Efficacy of Selected Nonvolatile Nematicides on Control of Ditylenchus destructor in Iris[1]

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Abstract: Greenhouse and field tests established that fenamiphos at 6.7 and 13.4 kg ai/ha applied in a 30-cm band directly on iris bulbs at planting effectively controlled *Ditylenchus destructor*. Aldicarb at rates of 5.6 to 11.2 kg ai/ha was less effective. Carbofuran, fensulfothion, and oxamyl at 6.7 to 13.4 kg ai/ha were ineffective. When applied on the bulbs, fenamiphos (granular or liquid) reduced nematode infection from 31 to 0.6% as determined by visual inspection of bulbs at harvest. Populations of *D. destructor* were reduced from 5.7 nematodes/g of fresh weight of bulb tissue to 0.04, 0.05, and 0.14 with applications of 13.4, 6.7, and 3.3 kg ai/ha fenamiphos, respectively. The most effective treatment was fenamiphos (granular or liquid) applied in a 30-cm band directly on the bulbs at time of planting. *Key words:* fenamiphos, oxamyl, fensulfothion, aldicarb, chemical control, iris.

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The bulb and stem nematode, *Ditylenchus destructor,* Thorne, 1945, was reported as an economic pest on iris (Dutch iris, derived from a cross of *Iris tingitana boisst* Reue × *Iris xiphium* L.) in western Washington and Oregon in the late 1940s (3,5). Limited control of *D. destructor* was achieved by dipping bulbs in hot water-formalin (4); however, the nematode continued to be an economically important pest on iris due to lack of complete eradication with hot water-formalin treatments. Also, field management practices allowed the bulbs to be reinfected with *D. destructor* (1).

Winfield (11,12) first reported on the effect of bulb dips in hot water-formalin or in nematicides and soil treatments with nonvolatile nematicides on the control of *D. dipsaci*. Nonvolatile nematicides in combination with hot water-formalin dips were more effective than hot water-formalin dips alone but nematode control was insufficient to justify commercial development (10,12). Winfield therefore concluded that a method had not yet been developed for *D. dipsaci* control in narcissus (13).

The introduction of nonvolatile organo phosphate and carbamate nematicides provided new control methods for specific nematode diseases (8,9). These compounds have successfully controlled both ectoparasitic and endoparasitic nematodes on annual and perennial crops (2,6,7). This investigation was initiated to evaluate the effectiveness of the nematicides, aldicarb, carbofuran, fenamiphos, fensulfothion, and oxamyl for the control of *D. destructor* in iris when the source of infection was either from bulbs, volunteer bulbs, weed hosts, or infested soil.

MATERIALS AND METHODS

Dutch iris cvs. Blue Ribbon and Sunshine, naturally infected with *D. destructor*, were used in these studies. Bulbs were examined for visual symptoms of nematode damage by removing the outer bulb scale and observing the basal portion of the bulb for typical nematode damage (3,5). Nematode infection was verified by maceration of the suspected tissue in water and direct observation of *D. destructor* using a dissecting scope.

Field studies were conducted at Washington State University, Northwestern Washington Research and Extension Unit, at Mount Vernon, on a site previously planted with nematode infected iris bulbs. The soil was Puget silt loam (silt 65%, clay 15%, sand 20%), pH 5.6–5.8, containing 3–5% organic matter. Fertilizer (10-10-10) was applied at planting with 330 kg/ha banded 7.5 cm below and to each side of the row. Bulbs were planted in early September and harvested in August of the following year. Each treatment was replicated four times in a randomized block design. Each replicate consisted of a single row, 12 m long, and were spaced 1 m apart. Liquid treatments were applied with tractor mounted injection shanks or a spray

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boom, and the desired amount of nematicide applied in a total of 190 liters of liquid per ha. Fenamiphos and aldicarb granules were preweighed and broadcast by hand in a 30-cm band. Band treatments were applied (a) below the bulb in the row by injection (liquid treatment only), (b) on the bulb prior to covering the soil, and (c) on the surface of the hill after planting. Soil treatments of aldicarb (10 G) were applied at 2.8, 5.6, and 11.2 kg ai/ha, and fenamiphos (15 G and 3 EC) at 3.3, 6.7, 13.4, 18.9, and 20.0 kg ai/ha. Carbofuran (4 F), fensulfothion (6 EC), and oxamyl (L) were applied at 6.7 and 13.4 kg ai/ha. Foliar sprays of carbofuran, fenamiphos, fensulfothion, and oxamyl were applied at 2.25 and 4.5 kg ai/ha in a total of 190 liters of liquid at full bloom (5 June) and 15 days after full bloom (20 June).

Yield was determined by hand harvesting bulbs from 4 m of row, air drying the bulbs (2–3 wk), cleaning, and weighing. Nematode infection was determined by visual observation of symptoms and/or extraction of *D. destructor* from intact bulbs. Visual inspection of the bulb scales near the basal plate determined the percentage of *D. destructor* infected bulbs. Nematodes were extracted from the bulbs by placing the test bulbs on a 2–3-mm screen suspended in water so the basal plate of the bulbs were immersed in 10–15 mm of water. All bulbs were incubated at 16–20 C for 48 h. The nematodes recovered were concentrated by gravity sedimentation and counted.

The efficacy of the nematicides was determined by reduction in percent of infected bulbs, reduction in number of nematodes recovered, and increase in yield.

Greenhouse studies were conducted in pasteurized Puget silt loam soil collected from the field test site. Soil was placed in screened bottom wooden trays, 60 × 30 × 14 cm deep, and planted with 20 nematode infected Blue Ribbon iris bulbs. Nematicides were applied to simulate field band treatments directly on the bulbs. Test nematicides were mixed into 1,000 cm^3 of soil and applied uniformly over the surface of the tray containing the infected bulbs prior to covering the bulbs with 5 cm of soil. Treatments were replicated four times in a randomized block design. Bulbs were planted in November and harvested in June. Greenhouse temperatures ranged from 12 to 20 C, and no supplemental light was used.

RESULT

In the initial field trials carbofuran, fenamiphos, oxamyl, and fensulfothion were injected below the bottom of a 30-cm-wide furrow, two injection points on 10-cm spacing. Fenamiphos was the only treatment that reduced the observable nematode infection of iris. Fenamiphos reduced the level of observable nematode infection of Blue Ribbon iris from 42% to 25 and 9% at rates of application of 9.0 and 18.0 kg ai/ha, respectively. Aldicarb, oxamyl, and fensulfothion did not reduce the level of observable nematode damaged bulbs. Foliar applications of carbofuran, fenamiphos, fensulfothion, and oxamyl at 4.5 and 9.0 kg ai/ha did not reduce the percent of *D. destructor* infected bulbs.

Four nematicides were compared in greenhouse and field tests using infected Blue Ribbon iris as the test plant (Table 1). Fenamiphos and aldicarb were effective in the greenhouse; however, only fenamiphos reduced the level of observable infection in field planted bulbs. Fenamiphos at 6.7 and 13.4 kg ai/ha and aldicarb at 5.6 kg ai/ha reduced the number of *D. destructor* recovered from the bulbs. The number of *D. destructor* recovered from carbofuran and fensulfothion treated bulbs were equal to the nontreated control.

The effect of placement of nematicide on Blue Ribbon and Sunshine iris is compared in Table 2. Fenamiphos applied in the furrow directly on the bulbs is more effective for the control of *D. destructor* than when applied to the surface of the hill. Fenamiphos at 3.3 kg ai/ha applied directly on the bulbs in the furrow reduced *D. destructor* populations in Sunshine iris more than the 13.4 and 20.0 kg ai/ha rates applied to the surface of the hills. When applied as a furrow or surface treatment to Blue Ribbon iris, aldicarb was intermediate in control and fensulfothion and oxamyl were ineffective.

The effect of method of application, time of treatment, and rate of application on the control of *D. destructor* with fena-

Table 1. Effect of four nonvolatile nematicides on *Ditylenchus destructor* and yield of 'Blue Ribon' iris under greenhouse and field conditions.

Treatment	Rate§ (kg ai/ha)	Greenhouse infection* (%)	Greenhouse weight† (g)	Field infection* (%)	Field weight† (g)	Field nematodes‡ (No.)
Fenamiphos	6.7	16 b‖	94 b	51 a	3030 ab	6.5b
	13.4	0 c	75 ab	18 b	4180 b	1.8 c
Aldicarb	2.8	0 c	75 ab	64 a	3060 ab	13.1 a
	5.6	0 c	83 ab	70 a	4426 b	9.7 b
Carbofuran	6.7	14 b	78 ab	77 a	3060 ab	20.9 a
	13.4	9 b	76 ab	55 a	3790 ab	26.2 a
Fensulfothion	6.7	58 a	62 a	58 a	3882 ab	20.1 a
	13.7	10 b	87 ab	51 a	3486 ab	18.0 a
Control	0	35 a	53 a	86 a	2070 a	22.8 a

*Percent infection. Greenhouse % based on four replications of 20 bulbs each; field % based on four replications of 50 bulbs each.

†Greenhouse data reported in grams of bulbs per replicate; field data bulb weight as kg/ha.

‡Number of *D. destructor* recovered per gram of bulb tissue. Data based on average of 10 bulbs per replicate.

§Applied in a 30-cm band directly on the bulbs in the greenhouse and on the surface of the hill (approximately 10 cm above the bulb) in the field.

‖Numbers in the same column followed by the same letter are not significantly different as determined by Duncan's multiple-range test ($P = .05$).

Table 2. Nematode (*Ditylenchus destructor*) infection and yield of 'Blue Ribbon' and 'Sunshine' iris as influenced by nematicide and method of application.

Treatment	Rate* (kg ai/ha)	Form.	Method†	Blue Ribbon Infection‡ (%)	Sunshine Infection‡ (%)	Sunshine Nematodes§ (g)	Sunshine Yield (kg/ha)
Fenamiphos	6.7	3 EC	Surface	17 b‖	...#	...	...
	13.4	3 EC		4 c	6 b	.70 b	3,562 b
	20.0	3 EC		6 c	...	...	...
Fenamiphos	3.3	3 EC	Furrow	...	0 c	.14 c	4,076 c
	6.7	3 EC		4 c	0 c	.05 d	3,570 b
	13.4	3 EC		0.6 d	1 c	.04 d	3,236 b
	6.7	15 G	Furrow	...	2 c	.19 c	3,598 b
Aldicarb	5.6	10 G	Surface	16 b	...	...	...
	11.2	10 G		16 b	...	...	...
Aldicarb	11.2	10 G	Furrow	12 b	0 c	.12 c	2,810 a
Oxamyl	13.4	4 L	Surface	22 a	...	...	...
	13.4	4 L	Furrow	26 a	...	...	...
Control	0			35 a	22 a	5.67 a	2,452 a

*Treatments applied in a 30-cm band.

†Placement of nematicide with reference to the bulbs. Surface = applied on the soil surface approximately 10 cm above the bulb; furrow = applied on the bulbs prior to hilling.

‡Percent of infection based on observation of 50 bulbs per replicate.

§*D. destructor* per gram of bulb tissue.

‖Numbers followed by the same letter are not significantly different from each other as determined by Duncan's multiple-range test. ($P = .05$).

#Indicates treatment was not included in experiment.

Table 3. Summary of effect of placement of fenamiphos on percent infections of irus bulbs by *Ditylenchus destructor*.

Exp.*	Method of application†	Time	Rate (kg ai/ha) 0	4.5	6.7	9.0	13.4	18.9	20.0
1	Foliar spray	June	46 a‡	43 a	...§	34 a	...	...	...
2	Surface	April	33 a	22 a	...	34 a	...	...	...
3	Surface	Oct.	50 a	...	...	20 b	...	4 c	...
4	Surface		35 a	...	17 b	...	4 c	...	6 c
5	Surface		61 a	...	...	...	11 b	...	6 b
6	Surface		78 a	...	...	...	21 b	...	6 c
4	Furrow	Sept.	35 a	...	4 c	...	0.6 b	...	...
5	Furrow		61 a	...	3 b	...	0.4 c	...	...
6	Furrow		78 a	...	3 c	...	0 d	...	...
7	Furrow-inject	Sept.	42 a	45 a	...	25 b	...	9 c	...

*Refers to seven individual field experiments.

†Foliar sprays, applied in 190 liters/ha of liquid. Surface applied in 20-cm band on the soil surface after hilling, approximately 10-cm over bulb; furrow applied directly on the bulbs at time of planting, 30-cm band treated; furrow-inject injected 3-cm above bottom of furrow with two shanks of 10-cm centers.

‡Numbers followed by same letter are not significantly different as determined by Duncan's multiple-range test ($P = .05$).

§Indicates treatment was not included in the experiment.

miphos is summarized in Table 3. Comparison of percent control of *D. destructor* from seven replicated field trials using Blue Ribbon iris as the test crop established that application of fenamiphos directly on the bulbs in the furrow is the efficient and cost effective method for the control of *D. destructor*.

DISCUSSION

The use of chemicals for the control of *D. destructor* on iris has to be cost effective, safe to use, and adaptable to the cultural management system used in the bulb growing industry. This research established that fenamiphos applied as a liquid or granule directly on the bulbs at time of planting is effective for the control of *D. destructor*. This control was observed when the infestation of *D. destructor* originated from planting stock, volunteer bulbs, or weed hosts. Also this method of application can be incorporated into the cultural management system used by commercial growers in Washington and Oregon.

The information obtained from this research and limited commercial tests conducted under a use permit established a Special Local Need (Section 24 [c]) registration for fenamiphos on iris in the states of Washington and Oregon. The registration of fenamiphos for *Ditylenchus* control has virtually eliminated this nematode as a grower problem in western Washington. Fenamiphos application of 6.7 to 13.4 kg ai/ha (6 to 12 pounds active material per planted acre) is applied to virtually all the commercial acreage of iris. Applications are made with liquid or granular formulation on commercial bulbs at planting time. Occasionally iris bulbs infected with *D. destructor* have been recovered in commercial plantings treated with fenamiphos. This may be due to failure of application equipment or excessive leaching of material from low spots in the field. The frequency of recovery of infected bulbs is not related to the level of infection in the planting stock or general soil type on which the iris are grown.

Fenamiphos is well suited to the general agricultural practices in bulb culture in western Washington and Oregon and has been incorporated into the normal cultural practice of iris growing.

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