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Management of *Globodera rostochiensis* as Influenced by Nematode Population Densities and Soil Type[1]

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Abstract: The effects of aldicarb, oxamyl, 1,3-D, and plastic mulch (solarization) on soil population densities of the golden nematode (GN) *Globodera rostochiensis* was assessed in field and microplot experiments with different soil types. Oxamyl was evaluated in both soil and foliar treatments, whereas aldicarb, 1,3-D, and solarization were applied only to soil. Soil applications of aldicarb and oxamyl resulted in reduced nematode populations after GN-susceptible potatoes in plots with initial population densities (Pi) of > 20 and 7.5 eggs/cm^3 soil, respectively, but nematode populations increased in treated soil when Pi were less than 20 and 7.5 eggs/cm^3 soil. In clay loam field plots with Pi of 19–76 eggs/cm^3 soil, nematode densities increased even with repeated foliar applications of oxamyl, whereas nematode populations at Pi greater than 76 eggs/cm^3 soil were reduced by foliar oxamyl. Treatment with 1,3-D or solarization, singly or in combination, reduced GN soil population densities regardless of soil type or Pi. Temperatures lethal to GN were achieved 5 cm deep under clear plastic but not 10 or 15 cm deep.

Key words: golden nematode, chemical management, nonchemical management, initial densities, potato, *Solanum tuberosum.*

Many studies have examined the effects of fumigant and nonfumigant nematicides on the golden nematode (GN) *Globodera rostochiensis* (Woll.) (12,14,16,18,20), but few have considered the relation of soil population densities of GN to nematicide efficacy (18). Chemical management of GN populations usually is aimed at improving potato yields in fields with nematode population densities sufficient to cause economic loss. In the United States, GN management efforts are aimed at keeping soil nematode densities below detectable levels to retard spread of the nematode. Consequently, most chemical management of GN is applied to regulated infested land on which the nematode is not detectable.

Soil fumigation increases plant growth and vigor, but densities of nematode cysts in soil following crop harvest are often greater than without fumigation (5,7). Applications of oxime carbamate nematicides increase potato yields and prevent increases in GN soil populations (20). Although oxime carbamates prevent GN population increases at high soil densities, that is, densities that affect yield, their effectiveness at preventing GN population increases at low soil densities is not known.

After 10 years of management studies, Brodie (unpubl.) concluded that oxime carbamate nematicides were less effective at very low GN population densities in soil than at plant damaging densities. *Globodera rostochiensis* population densities were reported to increase after treatment of lightly infested field soil with aldicarb and oxamyl (18). After GN-infested fields in the United States are fumigated and posttreatment surveys are negative for GN, susceptible potato cultivars are permitted to be grown provided an approved nematicide, such as aldicarb or oxamyl is applied. Consequently, viable GN remaining in fields after nematicide treatment may result in a population increase of this nematode.

Soil solarization using clear plastic mulch has been used to manage certain soilborne pests (8) or to supplement biological and chemical control (4). LaMondia and Brodie (9) demonstrated that solarization eliminated GN in the top 5 cm of soil, suggesting that it might be a useful nonchemical tool to manage *G. rostochiensis.* Our objective was to determine the efficacy of certain nematicides and nonchemical methods to reduce and control GN at several initial population densities (Pi).

Materials and Methods

Nematicides used were aldicarb, 2-methyl-2-(methylthio) propionaldehyde, O-

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(methylcarbamoyl) oxime (Temik 15G); oxamyl, methyl *N'*,*N'*-dimethyl-*N*{(methyl/carbamoyl)oxy}-1-thiooxammidate (Vydate 10G), Vydate L (25.2% oxamyl); and 1,3-dichloropropene, 92% (Telone II). Microplots (0.9 m diameter and 1.2 m deep) were lined with fiberglass and contained either silty clay (9.1% sand, 46.9% silt, 44.0% clay, pH 5.0) or clay loam soil (38.5% sand, 33.6% silt, 27.9% clay, pH 5.8). Different soil population densities of GN had developed in these microplots during 5 years of potato-GN research. Aldicarb and oxamyl 10G were applied to soil in 10 microplots of each soil type with GN densities of 3.7–44.1 eggs/cm^3 soil. The granular nematicides were applied at the rate of 5.6 kg a.i./ha to the soil surface and incorporated 5 cm deep with a rake. Telone II was applied at 93.5 liters/ha to the soil in 10 microplots of each soil type with GN densities of 2.9–47.3 eggs/cm^3 soil; the fumigant was applied with a hand injector in nine injections 15 cm apart and 15 cm deep in each treated microplot. All plots were planted to GN-susceptible potato, *Solanum tuberosum* L. cv. Superior, in May.

Nematode population densities were estimated from soil samples taken from each plot in October before treatments were applied and after harvest the following October. The top 30 cm of soil in each plot was thoroughly mixed, and 10 subsamples (each 50 cm^3) were removed to 15 cm deep with a soil sampling trowel (15). The subsamples from each plot were combined and mixed, and 150 cm^3 dry soil which had passed through a 850-μm-pore sieve processed with a USDA cyst extractor (15). Cysts separated from debris with acetone (1) were crushed and viable J2 contents determined. Using a conservative statistical procedure to reduce error, which may be magnified at low soil nematode population densities, initial and final densities were averaged over three initial density classes before calculating population changes (19).

Tests measuring the influence of foliar applications of oxamyl were conducted on potatoes growing in small field plots (2 × 15 m) containing soil naturally infested with GN. Nematode densities were 19–165 eggs/cm^3 soil in 1982 and 38.6–178.5 eggs/cm^3 soil in 1983. Vydate L was applied to potato foliage at the rate of 1.1 kg a.i./ha until runoff at weekly intervals beginning 11 and 9 weeks after 90% of the plants had emerged in 1982 and 1983, respectively. To obtain complete coverage, the oxamyl concentration of the spray was adjusted as the potato canopies enlarged. The experiment involved five initial soil GN density classes, with each class replicated eight times each year. Nematicide efficacy was determined by estimating nematode population densities in soil samples taken from plots before planting (Pi) and after harvest (Pf). Fifty soil subsamples (each 50 cm^3) taken to 10 cm deep were removed from each plot. The subsamples were combined and mixed, and 250 cm^3 was processed as described earlier to determine numbers of viable eggs and juveniles.

Fumigation–solarization was studied in field plots (3.7 × 7.6 m) naturally infested with densities of GN ranging from 65.1 to 238.9 eggs/cm^3 soil. The fumigant 1,3-D was chisel injected 20 cm deep at 168.3 liters/ha in one or two applications, turning the soil between applications, with and without a plastic seal (0.4 mil clear polyethylene); a plastic mulch without fumigant was also used. Plastic mulches were applied 26 July and removed 30 September 1983. Each treatment was replicated three times. Recording thermographs monitored soil temperatures at 5, 10, and 15 cm deep under the plastic. Ten 50-cm^3 soil subsamples collected to 10 cm deep from each plot were taken before treatments were applied and 2 months after treatment. Subsamples from plots were combined and mixed, and 250 cm^3 was processed to determine numbers of viable eggs and juveniles.

Results

Population density changes in clay loam and silty clay soils indicate that suppression of GN populations by aldicarb and oxamyl is positively correlated with initial GN density ($P = 0.01$) (Table 1). As Pi decreased, percentage of GN reduction in silty clay decreased until at low Pi populations increased under potatoes in treated plots. Nematode densities below which populations increased in silt clay soil treated with aldicarb and oxamyl were approximately

TABLE 1. Changes in *Globodera rostochiensis* population densities after a crop of potatoes in silty clay and clay loam soils with different initial nematode population densities (Pi) as influenced by application of aldicarb, oxamyl, and 1,3-D.

Pi (eggs/cm³ soil)*	Density changes (%)			
	Aldicarb	Oxamyl	1,3-D	No nematicide
Silty loam				
5.9–8.0	+45.0	+13.2	−64.4	+437.5
22.5–24.1	−20.3	−44.0	−60.1	+347.8
40.2–47.3	−64.7	−45.4	−76.7	+316.3
$y = -3.4x + 68.8$† $R^2 = 0.98$‡		$y = -1.5x + 10.8$ $R^2 = 0.69$	$y = -0.3x - 58.9$ $R^2 = 0.61$	
Clay loam				
2.9–4.1	−13.5	−43.9	−88.6	+280.5
9.1–11.1	−79.6	−53.2	−84.6	+345.8
18.4–24.8	−65.7	−66.3	−92.3	+288.3
$y = -2.8x - 20.8$ $R^2 = 0.45$		$y = -1.6x - 36.9$ $R^2 = 0.98$	$y = -0.23x - 85.7$ $R^2 = 0.46$	

* Measurements were averaged within each density class to reduce any error due to measurement (19).
† Regression equation.
‡ R^2 value for the regression equation.

20.0 and 7.5 eggs/cm³ soil, respectively. Reduction of GN population densities with 1,3-D was also proportionally less at low Pi than high Pi ($P = 0.05$), but populations did not increase under potatoes at any Pi. GN population reduction was also correlated with Pi in the clay loam soil, except Pf under potatoes did not exceed Pi. Control percentages with all chemicals were higher in clay loam than in silty clay soil.

The degree of GN population suppression or increase was regressed against Pi for each chemical and soil type combination. Slopes of the regression lines for the response of nematode populations to each chemical are similar for the two soil types but differ among chemicals. Slopes for nematode response to aldicarb are greater than those for oxamyl in both soils, indicating that control with aldicarb is influenced to a greater extent by Pi than is control with oxamyl. Slopes for 1,3-D are close to zero, indicating that the degree of GN control with 1,3-D is not significantly influenced by Pi.

Control of GN by foliar applications of oxamyl was also influenced by Pi ($P = 0.01$) (Table 2). At high Pi (> 57 eggs/cm³ soil in 1982 and > 76 eggs/cm³ soil in 1983) foliar applications of oxamyl resulted in a Pf less than Pi. At low Pi, Pf was greater than Pi despite 11 oxamyl applications in 1982 and 9 applications in 1983. Although the number of oxamyl applications and Pi differed somewhat between years, results were similar for both years.

Control of GN by 1,3-D and solarization (plastic mulch) application, alone or in combination, was not influenced by Pi (Table 3). The combination of 168 liters/ha of 1,3-D with plastic mulch for 2 months after application resulted in no detectable viable eggs or juveniles. Plastic mulch alone for 2 months reduced GN soil density by 95.6%, whereas two applications of 1,3-D at 168 liters/ha each 14 days apart, with plowing between applications (regulatory treatment), reduced the densities by only 92.2%. A single application of 1,3-D (168 liters/ha) reduced GN densities by less than 80%.

DISCUSSION

Aldicarb and oxamyl kill or reduce movement and invasion of roots by GN juveniles (6,16) but do not affect nematode development once the juveniles have infected roots (16). Whitehead (20) and Seinhorst (13) independently observed differences in the efficacy on GN of aldicarb applied at various soil depths. Efficacy of aldicarb decreased with increasing soil depth. GN populations increased below 20 cm because of lack of downward movement of the surface applied nematicides. Vertical movement in soil of nonvolatile

TABLE 2. Changes in *Globodera rostochiensis* final population densities as influenced by foliar applications of oxamyl to foliage of potatoes growing in silty clay with different initial nematode densities (Pi).

Pi (eggs/cm³ soil)*	Density change (%)	Pi (eggs/cm³ soil)*	Density change (%)
1982: oxamyl†		1983: oxamyl‡	
19.3	+68.7	38.6	+61.9
51.9	−3.1	68.6	+4.0
78.4	−22.7	91.6	−19.9
120.5	−27.3	118.4	−40.1
165.8	−60.2	178.5	−53.7
$y = 130x - 299$§	$R^2 = 0.96$	$y = 178x - 336$	$R^2 = 0.96$
1982: no nematicide		1983: no nematicide	
25.5	+138.4	21.0	+73.3
52.5	+21.1	32.8	+49.7
60.2	+13.0	68.6	−5.1
99.6	+13.5	123.4	−4.3

* Pi = initial density (average of eight plots per Pi class).
† Eleven weekly applications at 1.1 kg a.i./ha each.
‡ Nine weekly applications at 1.1 kg a.i./ha each.
§ Regression equation and R^2 value.

nematicides is influenced by soil type, with better efficacy in sandy than in heavy clay soils (2). Our data demonstrate that soil type appears to be important in determining the extent of increase of *G. rostochiensis* population densities in soil treated with aldicarb and oxamyl. The better control achieved in clay loam, as compared with silty clay, may be directly related to better movement of the chemical with less sorption to soil particles in the sandy soil.

Our data indicate that low GN Pi increase more slowly on susceptible potatoes when oxamyl is applied to soil than when aldicarb is applied in both soils. Trudgill (18) reported that oxamyl consistently controlled GN better than aldicarb. Also, soil application of oxamyl resulted in less GN increase on potatoes than foliar application.

Application of aldicarb and oxamyl to soils with low GN Pi may result in GN population increases, but population increases are much lower than would occur with *G.*

TABLE 3. Effect of initial population density (Pi) of *Globodera rostochiensis* on control with fumigation–solarization.

Treatment	Dosage	Pi (eggs/cm³ soil)	Density reduction (%)	Average density reduction (%)
1,3-D with a plastic mulch	168 liters/ha + 2 months mulch	65.1	100	100.0 a
		114.8	100	
		174.6	100	
Plastic mulch	2 months	37.2	96.4	95.6 ab
		90.5	95.0	
		238.9	95.3	
1,3-D	336 liters/ha*	112.9	95.1	92.2 b
		113.7	94.2	
		126.9	87.4	
1,3-D	168 liters/ha	60.3	78.0	78.7 c
		109.2	69.5	
		199.7	88.6	

Numbers followed by the same letter not significantly different ($P = 0.05$) according to Duncan's multiple-range test.
* Two applications of 168 liters/ha 14 days apart, with plowing between applications.

rostochiensis on susceptible potatoes in the absence of nematicide application. Aldicarb and oxamyl were withdrawn from use on Long Island, New York, in 1980 and 1984, respectively, and are not available for use in the U.S. golden nematode control program. Our data show that although the loss of these chemicals is important, it is not as critical in the GN control program as initially believed, because they are not as effective at low Pi of *G. rostochiensis* as they were previously assumed to be (16).

Degree of *G. rostochiensis* control with 1,3-D was not related to Pi. A major disadvantage of fumigant nematicides is that because of vapor loss at the soil surface they are less effective in the top 5 cm than they are deeper in soil (11,17). Lack of efficacy from surface loss can be compensated for by applying both fumigant and nonfumigant nematicides (12,14) or to fumigate, plow, and fumigate again (3). LaMondia and Brodie (9) demonstrated that solarization with clear plastic will eliminate *G. rostochiensis* in the top 5 cm of soil. We evaluated combined fumigation–solarization in an attempt to develop a more effective environmentally safe control tactic for *G. rostochiensis*. In our tests, solarization alone resulted in 95.6% GN population reduction. Time–temperature combinations lethal to encysted eggs of *G. rostochiensis*, 45 C for 2 hours (10), were achieved at 5 cm deep but not at 10 and 15 cm deep. When combined with a single application of 1,3-D, solarization reduced GN soil population densities to below detectable levels.

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