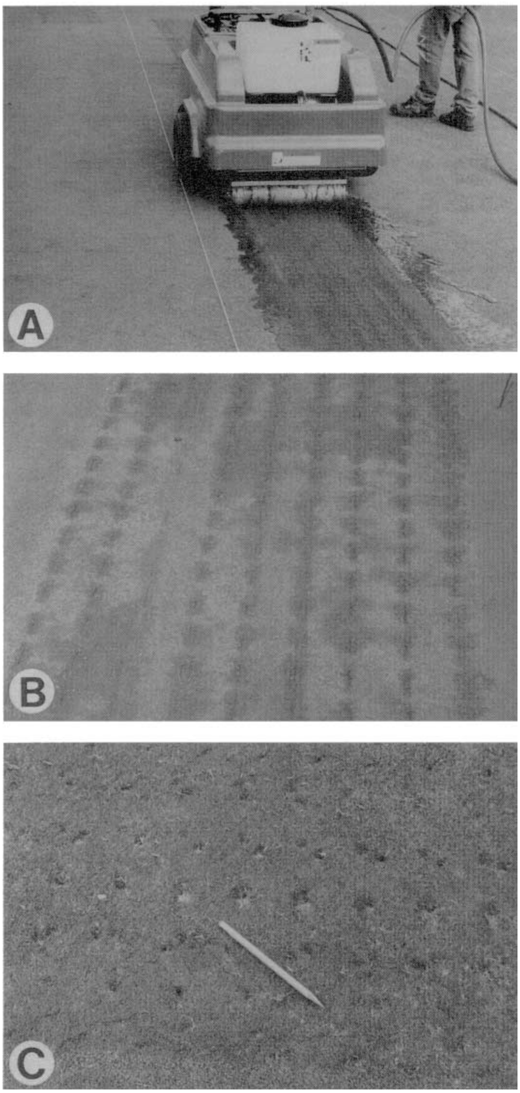

FIG. 1. Turf and soil effects of injectors. A) Landpride material injector. B) Envirojet landscape model. C) Rogers root-zone injector.

In the second experiment with the Rogers root-zone injector on a Kingstown velvet bentgrass green, 2.3 kg a.i./ha of isazofos applied through either 30° or 60° nozzles and granular fenamiphos significantly reduced *H. galeatus* populations 16 days after treatment one. Significant nematode reductions also were recorded 42 and 61 days after treatment two in plots treated with isazofos applied with 60° nozzles and fenamiphos, respectively (Table 2). At 30 and 43 days after the first chemical applications (14 and 27 days after the second application of isazofos), no differences were observed.

In the third experiment, significant *T. dubius* population reductions were recorded compared to controls 7 days after treatment with isazofos applied at 1.15 kg a.i./ha with the Envirojet turfgrass injector (Table 3). At 14, 28, and 48 days after treatment, no significant differences in nematode populations were detected. However, at 63 days after treatment a significant reduction in *T. dubius* numbers was seen in both 1.15 kg a.i./ha and 2.88 kg a.i./ha-treated plots.

In the fourth experiment, 6.9 and 13.8 kg a.i./ha of isazofos were applied with the Landpride injector. Significant reductions in *T. dubius* numbers were seen 7, 14, and 63 days after treatment with 13.8 kg a.i./ha and 63 days after applying 6.9 kg a.i./ha (Table 4). At 28 and 48 days after treatment, there were no significant differences in nematode populations.

The greater reductions in *T. dubius* numbers recorded in experiment four were probably due to the high rates of isazofos used. Since the recommended label rate for isazofos is 2.3 kg a.i./ha, it does not appear that the application of this chemical by high-pressure liquid injection will be an effective way to control *H. galeatus* and *T. dubius* infesting turfgrasses. The technology of high-pressure liquid injection, however, appears feasible if combined with an effective chemical treatment. Fluctuations in nematode numbers in the control plots over all experiments were probably due to natural population cycling.

The Landpride and Envirojet machines bring up a considerable amount of soil (Fig. 1A,B). Some of these machines may not be suitable at certain times during the season on golf greens due to abrasive soil particles brought to the surface. The Rogers machine did not displace soil in these studies (Fig. 1C).

In turfgrass environments, chemical management of nematodes is difficult because thatch hinders penetration and many chemicals sorb to thatch (Miller, 1978). Applications of nonfumigant nematicides are effective only if the active ingredient reaches the root zone (Vargas, 1994). The sorption coefficient of isazofos is 100 ml/g (Wauchope et al., 1992), which may have caused the material to bind with thatch or soil despite the use of high-pressure injection systems. Future work should concentrate on understanding the modes of action of nematicides and understanding sorption mechanisms and sites of chemicals introduced into the turfgrass environment.

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