Control of *Criconemella xenoplax* and *Meloidogyne incognita* and Improved Peach Tree Survival Following Multiple Fall Applications of Fenamiphos

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ABSTRACT

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No significant decrease in *Criconemella xenoplax* was detected within 2 mo of the initial fenamiphos application to peach (*Prunus persica*). After 1 yr, however, multiple or split applications of fenamiphos in the fall significantly reduced *C. xenoplax* and *Meloidogyne incognita* populations. The reduction of *C. xenoplax* populations to below detection levels did not prevent the occurrence of trunk cambial browning (winter injury); however, by the following spring, the fenamiphos-treated trees had better foliage condition than the untreated trees. Multiple foliar or soil oxamyl applications in the fall did not control *C. xenoplax* or *M. incognita* or improve tree survival compared with untreated trees.

In many of the peach-growing areas of the southeastern United States, peach trees (*Prunus persica* (L.) Batsch) often die prematurely, showing symptoms associated with the peach tree short life complex (PTSL) (2,12). This disease complex results from several direct factors and numerous predisposing factors. Major direct factors are freeze injury and bacterial canker caused by *Pseudomonas syringae* pv. *syringae* (2,12,13). Predisposing factors include the type of rootstock used (2,9,12,17), pruning before January (2,4,10,12,13), and nematodes, particularly *Criconemella xenoplax* (Raski) Luc & Raski (2,5,8,9, 11,13,14,16,17). Because no adequate controls are available for preventing freeze injury and bacterial canker, control of PTSL has been aimed primarily at the predisposing factors.

Treatment with DBCP (dibromochloropropane) every 2–3 yr improved tree survival (2,10,12,14,16,17). Since the suspension of DBCP in 1979, no registered nematicide as effective as DBCP has been available for use on bearing peach trees. Many of the carbamate and organophosphate nematicides have been tested for nematode control and for improved tree survival with little long-term success (16).

Potential for peach tree loss from PTSL is considered greatest when the tree is allowed to go into dormancy with large populations of *C. xenoplax* present (4,13,17). For these reasons, postplant fall applications of nematicides often were used in the past.

The objective of this research was to determine the efficacy of multiple postplant fall applications of fenamiphos and oxamyl to control *C. xenoplax* and *Meloidogyne incognita* (Kofoid & White) and improve peach tree survival.

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MATERIALS AND METHODS

Two experiments were conducted at the Sandhills Research Station, Jackson Springs, NC. Both experimental sites had been planted in peaches three times since the early 1950s and were fallow for at least 1 yr before the trees for these experiments were planted. The orchard sites were preplant broadcast fumigated with 467 L D-D (dichloropropane-dichloropropene) (Shell Chemical Co., Houston, TX 77001) per hectare in October 1978 and 1979. Soil analysis in 1981 at experiment sites 1 and 2 indicated soil pH was 5.6 and 5.8 and organic matter was 1.3 and 1.4%, respectively.

Fenamiphos-oxamyl test. Trees in experiment 1 were cultivar Lovell propagated on NA-2 seedling rootstock (a selection from a mountain natural selection susceptible to *Meloidogyne* spp.) and were planted in March 1979.

Two nematicides were tested: fenamiphos (Nemacur 3, Mobay Chemical Corp., Kansas City, MO 64120) and oxamyl (Vydate 2L, E.I. du Pont de Nemours & Co., Wilmington, DE 19898). Fenamiphos was applied to the soil in a 9.4-m^2 area beneath each treated tree, using a handgun at 517 kPa (75 psi) at two rates, 5.04 and 20.16 kg a.i./ha/application. At each rate, treatments consisted of one yearly fall application (9 September 1980, 8 September 1981, and 23 September 1982), two yearly fall applications (9 and 24 September 1980, 8 and 22 September 1981, and 23 and 30 September 1982), or three fall applications (9 and 24 September and 22 October 1980). In 1981 and 1982, only two fall applications were applied to the treatment that received three applications in 1980.

Oxamyl was applied in a 9.4-m^2 area beneath the tree or to the foliage, using a handgun at 517 kPa at 2.24 kg a.i./ha/application. Oxamyl treatments were applied on the same dates as the fenamiphos treatments except in 1982, when tree condition had become so poor that the oxamyl treatments were discontinued.

Nematode assays. Assays consisted of 10–12 soil cores (1.5 cm diameter) from around each tree, taken about 1 m from the base of the tree to a depth of 15–22 cm using a soil tube. The soil was mixed and a 500-cm^3 sample was used for assays. Nematodes were extracted by using a semiautomatic elutriator (3) and centrifugal-flotation (6). Soil samples were taken on 12 November 1980, 2 September 1981, 14 April 1982, 1 September 1982, and 15 March 1983. Because of the large number of dead trees, no samples were taken from the oxamyl treatments in 1983.

Cold injury and foliar measurements. On 3 February 1982 and 29 March 1983, trees in experiment 1 were rated for freeze damage on the amount of trunk cambial browning using a scale where 0 = healthy tissue with no browning visible and 9 = dark brown and dry tissue (tree dead). Trunk cambial browning was determined by making a slanting cut in the southwest side of each trunk and immediately rating the discoloration (15). On 4 May 1982, the foliar condition of each tree was rated on a scale of 0–4, where 0 = dark, lush green foliage and terminal growth; 1 = green foliage but reduced terminal growth; 2 = foliage slightly yellow; 3 = yellow foliage and no new terminal growth; and 4 = tree dead. The total number of dead trees was determined in May 1983.

Fenamiphos band application. In experiment 2, fenamiphos was applied twice in 467 L water/ha at the rate of 10.08 kg a.i./ha/application. A 1.5-m band on either side of the tree row was treated using a tractor-driven herbicide applicator operating at 152 kPa (22 psi). Within 48 hr of application, the soil was disked to a maximum depth of 8 cm to incorporate the fenamiphos. This experiment consisted of four cultivars, Carolina Red (nectarine) and Clayton, Rubired, and Derby, on Lovell rootstock. Each cultivar planting consisted of 1.1 ha and was considered one replicate. Within each replicate, six trees served as checks and were not treated.

Nematode assays. In experiment 2, soil samples were taken from beneath 25–30 trees of each replicate and from the six check trees in each replicate as described for experiment 1 and combined into one 500-cm^3 composite sample for each replicate of treated and untreated soil.

Weather. Rainfall and mean daily temperature were recorded for September and October 1980, 1981, and 1982 at a weather station about 400 m from experiment 1 and 1.5 km from experiment 2. In 1980 and 1982, at least 1 cm of rain occurred within 7 days of each application. In 1981, only two periods of rainfall totaling 2 cm occurred from 9 September to 25 October.

RESULTS

Nematode populations. In experiment 1, no treatment significantly reduced nematode populations within 2 mo of the initial treatment (Table 1). Fenamiphos treatments significantly decreased *C. xenoplax* populations by 2 September 1981, 1 yr after treatments were begun. All fenamiphos-treated trees had significantly ($P = 0.01$) fewer *C. xenoplax* than did the untreated trees (Table 1). Trees receiving two or three applications of 5.04 kg a.i./ha had fewer *C. xenoplax* than trees receiving a single application of 20.16 kg a.i./ha, but the difference was not statistically significant. Soil receiving two or three applications in September and October 1980 and two applications in September 1981 had fewer *C. xenoplax* on 14 April 1982 than soil receiving a single application, regardless of application rate (Table 1). By 1 September 1982, *C. xenoplax* populations increased, but populations in all fenamiphos treatments remained below those in the check. Multiple applications at the high rate were the most effective. By 15 March 1983, all fenamiphos treatments decreased the *C. xenoplax* populations, whereas populations in the check increased.

Based on male characterization, the species of root knot was *M. incognita. M. incognita* populations increased gradually during the 3 yr of the experiment. By September 1982 and March 1983, significant effects of fenamiphos were detected (Table 1). All multiple applications at the low rate reduced the number of *M. incognita* below that in the single application or check; all treatments at the high rate, regardless of the number of applications, significantly reduced *M. incognita* populations (Table 1). No significant reduction of *C. xenoplax* or *M. incognita* populations was detected in the oxamyl-treated plot (Table 2).

In experiment 2, the number of *C. xenoplax* in the treated plots compared with the untreated check was reduced 3× in April 1983. Populations in late May 1983 were reduced about 6× compared with the check (Table 3).

Cold injury and foliar measurements. Trunk cambial browning was recorded for experiment 1 on 3 February 1982. None of the trees treated with fenamiphos was free from injury, but those receiving multiple applications at the high rate had significantly less browning (Table 4). On 4 May 1982, foliar condition was rated. Foliage and terminal growth of fenamiphos-treated trees was significantly improved compared with that of the untreated trees (Table 4). On 29 March 1983, trees were rated again for trunk cambial browning. Only trees receiving multiple applications at the high rate of fenamiphos had significantly less cambial browning than check trees (Table 4). The oxamyl treatments did not reduce trunk cambial browning in 1982.

Tree death. On 24 May 1983 in the fenamiphos plot, 80% of the check trees and trees receiving a single application at the low rate were dead; 40% of the trees receiving multiple applications at the low rate and the trees receiving a single application at the high rate were dead. None of the trees receiving multiple applications at the high rate were dead (Table 4). In experiment 2, no differences in tree death were observed after 1 yr.

Table 1. Effect of postplant fall applications of fenamiphos to peach on *Criconemella xenoplax* and *Meloidogyne incognita* larvae populations in experiment 1

Fenamiphos application rate (kg a.i./ha)	No. of applications[w]	Sample dates and mean number of nematodes/100 cm^3 soil[x] 12 Nov. 1980	2 Sept. 1981	14 Apr. 1982	1 Sept. 1982	15 Mar. 1983
Criconemella xenoplax						
Untreated check	···	156	941	264	644	891
5.04	1	118	139 a[y]	42 a[y]	236 a[y]	166 a[y]
5.04	2	197	12 a	10 ab[z]	125 a	65 a
5.04	3	72	3 a	0 ab	158 a	52 ab[z]
20.16	1	118	102 a	38 a	58 a	16 a
20.16	2	67	0 a	1 ab	2 ab[z]	0 ab
20.16	3	92	0 a	0 ab	0 ab	0 ab
Meloidogyne incognita						
Untreated check	···	0	3	3	14	58
5.04	1	0	3	4	21	10
5.04	2	2	0	10	8	1 a[y]
5.04	3	0	0	1 a[y]	6	2 a
20.16	1	0	0	1 a	0 a[y]	0 a
20.16	2	0	0	0 a	0 a	0 a
20.16	3	0	0	0 a	0 a	0 a

[w]Application dates: one application—9 September 1980, 8 September 1981, and 23 September 1982; two applications—9 and 24 September 1980, 8 and 22 September 1981, and 13 and 30 September 1982; three applications—9 and 24 September and 22 October 1980, 8 and 22 September 1981, and 23 and 30 September 1982.

[x]Means of five single-tree replicates per treatment, except for untreated check on 1 September 1982 and 15 March 1983, which was the mean of three replicates.

[y]Means in the same column followed by the letter "a" are significantly different from the untreated check using LSD ($P = 0.01$).

[z]Means in the same column followed by the letter "b" are significantly different from the mean of treatments receiving a single application using LSD ($P = 0.01$).

Table 2. Effect of postplant fall applications of oxamyl to peach on *Criconemella xenoplax* (ring) and *Meloidogyne incognita* (root knot) larvae populations in experiment 1

			Sample dates and mean number of nematodes/100 cm^3 soil[b]					
			12 Nov. 1980		2 Sept. 1981		1 Sept. 1982	
Oxamyl application	Rate (kg a.i./ha)	No. of applications[a]	Ring	Root knot	Ring	Root knot	Ring	Root knot
Untreated check	···	···	229	10	839	34	724	57
Foliar	2.24	1	127	22	653	25	678	22
	2.24	2	187	1	638	11	676	45
	2.24	3	72	1	511	1	400	119
Soil	2.24	1	240	1	1,031	0	1,004	55
	2.24	2	160	4	496	1	–[c]	–[c]
	2.24	3	145	4	968	56	618	55

[a]Application dates: one application—9 September 1980 and 8 September 1981; two applications—9 and 24 September 1980 and 8 and 22 September 1981; three applications—9 and 24 September and 22 October 1980 and 8 and 22 September 1981.

[b]Means of five single-tree replicates per treatment, except where trees were missing.

[c]All trees were dead at time of sampling.

In the oxamyl-treated plot, the only treatment with more than 20% living trees was the treatment receiving three applications to the soil in 1980 and two applications in 1981.

DISCUSSION

Fenamiphos can suppress or reduce populations of *C. xenoplax* and *M. incognita* and improve tree survival when applied yearly as multiple or split postplant fall treatments. A temporary suppression of *C. xenoplax* after use of fenamiphos was reported by Zehr et al (16), who suggested improved control may be achieved if applied at higher rates and in fall applications. My results support this. Continued nematode control and improved tree survival can be achieved by applying yearly multiple or split applications of fenamiphos. A single application equivalent to the total amount applied in the multiple applications was not used in these experiments; however, comparison of the results from the treatments receiving two and three applications at the low rate with a single application at the high rate indicate multiple applications are more effective than a single application for reduction of the initial *C. xenoplax* population (Table 1).

The most effective rates used in experiment 1 are prohibitively great from the standpoint of label registration, economics, and possibly, residues in fruit, but they do reflect the efficacy of fenamiphos. However, fenamiphos applied in experiment 2 at lower rates, using a method applicable to grower use, reduced *C. xenoplax* populations significantly (Table 3).

Table 3. Effects of two fall applications of fenamiphos to peach on reduction of *Criconemella xenoplax* in experiment 2

			Sample dates and mean number of nematodes/100 cm^3 soil[b]			
Treatment[a]	Rate (kg a.i./ha)	No. of applications	8 Aug. 1982	13 Apr. 1983	24 May 1983	30 Aug. 1983
Untreated check	···	···	366	572	433	207
Fenamiphos	10.08	2	428	203*[c]	72*	26*

[a]Treatment dates: first application 1 September 1982 and second application 23 September 1982. Within 48 hr of each application, soil was disked to a maximum depth of 8 cm.
[b]Means of four replicates.
[c]* = Significantly different from untreated check using LSD ($P \leqslant 0.03$).

Table 4. Relationship of fenamiphos treatments to peach and occurrence of trunk cambial browning (CB), foliage rating (FR), and tree death in experiment 1

Fenamiphos application rate[a] (kg a.i./ha)	No. of applications	CB rating[b] (3 Feb. 1982)	FR rating[b] (4 May 1982)	CB rating[b] (29 Mar. 1983)	Percent dead trees[b] (1983)
Untreated check	···	6.8[c]	2.8[d]	8.4[c]	80
5.04	1	5.4	0.8*[e]	8.0	80
5.04	2	6.2	1.4*	5.0	40
5.04	3	5.4	1.4*	5.0	40
20.16	1	5.2	1.0*	6.2	40
20.16	2	4.0*	0.2*	0.6*	0*
20.16	3	4.6*	0.0*	1.0*	0*

[a]Application dates: one application—9 September 1980, 8 September 1981, and 23 September 1982; two applications—9 and 24 September 1980, 8 and 22 September 1981, and 23 and 30 September 1982; three applications—9 and 24 September and 22 October 1980, 8 and 22 September 1981, and 23 and 30 September 1982.
[b]Means of five single-tree replicates per treatment.
[c]Trunk cambial browning rated on a scale of 0–9, where 0 = no browning observed and 9 = total examined cambial area dark brown.
[d]Foliage rating on a scale of 0–4, where 0 = tree healthy in appearance, with lush growth and dark green foliage; 1 = green foliage but lacking lush growth; 2 = slight yellowing of foliage; 3 = yellow foliage, with slight or no terminal growth; and 4 = dead tree.
[e]* = Significantly different from the untreated control using LSD ($P = 0.05$).

In experiment 1, fenamiphos significantly reduced nematode populations for some treatments to an undetectable level but did not prevent trunk cambial browning (freeze injury) and PTSL symptoms. In 1982, however, the fenamiphos-treated trees were able to recover from the injury, as indicated by improved foliage condition compared with the check, especially those trees receiving multiple applications at the high rate (Table 4). In contrast, in the oxamyl plot, *C. xenoplax* populations remained high and freeze injury was similar across all treatments. Possibly, higher rates of oxamyl would be more effective. In 1983, only the trees with very low *C. xenoplax* populations had significantly less freeze injury. This indicates that controlling *C. xenoplax* populations may not necessarily result in a reduced susceptibility to freeze injury, or that the feeding effects of *C. xenoplax* remain for a period of time. Tree recovery could have resulted from better root growth attributable to nematode control or direct growth effects from fenamiphos or a combination of both.

A fumigant nematicide such as DBCP kills nematodes, and population decreases can be detected within several weeks of application (7,16). In contrast, with fenamiphos, a decline in *C. xenoplax* populations may not be detected for several months. This difference may result from the amount of time required for fenamiphos to move to the point of contact with the nematode, and/or the period of time required for nematode death after contact with the nematicide. The nematode assays did not differentiate between living and dead nematodes. Fenamiphos can reduce large populations of *C. xenoplax*, but its slowness in doing so may necessitate starting treatments before the occurrence of large populations for optimum results. Rainfall within a few days of application or use of mechanical incorporation may improve the activity of fenamiphos.

Lovell or Halford rootstocks, although susceptible to *C. xenoplax*, are recommended to improve scion survival, particularly in short life orchard sites (2,17). However, because Lovell and Halford also are very suscepible to *Meloidogyne* spp., DBCP was recommended as a postplant treatment. Although *C. xenoplax* is important in PTSL as a predisposing agent (8,11, 13,14), root knot can become a serious problem on Lovell and Halford (1). Thus, the availability of an effective nematicide for control of *Meliodogyne* spp. is important because it permits the use of these two root-knot-susceptible rootstocks, which provide better scion survival than can be obtained with root-knot-resistant rootstocks (12,16).

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