Effectiveness of Certain Nematicides for Control of *Macroposthonia xenoplax* and Short Life of Peach Trees

ELDON I. ZEHR, Professor, and STEPHEN A. LEWIS, Associate Professor, Department of Plant Pathology and Physiology, and C. E. GAMBRELL, Jr., Associate Professor, Department of Horticulture, Clemson University, Clemson, SC 29631

ABSTRACT

Zehr, E. I., Lewis, S. A., and Gambrell, C. E., Jr. 1982. Effectiveness of certain nematicides for control of *Macroposthonia xenoplax* and short life of peach trees. Plant Disease 66:225-228.

Dibromochloropropane was very effective as a preplant and postplant nematicide for *Macroposthonia xenoplax* control in a peach orchard where short life became severe 1 yr after planting. Prevention of tree loss and stimulated growth accompanied nematode control. Oxamyl as a foliar spray partially suppressed nematode populations and improved tree vigor in 3-yr-old trees, but it appeared to reduce growth of trees in their first year and did not improve tree survival. As postplant treatments, ethylene dibromide, 1,3-dichloropropene, and fenamiphos temporarily suppressed *M. xenoplax*; however, the effect did not persist and the treatments did not prevent tree death. Evidence of weakness during fall months was an indication of susceptibility to peach tree short life.

Additional key words: bacterial canker, cold injury, *Pseudomonas syringae*

Ring nematodes, especially *Macroposthonia xenoplax* (Raski) DeGrisse and Loof, are associated with short life of peach trees (*Prunus persica* (L.) Batsch) in several eastern states (1,4,5,8,14,17,19). *M. xenoplax* also enhances the development of bacterial canker following infection by *Pseudomonas syringae* (10), and soil fumigation for ring nematode control alleviates bacterial canker in California (7).

Cold injury or bacterial canker is usually the immediate cause of tree death in short-life situations. Although the etiology of peach tree short life (PTSL) is not clearly defined, ring nematodes appear to act as predisposing agents both for cold injury and bacterial canker. Soil fumigation with dibromochloropropane (DBCP) for control of *M. xenoplax* improved cold hardiness in peach trees (13), reduced tree losses to cold injury (12), and increased tree growth. Fumigation of infested soil with DBCP decreased the indole-3-acetic-acid (IAA) content of peach tissues (3). IAA level is inversely correlated with cold hardiness in peach trees (3). Nyczepir (*unpublished*) determined that elevated levels of IAA in autumn months follows feeding activity of *M. xenoplax* on peach roots. These studies indicate that feeding of *M. xenoplax* stimulates IAA activity, which in turn interferes with dormancy in peach trees, thereby increasing susceptibility to cold injury.

The nature of predisposition of peach trees to bacterial canker has not been determined. Weaver (15) found an interaction between cold injury and infection by *P. syringae*, but infection of twigs also occurred without cold injury. Ring nematodes might act merely as predisposing agents to cold injury, which then is followed by bacterial canker development, but they have been shown to predispose peach trees to bacterial canker in the absence of cold injury (11).

Ring nematodes have other important influences on peach trees. They injure feeder roots severely (10), and they reduce the total growth of peach trees when present in large numbers (1). When ring nematodes are controlled by soil fumigation with DBCP, fruit production is increased 20–40% (Zehr, *unpublished*), and damage from cold injury and bacterial canker is reduced (3,4,6,7,12,19). Soil fumigation to improve productivity and to prevent early tree death has become a widespread practice in commercial peach orchards in South Carolina.

Reported here are studies of certain postplant nematicides following preplant soil fumigation for ring nematode control and prevention of cold injury and bacterial canker of peach trees on three rootstocks. Experiments using oxamyl as a foliar application for ring nematode control are also described. A brief report of a portion of these results was published previously (18).

Technical Contribution 1898 of the South Carolina Agricultural Experiment Station, Clemson University.

Accepted for publication 11 May 1981.

The publication costs of this article were defrayed in part by page charge payment. This article must therefore be hereby marked "*advertisement*" in accordance with 18 U.S.C. § 1734 solely to indicate this fact.

0191-2917/82/03022504/$03.00/0
©1982 American Phytopathological Society

MATERIALS AND METHODS

The experiments described herein involve preplant soil fumigation and its interaction with rootstocks, foliar sprays of oxamyl during the first year after orchard establishment and in a nearby 3-yr-old peach orchard, and soil applications of nematicides beginning 6 yr after orchard establishment. Except for the oxamyl experiment with the 3-yr-old trees, all experiments were done in the same orchard, which was established in 1972 in Lakeland fine sand at the Clemson University Sandhill Experiment Station near Columbia, SC. Peach trees had been grown at this site twice previously; the last trees were removed in 1964. Natural vegetation was permitted to grow between 1964 and 1972. In August 1972, populations of *M. xenoplax* ranged from 2 to 1,280/100 cm^3 of soil. The topsoil pH was 4.7–5.5.

Approximately 4.5 metric tons of dolomitic lime per hectare was spread on the surface and plowed in to a depth of 30 cm in October 1972. Experimental plots were established in the site in November 1972 for Blake cultivar on Elberta, Lovell, and Halford rootstocks. Trees on Elberta and Halford rootstocks were obtained from commercial nurseries; those on Lovell were received from C. N. Clayton, North Carolina State University. Elberta represented the rootstock being received by most South Carolina peach growers in 1972, and probably included stocks from other cultivars that ripen at the same time.

Preplant soil fumigation. Each rootstock was replicated four times in a randomized complete block, and the replicates were split for preplant soil fumigation. Each replicate consisted of 36 trees, 18 of which were planted in unfumigated soil and 18 in soil fumigated in November 1972 with 47 L of DBCP 86E per hectare applied 20 cm deep in strips 2.4 m wide centered on the tree row. The trees were planted in December 1972, in holes 60 cm in diameter bored 1.25 m deep. Dolomitic lime (0.4 kg/tree site) was added as the holes were filled. This procedure raised the topsoil pH to 7.2 by February 1974.

After planting, the orchard was maintained as recommended for control of PTSL (2), except for the variable of postplant nematicide treatments. The trees were watered as needed by trickle irrigation during the first 3 yr after planting.

Foliar applications of oxamyl. Oxamyl was tested as a foliar nematicide during the first year (1973), beginning 1 May when young shoots were 15–25 cm long. Forty-eight trees per rootstock, half in fumigated and half in unfumigated soil, were sprayed four times at 2-wk intervals with 60 g of oxamyl 2E in 100 L of water, plus 31 ml of Du Pont Spreader as a wetting agent. Sprays were applied with a hand-held nozzle at 1,723 kPa (250 psi) until runoff. No further nematicides were applied during the first 5 yr after establishment of the orchard.

Three-year-old peach trees of mixed cultivars on Nemaguard rootstock in a nearby orchard were also sprayed with oxamyl in 1972 and 1973. These trees had been used for herbicide research in 1971, but in the spring of 1972 about 20% of 250 trees experienced cold injury. The soil was infested with *M. xenoplax*, and feeder roots of both injured and uninjured trees were sparse and necrotic.

Twenty-four surviving and apparently uninjured trees selected at random were sprayed with oxamyl (60 g/100 L) at 2-wk intervals in the spring each year beginning when young shoots were 20–30 cm long (4 May 1972 and 1 May 1973) and in autumn on 19 September and 6 October 1972. Sprays were applied to the point of runoff using a single-nozzle handgun and a sprayer operating at 1,723 kPa (250 psi) pressure. Du Pont Spreader or Triton B-1956, 31 ml/100 L, was added to enhance absorption.

Samples for nematode assays were taken by a garden trowel at a depth of 5–15 cm around the roots of trees beginning on 4 May 1972 and continuing until February 1974. Soil from 12 sprayed and 12 unsprayed trees at random was sampled each date. Each sample consisted of four subsamples of about 100 cm^3 of soil each per tree, mixed together in a polyethylene bag. Nematodes in 100 cm^3 of the mixture were extracted by the centrifugal-flotation procedure (9).

Tree health and vigor on 9 September 1972 were rated on a 1–5 scale, where 1 = one or more dead limbs, 2 = premature yellowing of foliage or dieback of small branches, 3 = light green foliage and slender shoot growth, 4 = vigorous shoot growth but slight yellowing of foliage, and 5 = vigorous shoot growth and dark green foliage.

Postplant nematicides. On 8 April 1978, experimental nematicides were applied to the soil around trees surviving the preplant soil fumigation experiment. All surviving trees were growing in preplant fumigated soil. Each treatment was replicated four times, with four trees per replicate in a randomized complete block. Materials tested were DBCP at 1,450 g/L, 47 L/ha; aldoxycarb 50W at 11.2 kg a.i./ha; aldicarb 15G at 11.2 kg a.i./ha; fenamiphos 15G at 11.2 kg a.i./ha; ethoprop 15G at 11.2 kg a.i./ha; dichloro-diisopropyl ether at 958 g/L emulsifiable, 112 L/ha; ethylene dibromide at 93 L/ha; and 1,3-dichloropropene at 93 L/ha. Granular formulations were spread on the soil surface and worked in 2.5–5 cm deep with a tree hoe. Liquid formulations were applied by chisel 10 cm deep in strips 2.4 m wide. Aldoxycarb was sprayed on the surface and worked in with a tree hoe. Soil assays for nematodes were made as previously described from two trees per replicate on each sampling date.

Table 1. Populations of *Macroposthonia xenoplax* during the first year of peach tree growth following preplant treatment with DBCP or foliar applications of oxamyl

Treatment	No. of *M. xenoplax*/100 cm^3 of soil on: 31 May 1973	20 Aug 1973	4 Feb 1974	29 May 1974
None	31[a]	90	313	131
DBCP before planting[b]	7	0	12	0
Oxamyl after planting[c]	13	18	189	137
DBCP before + oxamyl after planting	...	0	2	...

[a] Dibromochloropropane (DBCP) significantly reduced the nematode population on all sampling dates; oxamyl did not ($P = 0.05$).
[b] DBCP 86E, 47 L/ha, was applied in November 1972.
[c] Foliar spray applied as oxamyl 2E, 60 g a.i./100 L of water, on 1, 16, and 30 May and 11 June 1973.

Table 2. Growth of peach trees planted in 1973 in soil infested with *Macroposthonia xenoplax* and death from bacterial canker, cold injury, or both as affected by rootstock and preplant treatment with DBCP or foliar applications of oxamyl in the spring of 1973

Treatment	Rootstock	Avg trunk diameters (mm) in December[a]: 1973	1974	Trees died (%)[b]: 1974	1975	Total
Untreated control	Lovell	20	34	23	8	31
	Halford	21	36	19	14	33
	Elberta	22	35	44	17	61
DBCP before planting[c]	Lovell	22	45	0	0	0
	Halford	27	48	0	0	0
	Elberta	25	47	2	2	4
Oxamyl after planting[d]	Lovell	17	32	12	33	45
	Halford	22	38	12	37	50
	Elberta	20	37	42	21	63
DBCP before + oxamyl after planting	Lovell	21	43	0	0	0
	Halford	26	48	0	0	0
	Elberta	23	42	0	0	0

[a] Differences between dibromochloropropane (DBCP) and check treatments are significant at $P = 0.001$. Oxamyl did not significantly affect growth ($P = 0.05$).
[b] Tree death was significantly greater on Elberta than on Halford or Lovell rootstocks. Oxamyl did not significantly affect tree death ($P = 0.05$).
[c] DBCP 86E applied at the rate of 47 L/ha in strips 2.4 m wide in November 1972.
[d] Applied as oxamyl 2E at 67 g a.i./100 L of water as a foliar spray on 1, 16, and 20 May and 11 June 1973.

Table 3. Populations of *Macroposthonia xenoplax* as influenced by foliar applications of oxamyl on 3-yr-old peach trees on Nemaguard rootstock

Treatment	No. of *M. xenoplax*/100^3 cm of soil[a] on: 4 May	13 June	20 July	9 Nov	6 Feb	19 Apr	30 May	5 July	20 Aug	19 Sept
Oxamyl[b]	23	17	306	24	233	50	57*[c]	2*	6*	458
Check	23	46	402	77	286	209	205	79	115	210

[a] Soil was collected around roots of trees from 4 May 1972 to 19 September 1973.
[b] Applied as oxamyl 2E at 60 g a.i./100 L of water on 4 and 17 May, 2 and 13 June, 19 September, and 6 October 1972; and on 1, 16, and 30 May and 11 June 1973.
[c] * = Difference between control and oxamyl is significant at $P = 0.05$.

RESULTS

Preplant soil fumigation. Preplant fumigation with DBCP in November 1973 reduced ring nematodes to a small number, and trees planted in the fumigated strips were relatively free of nematode parasites through 1975. By April 1976, ring nematodes had become reestablished around trees in the fumigated soil. The DBCP preplant treatment controlled ring nematodes effectively for about 3 yr.

In unfumigated soil, ring nematodes were few during the early part of the 1973 growing season, but they increased tenfold by February 1974 (Table 1). Rootstock did not affect the population level.

During 1973, trees in fumigated and

unfumigated soil grew at equivalent rates. However, shoot elongation continued longer for the trees in fumigated soil than those in unfumigated soil. Trunk diameters 15 cm above the soil line in December 1973 were larger for trees in fumigated soil than for those in unfumigated soil (Table 2). The smaller size of trees on Lovell rootstock in December 1973 (Table 2) was caused by smaller tree size at planting.

During 1974, size differences increased between trees in fumigated versus unfumigated soil. Trees in fumigated soil had larger trunk diameters (Table 2) and visibly larger canopies.

Soil fumigation and tree survival. Symptoms of cold injury and bacterial canker, typical of peach tree short life, became visible in late February 1974, only 1 yr after the trees were planted. Bacterial canker developed on twigs and spread into the limbs and trunk of affected trees, and many trees were killed following cold injury in the cambium and phloem. Some trees died before bloom, but most died soon after bloom in mid-March. Similar symptoms were also widespread in the spring of 1975, 2 yr after planting. Of 100 dead trees only two had been growing in soil that was fumigated with DBCP. Tree losses were more severe with Elberta rootstock than with Halford or Lovell (Table 2).

Effects of oxamyl. Following the preplant treatment with DBCP, oxamyl was applied as foliar sprays during the first year, both on trees in DBCP-treated and untreated soil. Four foliar applications of oxamyl in May and June 1973 partially suppressed *M. xenoplax*, but oxamyl was not as effective as the preplant treatment of DBCP. By February 1974, nematode populations in soil around the sprayed trees were nearly as large as those around unsprayed trees in unfumigated soil (Table 1). Oxamyl may have suppressed growth slightly both in fumigated and in unfumigated soil, but the differences between sprayed and unsprayed trees were not significant.

Oxamyl applied during the first year of growth without a preplant treatment was ineffective for preventing cold injury and bacterial canker, and there was no improvement over the check after 2 yr (Table 2).

Nematode populations around the 3-yr-old trees were monitored during and after four foliar applications of oxamyl in the spring of 1972 and again following the fall applications in 1972 and the spring applications of 1973 (Table 3). Oxamyl partially suppressed *M. xenoplax* during and shortly after the spray period but not during the entire year. Oxamyl was more effective for nematode suppression during the second year (1973) than during the first year.

Ratings of tree vigor in September 1972 were linked strongly to the frequency of cold injury in 1973 (Table 4). As vigor improved, cold injury decreased; trees of optimum vigor (rated as 5 on the 1–5 scale) thus suffered little cold injury. Vigor ratings made earlier (July 1972) were not correlated with the frequency of cold injury. Oxamyl improved tree vigor slightly ($P = 0.05$) in September, but tree survival did not improve significantly.

Postplant nematicides. Trees in the unfumigated soil were removed following severe tree losses soon after planting (Table 2). Nematode populations in the preplant-fumigated soil were not monitored after April 1976, but all trees remaining were growing in nematode-infested soil by April 1978. Scattered tree death from cold injury occurred during the 1976–1978 period.

In April 1978, postplant nematicides were applied to the remaining trees. DBCP, ethylene dibromide, and fenamiphos partially suppressed nematode populations through September 1978. Only DBCP suppressed nematodes through the winter of 1978–1979 (Table 5). 1,3-Dichloropropene suppressed the population for a brief period after application. Aldicarb, aldoxycarb, ethoprop, and dichloro-diisopropyl ether were ineffective. Aldoxycarb caused substantial defoliation—enough to preclude its use on peaches. Slight defoliation also followed the application of aldicarb.

Among the nematicides tested as postplant treatments, only DBCP was effective for preventing cold injury. Cold injury in trees treated with other nematicides was as severe as in the untreated check. Control of *M. xenoplax* through the winter months appeared to be important for preventing cold injury.

DISCUSSION

These results emphasize the importance of effective nematode control in any program for control of peach tree short life. Strict adherence to such known beneficial practices as maintenance of optimum soil pH, delayed pruning, appropriate rootstocks, avoidance of root injury during cultivation, and irrigation during drought were of little benefit in the absence of nematode control. However, the importance of these additional practices for controlling short life must not be minimized (6,12,14,16,17).

Peach tree short life appeared earlier in the test orchards than is usually experienced in commercial orchards. However, severe losses of 1- to 3-yr-old trees sometimes occur when control practices are insufficient. The tree loss experienced in these experiments would cause total loss of orchards for commercial purposes before the trees produced any fruit, thus resulting in large financial losses for farmers.

The 3-yr period of effectiveness of preplant fumigation with DBCP probably represents the maximum period of control for *M. xenoplax* in South Carolina peach orchards. Most orchards require treatment again after 2 yr. The need for continued maintenance of effective nematode control was demonstrated by the severe tree losses in preplant-fumigated soil in 1979, when the trees were 6 yr old and 3 yr after nematodes had become reestablished. Some experimental nematicides were partially effective, but only DBCP suppressed populations of *M. xenoplax* through the growing season and the

Table 4. Peach tree vigor in September 1972 as related to occurrence of cold injury during the following winter

Tree vigor rating[a]	No. of trees	Trees injured (%)[b]
5	29	3
4	36	19
3	41	27
2	18	44
1	13	85

[a] Tree vigor scale of 1–5 based on color of foliage, presence of dead twigs or branches, and relative vigor of shoot growth. Rating of 5 was judged to be optimum vigor.

[b] Correlation coefficient of injury and vigor rating ($r = 0.95$) is significant at $P = 0.01$.

Table 5. *Macroposthonia xenoplax* populations and cold injury of 6-yr-old Blake peach trees following postplant applications of selected nematicides in April 1978

Treatment and rate per hectare	No. of ring nematodes/100 cm^3 of soil on 7 Apr 1978[a]	18 May 1978	20 June 1978	28 Sept 1978	12 Mar 1979	Trees having cold injury in 1979 (%)[b]
Dibromochloropropane 12.1 C at 47 L	35	34*[c]	8*	20*	25*	13*
Aldoxycarb at 11.2 kg a.i.	40	205	84	182	432	69
Aldicarb 15G at 11.2 kg a.i.	31	228	60	275	452	53
1,3-Dichloropropene at 93 L	6*	53*	64	365	252	50
Fenamiphos at 11.2 kg a.i.	39	116	36*	52	190	60
Ethylene dibromide 85% at 93 L	24	47*	18*	90	160	62
Ethoprop at 11.2 kg a.i.	38	164	65	471*	175	80
Dichloro-diisopropyl ether 8E at 112 L	139	197	162	282	192	60
Untreated control	24	268	119	173	220	50

[a] Initial population before treatment.

[b] Cold injury in trunk and scaffold limbs resulting in tree death or loss of one or more major limbs.

[c] * = Significantly different from the untreated control at $P = 0.05$.

following winter. In South Carolina, where soil in the root zone does not freeze during the winter, nematodes appear to be active throughout the year. If these nematodes affect growth regulators during the winter (3; Nyczepir, *unpublished*), nematode suppression during the winter appears to be essential for prevention of short life. The ineffectiveness of oxamyl and other nematicides for preventing short life was probably related to the lack of effective control during winter months.

Despite the absence of effective control, fenamiphos, ethylene dibromide, and 1,3-dichloropropene deserve further study as postplant soil treatments for peach trees. The rates used may not have been sufficient for control. Fall application might also be more effective than spring application.

Oxamyl was less effective than DBCP for control of *M. xenoplax,* and foliar applications of oxamyl appeared to be of doubtful value in short-life sites. Injury to foliage has been observed when twice the rate used here was applied (*unpublished data*), and foliar sprays on trees in the first year of growth appeared to reduce growth slightly.

Following severe outbreaks of PTSL, farmers frequently complain that no warning of impending losses occurred before the onset of the disease. Careful examination of peach trees over time shows that this statement is not always true. Uneven, willowy growth of trees and premature yellowing of foliage in the fall are signals that peach trees are under stress (Table 4). Poor growth, even when trees are well fertilized and managed, is another danger signal (Table 2). This signal is hard to interpret because many factors may be responsible for poor growth, and one may not be able to define what the growth should be. A third danger signal is poor development and necrosis of the tertiary roots of peach trees. Many of the practices that help to extend the life of peach trees also help to maintain a healthy, vigorous root system. Necrosis of fine roots always accompanies PTSL, and it is a sign that trees are under stress.

ACKNOWLEDGMENTS

We are grateful to C. N. Clayton, North Carolina State University, for providing peach trees on Lovell rootstock and to J. E. Toler for statistical analyses.

LITERATURE CITED

1. Barker, K. R., and Clayton, C. N. 1973. Nematodes attacking cultivars of peach in North Carolina. J. Nematol. 5:265-271.
2. Brittain, J. A., and Miller, R. W., eds. 1978. Managing peach tree short life in the Southeast. Ga., Ala., N.C., S.C., and U.S. Dep. Agric. Ext. Circ. 585. 19 pp.
3. Carter, G. E., Jr. 1976. Effect of soil fumigation and pruning date on indole-acetic acid content of peach trees in a short life site. HortScience 11:594-595.
4. Chandler, W. A. 1969. Reduction of mortality in peach trees following preplant soil fumigation. Plant Dis. Rep. 53:49-53.
5. Chitwood, B. G. 1949. Ring nematodes (Criconematinae). A possible factor in decline and replanting problems of peach orchards. Proc. Helminthol. Soc. Wash. 16:6-7.
6. Correll, F. E., Clayton, C. N., and Cummings, G. A. 1973. Peach tree survival as influenced by stock, soil fumigation, time of pruning, and nitrogen level. (Abstr.) HortScience 8:267.
7. English, H., and DeVay, J. E. 1964. Influence of soil fumigation on growth and canker resistance of young stone fruit trees in California. Down Earth 20(3):6-8.
8. Hung, C.-L. P., and Jenkins, W. R. 1969. *Criconemoides curvatum* and the peach tree decline problem. (Abstr.) J. Nematol. 1:12.
9. Jenkins, W. R. 1964. A rapid centrifugal-flotation technique for separating nematodes from soil. Plant Dis. Rep. 48:692.
10. Lownsbery, B. F., English, H., Moody, E. H., and Schick, F. J. 1973. *Criconemoides xenoplax* experimentally associated with a disease of peach. Phytopathology 63:994-998.
11. Lownsbery, B. F., English, H., Noel, G. R., and Schick, F. J. 1977. Influence of Nemaguard and Lovell rootstocks and *Macroposthonia xenoplax* on bacterial canker of peach. J. Nematol. 9:221-224.
12. Nesmith, W. C., and Dowler, W. M. 1975. Soil fumigation and fall pruning related to peach tree short life. Phytopathology 65:277-280.
13. Nesmith, W. C., and Dowler, W. M. 1976. Cultural practices affect cold hardiness and peach tree short life. J. Am. Soc. Hortic. Sci. 101:116-119.
14. Taylor, J., Biesbrock, J. A., Hendrix, F. F., Jr., Powell, W. M., Daniell, J. W., and Crosby, F. L. 1970. Peach tree decline in Georgia. Ga. Agric. Exp. Stn. Res. Bull. 77. 45 pp.
15. Weaver, D. J. 1978. Interaction of *Pseudomonas syringae* and freezing in bacterial canker on excised peach twigs. Phytopathology 68:1460-1463.
16. Weaver, D. J., and Wehunt, E. J. 1975. Effect of soil pH on susceptibility of peach to *Pseudomonas syringae.* Phytopathology 65:984-989.
17. Weaver, D. J., Wehunt, E. J., and Dowler, W. M. 1974. Association of tree site, *Pseudomonas syringae, Criconemoides xenoplax,* and pruning date with short life of peach trees in Georgia. Plant Dis. Rep. 58:76-79.
18. Zehr, E. I., and Lewis, S. A. 1980. Postplant nematicides for control of ring nematodes and cold injury in peach, 1979. Fungic. Nematic. Tests 35:316.
19. Zehr, E. I., Miller, R. W., and Smith, F. H. 1976. Soil fumigation and peach rootstocks for protection against peach tree short life. Phytopathology 66:689-694.