Influence of irrigation on effectiveness of nematicides for management of Columbia root knot nematode on potatoes

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Abstract

In the Pacific Northwest of the United States of America, the Columbia root knot nematode, *Meloidogyne chitwoodi*, causes yield reduction and significant numbers of blemished and thus unmarketable potato tubers. Depending on market conditions, an entire field can be declared unmarketable when 5 to 10% of the tubers are found to be blemished. The influence of irrigation on nematicide effectiveness was evaluated in two field trials conducted in a silty clay loam soil with 12% organic matter. Plots were 0.9 m wide by 18 m long arranged in a randomized block design with four replicates per treatment. Nematicide applications were injected into drip irrigation tubing with a piston pump. Treatment effectiveness was monitored via tuber yield and percent tubers with blemish. Nematode population levels were determined from soil samples taken pretreatment and at harvest. Drip irrigation applications of the fumigants metam sodium, 1,3-dichloropropene, oxamyl, and sodium tetrathiocarbonate applied in different volumes of water showed greater effectiveness with increasing volume of water. Of the products evaluated, the carbamate oxamyl was the most effective in reducing tuber blemish and nematode populations.

Keywords: irrigation, nematode, nematicide, potato, root knot nematode

INTRODUCTION

In the Pacific Northwest of the United States of America, the Columbia root knot nematode, *Meloidogyne chitwoodi,* reduces yield and significant numbers of blemished and thus unmarketable potato tubers. Depending on market conditions, an entire field can be declared unmarketable when 5-10% of the tubers are found to be blemished. The influence of drip irrigation application on nematicide effectiveness was evaluated in two field trials conducted in a silty clay loam soil with 12% organic matter. Although this nematode is widespread throughout the Northwest (Nyczepir et al., 1981; Santo et al., 1980), much of the research conducted elsewhere on control of this pest (Griffin, 1989; Pinkerton et al., 1986) is not applicable to the Tulelake Basin because of the unique soil type (a silty clay loam with 10-13% organic matter) found in this area (Smelt and Leistra, 1974).

Broadcast shank injected applications of fumigant nematicides have traditionally provided the most effective preplant nematode control (Goring, 1962). However, in experiments conducted in response to grower complaints of fumigation failures with 1,3-dichloropropene (1,3-D) in Tulelake Basin soils, we found that in the high organic matter soils of this region, 1,3-D moves 15 cm or less from the point of injection. Under optimum conditions, this material should disperse at least twice as far from the point of injection. Rates as high as 327 L ha^{-1} did not improve dispersal (Westerdahl et al., 1988). The fine textured soils in this area remain too wet and contain too much organic matter for optimum dispersal.

Research on the application of nematicides via drip irrigation systems has shown this to be an effective means of applying these products (Apt and Caswell, 1988; Radewald et al., 1985; Roberts et al., 1988). Two fumigants (1,3-D and metam sodium) and one carbamate (oxamyl) registered in the United States for use on potatoes were evaluated in two field trials

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conducted in the Tulelake Basin of California. An experimental fumigant (sodium tetrathiocarbonate) was also evaluated. The first trial evaluated the importance of timing of applications with treatments applied either preplant, preplant and postplant, or only postplant. The second trial repeated several preplant treatments from the first trial and evaluated whether the same rate of product applied over a 6-h interval would improve control over that applied in 3 h.

MATERIALS AND METHODS

Two experiments were conducted in a field with a history of infestation with Columbia root knot nematode. Experiments utilized Russet Burbank potatoes (*Solanum tuberosum* 'Russet Burbank'). Planting dates (mid-May), harvest dates (mid-October), and crop cultural practices were consistent with normal potato production practices in the Tulelake Basin. Both experiments were conducted as a randomized block with four replications per treatment and a plot size of 0.9 by 18 m. Prior to treatments, drip irrigation tubing (Drip In Irrigation Company, Fresno, CA) was laid out on top of pre-made raised beds that had a 92 cm row spacing. The drip tubing had 2 L h^{-1} emitters with a 30 cm spacing between emitters. Treatments were injected into the irrigation lines with a piston pump (Inject-O-Meter, Model 1-70, Clovis, NM).

Nematode samples from each experiment were taken prior to chemical applications to establish the presence of a nematode population and at harvest. Each sample was composed of ten 2.5 cm cores to a depth of 30 cm. Nematodes were extracted from soil using a modified semiautomatic elutriator and sugar flotation technique (Byrd et al., 1976). At maturity, plots were harvested, and the percentage of tubers exhibiting a surface blemish due to nematodes was determined. Results are presented as total yield, percent reductions in blemished tubers, and the number of root-knot nematode juveniles in soil present at harvest. Results were analyzed with analysis of variance followed by Fisher's protected least significant difference test at $P=0.05$.

In the first trial, 18 treatments were compared to an untreated check. 1,3-D (Telone II. Dow Agrosciences) was applied at 15 L ha^{-1} over 3 h preplant (Pre), both preplant and postplant (PrePost), or postplant (Post); and at 30 L ha^{-1} over 6 h Pre, PrePost, or Post. Sodium tetrathiocarbonate (Enzone, NaTetra, Adama) was applied at 786 L ha^{-1} over 3 h Pre, PrePost, or Post; and at 1,572 L ha^{-1} over 6 h Pre, PrePost, or Post. Oxamyl (Vydate, Dupont) was applied at 42 L ha^{-1} over 3 h Pre, PrePost, or Post; and at 84 L ha^{-1} over 6 h Pre, PrePost, or Post.

In the second trial, the untreated check, the highest and lowest Pre rates for NaTetra and Oxamyl, and the highest rate Pre for 1,3-D from the first trial were repeated. In addition, an additional fumigant, metam sodium (Vapam, Metam, Amvac), was evaluated. 1,3-D was applied at 30 L ha^{-1} over a 3-h period, 60 L ha^{-1} over 3 and 6 h, and 120 L ha^{-1} over 6 h. Metam was applied at 234 L ha^{-1} over a 3-h period, 468 L ha^{-1} over 3 and 6 h, and 936 L ha^{-1} over 6 h. NaTetra was applied at 786 L ha^{-1} over a 3-h period, 1,572 L ha^{-1} over 3 and 6 h, and 3,144 L ha^{-1} over 6 h. Oxamyl was applied at 21 L ha^{-1} over a 3-h period, 42 L ha^{-1} over 3 and 6 h, and 84 L ha^{-1} over 6 h.

RESULTS

In the first trial, reductions in nematode blemished tubers compared to untreated ranged from 0-100% (Table 1).

Fourteen treatments reduced nematode blemish compared to the untreated, with 11 of these being statistically significant. Reductions in nematode levels at harvest compared to untreated ranged from 0-97%. Sixteen treatments reduced root-knot nematode numbers compared to the untreated, with 8 of these being statistically significant. Four treatments increased overall yields, while 14 had decreased yields compared to untreated. Highest yields were obtained by the low rate of Oxamyl applied Pre and PrePost, the high rate of Oxamyl applied PrePost, and the low rate of 1,3-D applied Pre. Statistically, all NaTetra and 1,3-D treatments that included Post applications decreased yields. Three treatments both increased yields and reduced blemish to below 5%: Oxamyl at 42 L ha^{-1} Pre and PrePost, and Oxamyl at 84 L ha^{-1} PrePost.

Table 1. Effects of drip irrigation applied nematicides on tuber yield, nematode blemish, and root-knot nematode in Trial 1.

Treatment	Rate (L ha^{-1})	Hours applied over	Frequency	Tuber yield (kg ha^{-1})		Tuber yield: Percent with nematode blemish		Tuber yield: Percent reduction compared to untreated	Root-knot nematode (L^{-1} of soil)		Root-knot nematode: Percent reduction compared to untreated
NaTetra	786	3	Pre	41,050	defgh	95.3	j	0	11,813	bcdef	36
	786	3	PrePost	33,141	bcd	60.6	ef	29	10,887	bcdef	41
	786	3	Post	34,899	cde	74.8	fgh	12	19,679	ab	0
	1,572	6	Pre	40,548	defg	74.0	fgh	13	14,250	bcd	23
	1,572	6	PrePost	24,730	ab	15.4	ab	82	1,824	ef	90
	1,572	6	Post	24,730	ab	40.7	cd	52	6,142	cdef	67
Oxamyl	42	3	Pre	48,080	gh	1.7	a	98	570	f	97
	42	3	PrePost	52,097	h	1.2	a	99	983	f	95
	42	3	Post	43,812	efgh	67.8	efg	20	16,131	bc	13
	84	6	Pre	44,439	fgh	6.9	a	92	3,677	def	80
	84	6	PrePost	52,725	h	0.0	a	100	641	f	97
	84	6	Post	44,816	h	88.8	hij	0	14,179	bcd	23
1,3-D	15	3	Pre	48,708	gh	67.9	efg	20	28,329	ab	0
	15	3	PrePost	35,652	cdef	85.9	hij	0	12,654	bcdef	32
	15	3	Post	35,401	cdef	92.1	ij	0	9,149	bcdef	51
	30	6	Pre	40,799	defg	55.6	de	34	13,552	bcdef	27
	30	6	PrePost	28,245	bc	78.2	ghi	8	5,771	cdef	69
	30	6	Post	17,952	a	31.8	bc	63	1,055	f	94
Untreated	0	0		46,825	gh	84.8	hij	0	18,482	ab	0

NaTetra (sodium tetrathiocarbonate), 1,3-D (1,3-dichloropropene). Nematode counts were transformed by log(X+1) prior to statistical analysis. Results presented are nontransformed means of four replications. Means within a column followed by the same letter(s) are not significantly different according to LSD test, *P=0.05*.

In the second trial, reductions in nematode blemished tubers compared to untreated ranged from 11 to 95%, with seven treatments showing significant reductions (Table 2).

Table 2. Effects of drip irrigation applied nematicides on tuber yield, nematode blemish, and root-knot nematode in Trial 2.

Treatments	Rate (L ha^{-1})	Hours	Tuber yield (kg ha^{-1})		Percent with nematode blemish		Percent reduction compared to untreated	Root-knot nematode (L^{-1} of soil)		Percent reduction compared to untreated
NaTetra	3,144	6	40,142	a	46	cde	29	11,970	b	75
	1,572	6	38,284	a	27	abcde	58	14,008	b	71
	1,572	3	37,054	a	54	e	17	37,791	ab	21
	786	3	33,975	a	47	cde	28	20,021	ab	58
Oxamyl	84	6	42,431	a	6	a	91	14,834	b	69
	42	6	43,937	a	12	ab	82	43,819	ab	9
	42	3	37,535	a	3	a	95	18,539	ab	61
	21	3	37,912	a	7	a	89	19,409	ab	60
1,3-D	120	6	36,531	a	12	ab	82	20,506	ab	57
	60	6	36,280	a	43	bcde	34	33,060	ab	31
	60	3	34,773	a	58	e	11	38,860	ab	19
	30	3	36,656	a	50	cde	23	25,094	ab	48
Metam	936	6	36,531	a	19	abcd	71	32,818	ab	32
	468	6	36,280	a	17	abc	74	11,243	b	77
	468	3	36,154	a	30	abcde	54	20,720	ab	57
	234	3	35,777	a	33	abcde	49	31,208	ab	35
Untreated	0	0	35,150	a	65	e	0	48,065	a	0

NaTetra (Sodium Tetrathiocarbonate), Metam (Metam Sodium), 1,3-D (1,3-Dichloropropene). Nematode counts were transformed by log(X+1) prior to statistical analysis. Results presented are nontransformed means of four replications. Means within a column followed by the same letter(s) are not significantly different according to LSD test, *P=0.05*.

These included all treatments with Oxamyl, both six-hour applications with NaTetra, and the high rate of 1,3-D applied over six hours. Reductions in nematode levels at harvest compared to untreated ranged from 11 to 91 percent. All treatments reduced root-knot nematode levels compared to the untreated, with four of these being statistically significant: the high rate of Oxamyl applied over six hours, both rates of NaTetra applied over six hours, and the low rate of Metam applied over six hours. Numerically, all treatments except two increased yields compared to the untreated.

DISCUSSION AND CONCLUSIONS

In these trials, three fumigants and one carbamate nematicide were evaluated. 1,3-D is a chlorinated hydrocarbon fumigant that has been widely used and has provided excellent nematode control in a variety of crops since the 1940s. After being injected as a liquid, it moves through air in the soil pores as a gas and then dissolves in the water film lining the pores to kill nematodes. Metam has been available for use as a soil fumigant since the 1950s. It has a lower vapor pressure than 1,3-D and therefore does not move as well through air in soil pores. Also, in comparison with 1,3-D, significantly more Metam is found in the water than in the air phase of the soil and is thus not available for diffusion (Smelt and Leistra, 1974). Oxamyl is a highly soluble systemic carbamate with registrations on selected crops that has been registered as a nematicide since the 1960s. NaTetra is a relatively new liquid fumigant that decomposes in soil to produce the gas carbon disulfide.

In both trials, Oxamyl provided the highest degree of nematode blemish reduction. For all products, there was good agreement between reduction in tuber blemish, and in the reduction of root-knot nematode present at harvest. In the first trial, both Pre and PrePost rates of Oxamyl statistically reduced levels of root-knot nematode, but Post did not. Results were similar for blemish reduction with the exception of 42 L Post that had a relatively high level of blemish in spite of showing a significant reduction in nematodes. These results indicate that a Pre application of Oxamyl can provide effective nematode control and reduction of tuber blemish when applied via drip irrigation to a silty clay loam soil with high organic matter content. In the second trial, the fumigants 1,3D, Metam, and NaTetra were more effective when the same rate was applied over 6 h rather than 3 h. In contrast, the opposite was true for the carbamate product Oxamyl.

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