Control of Citrus Nematode Tylenchulus semipenetrans on Fine-textured Soil with DBCP and Oxamyl

L. W. TIMMER[1]

Abstract: Three grapefruit orchards on sour orange rootstock were treated by metering DBCP (1,2-dibromo-3-chloropropane) at 56 kg(a.i.)/ha into 15 cm of water in a flood irrigation system. In orchards with 43-49% clay in the surface foot, DBCP reduced numbers of *Tylenchulus semipenetrans* below control levels for 1.5-2.0 years. In the 3 orchards, DBCP treatment resulted in increases in yield or fruit size in the 2 seasons following treatment. No increases in yield, fruit size, or fruit numbers were observed the third season after treatment, but retreatment of a portion of one orchard after 2 years resulted in large increases in yield and fruit numbers the following harvest. Application of oxamyl twice annually as a foliar spray at 2.8 kg(a.i.)/ha reduced nematode populations to about 50% of control levels and resulted in a large increase in yield in 1 of the 2 seasons tested. DBCP treatment of fine-textured soils controlled citrus nematode and increased yields, but its effect was not as long lasting as on coarser soil in other citrus areas. Foliar applications of oxamyl reduced nematode populations but were not as consistently effective as DBCP treatments. *Key Words:* population dynamics, soil type.

The citrus nematode, *Tylenchulus semipenetrans* Cobb, is a widespread pest in Texas citrus orchards with about 90% being infested (4). Presently, DBCP (1,2-dibromo-3-chloropropane) is the only material registered for postplant treatment of orchards. Application of DBCP into flood irrigation systems at rates of 56-69 kg(a.i.)/ha has resulted in reduction of nematode populations and increased yields on some Texas soils (1, 5).

Penetration of DBCP into soils is retarded by high clay (11, 17) or organic matter content (8). Baines et al. (3) recommended rates of DBCP from 39 kg(a.i.)/ha for soils with 2-3% clay to 97 kg(a.i.)/ha for soils with 15-18% clay. Soils with greater than 20% clay were considered to require high rates which could be phytotoxic and

Received for publication 3 May 1976.

[1] Associate Professor, Texas A&I University Citrus Center, Weslaco, Texas 78596. The author is indebted to J. E. Fucik for collection of a portion of the yield data, to R. F. Leyden for assistance with the soil analyses, and to S. Villarreal for technical assistance.

excessively expensive. Much of Texas citrus is planted on fine sandy loam soils on which good nematode control has been demonstrated (1, 5). However, substantial citrus is planted on sandy clay loam and some on clay soils ranging in clay content from 25-50%. Organic matter content (< 2%) and silt content (ca. 10%) of most soils are relatively low and would not be expected to interfere with DBCP penetration.

The present study was undertaken to determine the efficacy of DBCP for citrus nematode control on soils of high clay content and the effectiveness of foliar applications of oxamyl as a possible alternative method of control. A preliminary report of the work with DBCP (16) and initial findings of experiments with oxamyl (15) have been published.

MATERIALS AND METHODS

Soil samples for nematode counts were taken under the drip-line of trees to a depth of 15 cm. Except as noted, three to four soil samples were taken near the center of each plot, composited, and a single determination made for each replication. Larvae were extracted by using a modified Baermann funnel technique (12), counted, and reported as number/100 cm^3 of soil.

Percents of sand, silt, and clay in the surface foot in each orchard were obtained by the hydrometer method (4). In orchard A, two samples/plot were taken for a total of 16 for the orchard. In orchard B, one sample/plot was taken for a total of 8 in the orchard. In orchard C, only the portion treated in 1973 was sampled, and 10 samples from various locations were analyzed. All samples consisted of a composite of three cores. In orchard A, the soil averaged 48% sand, 9% silt, and 43% clay; clay content ranged from 27-60% at different sites. Orchard B had 36% sand, 13% silt, and 51% clay; clay content ranged from 47-57%. Orchard C averaged 45% sand, 10% silt, and 45% clay; clay content ranged from 32-57%.

Emulsifiable DBCP at 56 kg(a.i.)/ha was metered into 15 cm of water in a flood irrigation system by using a gravity flow applicator. In orchard A, DBCP-treated and nontreated trees were compared in a randomized complete block design with four replications of each treatment. Each plot consisted of 3 rows of 19 trees each, of 12- to 15-year-old nucellar 'Webb Redblush' grapefruit (*Citrus paradisi* Macf.) on sour orange (*C. aurantium* L.) rootstock. The fruit from nine trees in the center row of each plot was harvested, weighed, and graded for size each year.

In orchard B, DBCP-treated and nontreated trees were compared in a randomized complete block design with four replications/treatment. Each plot consisted of a block of 25-36 trees of 12- to 15-year-old nucellar Webb Redblush grapefruit on sour orange rootstock. The fruit from the center nine trees in each plot was harvested and weighed the first harvest after treatment and graded for size the second harvest after treatment.

Orchard C was a 4-ha planting of 7- to 9-year-old, old-line 'Riddle Red Gold' grapefruit on sour orange rootstock. It was designed to compare eight different tree spacings with spacings replicated 4 times. In April 1973, one-half of the orchard was treated with DBCP in such a manner that two replications of each spacing treatment were treated and two were not. Twenty nematode-sample sites were used in the treated area and 20 in the control area. Fruit yields in kg/tree and total numbers were taken from three or more trees in each spacing treatment for a total of at least 48 trees in each the treatment and the control. In February 1975, one replication of the spacing treatments in the treated half was retreated and one replication of the spacing treatments in the nontreated half was treated to give four separate nematicide treatments: *(i)* treated 1973 and 1975, *(ii)* treated 1973 only, *(iii)* treated 1975 only, *(iv)* never treated. Each spacing treatment was represented once in each nematicide treatment. Fruit yields in kg/tree and total numbers were taken from three or more trees at each spacing for a total of at least 24 in each treatment.

Foliar treatments with aqueous solutions of oxamyl at 2.8 and 11.4 kg(a.i.)/ha were compared to nontreated controls on 12- to 15-year-old Webb Redblush grapefruit on sour orange rootstock. Each treatment was applied to five plots of six trees each arranged in a randomized complete block design. Oxamyl (about 10,000 liters/ha) was applied with the oscillating boom of a

Hardie hydraulic sprayer. The plots treated at the lower rate received three applications in 1972 and two in 1973 (15). In the present study, two applications were made in February 1974, one in January 1975, and one in March 1975. Plots treated at the high rate were first sprayed in April 1972, and received the last application in March 1973 (15), but nematode populations and yields were obtained in 1974 and 1975 to detect any continuing effect of treatments.

Where appropriate, data were treated by analysis of variance and means separated by Duncan's Multiple Range Test.

RESULTS

DBCP reduced larval populations to minimal levels 3-4 months after treatment in all orchards (Table 1). Populations remained at relatively low levels through the first year but began increasing rapidly in the second year. Populations built up to or surpassed control levels by 21-28 months after treatment.

Nematode populations did not build up as rapidly in the sandier portions of orchards A and C as in plots with a higher clay content. In treated areas of A, plots with less clay (avg = 31%) had 300 larvae per 100 cm^3 soil, whereas plots of higher clay content (avg = 55%) had 3,000 larvae per 100 cm^3 of soil 16 months after treatment. In orchard C, areas with less clay (avg = 39%) had 4,120 larvae/100 cm^3 soil, whereas areas of higher clay content (avg = 52%) had 7,200 larvae/100 cm^3 soil 13 months after treatment. No other differences between areas of high and low clay content were noted at other count dates.

In orchard A, treatment did not increase yields at either harvest date, but fruit size was larger on treated trees than on nontreated trees at both harvest dates (Table 2). In orchard B, an increase in yield was observed the first harvest after treatment, but only an increase in fruit size was observed in the second harvest after treatment. In orchard C, a small increase in yield was noted in both years following treatment, but the difference was significant in only one season. Treatment did not affect the number of fruit/tree, but it did result in an increase in the average fruit weight.

Retreatment of portions of orchard C in February 1975 substantially reduced nematode populations the remainder of the year (Table 3). In the 1976 harvest, DBCP treatments applied in 1975 resulted in a substantial increase in yield, but the 1973 treatment did not bring about a yield increase above the nontreated controls (Table 3). In contrast to the previous 2 years in this orchard (Table 2), the yield increase observed in 1976 was attributable to an increase in fruit numbers rather than to an increase in average fruit weight.

In plots where oxamyl had been applied previously at 11.4 kg/ha, but had been

TABLE 1. Effects of soil treatment with DBCP on larval populations of *Tylenchulus semipenetrans*.

Orchard and Treatment	Pre-treatment	No. of larvae (in 1000's)/100 cm^3 of soil[y] — Months post-treatment				
Orchard A		4	9	16	21	28
DBCP[x]	9.4a	0.2a	0.2a	1.7a	9.3a	6.6a
Control	11.1a	5.5b	13.9b	13.4b	22.0a	4.9a
Orchard B		4	6	9	14	21
DBCP[x]	11.9a	0.3a	1.1a	1.8a	2.1a	9.5a
Control	8.6a	10.0b	11.4b	9.9b	13.4b	9.3a
Orchard C		3	9	13	21	26
DBCP[x]	7.9a	0.1a	0.2a	5.7a	8.3a	7.2a
Control	12.2a	2.1b	15.4b	15.4b	17.4a	5.5a

[x]DBCP metered into 15 cm of water in a flood irrigation system at 56 kg(a.i.)/ha in October 1972 in orchard A and in April 1973 in orchards B and C.
[y]Mean separation by Duncan's Multiple Range Test ($P = 0.05$).

TABLE 2. Effects of soil treatment with DBCP on yields of grapefruit trees.

Orchard and Treatment[z]	Yield (kg/tree)	Fruit size (% > 9.2 cm)[y]		Yield (kg/tree)	Fruit size (% > 9.2 cm)[y]	
Orchard A	January 1974			January 1975		
DBCP[x]	125a	28a		68a	54a	
Control	126a	16b		65a	40b	
Orchard B	February 1974			January 1975		
DBCP[x]	134a			79a	37a	
Control	102b			81a	21b	
	March 1974			March 1975		
Orchard C	Yield (kg/tree)	No. of fruit/tree	Avg. fruit wt. (gm)	Yield (kg/tree)	No. of fruit/tree	Avg. fruit wt. (gm)
DBCP[x]	88a	169a	518a	83a	149a	599a
Control	75b	161a	468b	70a	135a	549b

[x]DBCP metered into 15 cm of water in a flood irrigation system at 56 kg(a.i.)/ha in October 1972 in Orchard A and in April 1973 in Orchards B and C.
[y]% of total fruit weight composed of fruit 9.2 cm in diam or larger.
[z]Mean separation by Duncan's Multiple Range Test ($P = 0.05$).

discontinued, nematode populations increased throughout 1974 and 1975, and neither yield nor fruit size was different from controls in either year (Table 4). Where oxamyl had been previously applied at 2.8 kg(a.i.)/ha and continued in 1974, larval populations were reduced and a large increase in yield occurred. However, populations increased to damaging levels in late 1974 and early 1975. Two applications made early in 1975 suppressed populations below control levels from April-October, but this reduction was too late to effect a yield increase in 1975. Fruit size was not affected by oxamyl treatment in previous work (15) nor in the present study.

DISCUSSION

The high clay content of the soil treated in this study apparently interfered with the penetration of DBCP, a factor which was anticipated on the basis of previous studies (11, 17). However, nematode populations were significantly reduced in the upper 15 cm of soil for 1.5-2.0 years in all three orchards studied. Although substantial control was attained, the duration of control was considerably shorter than the 3-4 years usually attained on sandier soils in other studies (3, 7, 10, 14). In some instances, yield increases were observed following treatment, but at least an increase

TABLE 3. Effects of retreatment of soils with DBCP after 2 years on larval populations of *Tylenchulus semipenetrans* and grapefruit yields.

Treatment[x]	Dates of application	No. of larvae (in 1000's)/100 cm³ soil: Jun 75[y]	No. of larvae (in 1000's)/100 cm³ soil: Oct 75[y]	Yield (Jan 76): Kg/tree[y]	Yield (Jan 76): No. of fruit/tree[y]	Yield (Jan 76): Avg. fruit wt. (gm)[y]
DBCP	Apr 73	7.2a	12.8a	85b	237b	360a
DBCP	Feb 75	0.1b	0.3b	115a	316a	365a
DBCP	Apr. 73 & Feb. 75	0.2b	0.4b	123a	331a	372a
Control	—	5.5a	14.3a	76b	212b	360a

[x]DBCP metered into 15 cm of water in a flood irrigation system at 56 kg(a.i.)/ha on indicated date (orchard C).
[y]Mean separation by Duncan's Multiple Range Test ($P = 0.05$).

TABLE 4. Larval populations of *Tylenchulus semipenetrans* and yields of grapefruit following foliar applications of oxamyl.

Treatment and rate [kg(a.i.)/ha]	No. of larvae (in 1,000's)/100 cm³ soil							Yield (kg/tree)[y]	Fruit size (% > 9.2 cm)[yz]
1974		Mar	May	July	Sep	Avg.[y]			
Oxamyl 11.4[w]		11.8	13.0	3.4	3.7	7.9a		135b	54a
Oxamyl 2.8[x]		6.3	3.1	1.6	3.3	3.6b		181a	52a
Control		10.5	8.8	4.2	6.2	7.4a		104b	56a
1975	Jan	Mar	Apr	May	Aug	Oct	Avg. Apr-Oct[y]		
Oxamyl 11.4[w]	9.0	5.8	8.7	3.7	0.8	5.6	4.7a	237a	9a
Oxamyl 2.8[x]	9.7	7.0	5.1	2.2	0.9	3.0	2.8b	241a	8a
Control	8.9	4.8	8.1	4.0	1.3	5.7	4.8a	248a	6a

[w]Treatment discontinued after 1973; no applications made in 1974 or 1975.
[x]Two applications made in Feb 1974; one in Jan 1975 and Mar 1975.
[y]Mean separation by Duncan's Multiple Range Test ($P = 0.05$).
[z]Percent of total fruit weight composed of fruit 9.2 cm in diam or larger.

in fruit size or weight occurred in all orchards for the first two harvests following DBCP treatment (Tables 2, 3). In all cases, returns exceeded the cost of treatment and, in some cases, benefits were substantial. More effective nematode control would probably result in even greater yield increases. Annual applications of DBCP at low rates are at least as effective as triennial application at higher rates (6) and might be more effective on clay soils. On the basis of the present study, it appears that biennial rather than triennial applications of DBCP on fine-textured soils would be necessary for continuing control of citrus nematode.

The relationship between fruit numbers, size, and total fruit weight/tree is a complex one. In some cases, increases in fruit size were obtained without corresponding increases in fruit weight/tree, a result implying fewer fruit formed on DBCP-treated trees. However, this result was probably due to the higher density of small fruit in the control rather than to fewer fruit/tree in the treated area. Increases in both total weight per tree and fruit size were not usually observed in the same season. Where fruit numbers were recorded, yield increases were directly attributable to increases in fruit size the first two seasons after treatment (Table 2), but in 1976, yield increases were due exclusively to increased fruit numbers (Table 3). Although the numbers of fruit per tree were not determined in most previous studies (3, 5, 10, 14,), an increase followed DBCP treatment in one investigation (7). All yield increases following oxamyl treatment have been directly attributable to increases in fruit numbers/tree [(15); Table 4]. Economically, increases in fruit numbers and total yield/tree are nearly always beneficial, but where yields are low and fruit sizes already large, increases in fruit size may lower the percentage of marketable fruit.

Foliar applications of oxamyl suppressed nematode populations by about 50% [(15); Table 4] but did not reduce counts as much as soil applications of DBCP. Nematode control with oxamyl may be as good as with DBCP since oxamyl presumably affects the entire root system, whereas DBCP controls nematodes only in the upper layers of soil. Yield increases following oxamyl applications have been substantial in some years [(15); Table 4], but in other years no yield increases have been observed. Some applications of oxamyl have been highly effective (9, 15) in reducing populations of citrus nematode, whereas others appear to be completely ineffective (2, 9, 15). Attempts to improve the efficacy of oxamyl by the use of adjuvants have been unsuccessful (13). Until means can be found to improve the consistency of oxamyl treatments and programs developed which give dependable yield increases, oxamyl cannot be used as an effective substitute for DBCP on fine-textured soils.

LITERATURE CITED

1. AMADOR, J. 1975. Chemical control of citrus nematodes in mature grapefruit. Citrograph 60:154-155.
2. BAINES, R. C., and R. H. SMALL. 1974. Evidence of modes of action of oxamyl nematicide on Tylenchulus semipenetrans. J. Nematol. 6:135(Abstr.).
3. BAINES, R. C., R. H. SMALL, and L. H. STOLZY. 1965. DBCP recommended for control of citrus nematode on bearing trees. Calif. Citrogr. 50:333, 342, 344, 346.
4. DAY, P. R. 1956. Report of the committee on physical analyses, 1954-55, Soil Science Society of America. Soil Sci. Soc. Am., Proc. 20:167-169.
5. HEALD, C. M. 1970. Distribution and control of the citrus nematode in the Lower Rio Grande Valley of Texas. J. Rio Grande Valley Hortic. Soc. 24:32-35.
6. HEALD, C. M. 1974. Citrus nematode control with a low annual rate of DBCP. J. Nematol. 6:142(Abstr.).
7. NATOUR, R. M., J. M. ALLOW, and Z. A. KATCHO. 1975. The effects of DBCP on citrus nematode and citrus growth and yield in Iraq. J. Nematol. 7:270-274.
8. O'BANNON, J. H., A. T. TOMERLIN, and G. K. RASMUSSEN. 1975. Penetration of 1,2-dibromo-3-chloropropane in a Florida soil. J. Nematol. 7:252-255.
9. RADEWALD, J. D., D. ROSEDALE, F. SHIBUYA, and J. NELSON. 1973. Control of the citrus nematode, Tylenchulus semipenetrans, with foliar Vydate sprays on Valencia oranges in southern California. Phytopathology 63:1217(Abstr.).
10. REYNOLDS, H. W., and J. H. O'BANNON. 1963. Decline of grapefruit trees in relation to citrus nematode populations and tree recovery after chemical treatment. Phytopathology 53:1011-1015.
11. RINKOV, A., S. D. VAN GUNDY, R. L. RACKHAM, and M. J. GARBER. 1960. The use of the onion test as a quantitative method for determining the distribution of emulsifiable DBCP in soil. Plant Dis. Rep. 44:510-515.
12. SCHINDLER, A. F. 1961. A simple substitute for a Baermann funnel. Plant Dis. Rep. 45:747-748.
13. STARR, J. L., and W. F. MAI. 1975. Effect of adjuvants on the efficacy of oxamyl. Plant Dis. Rep. 59:510-512.
14. TARJAN, A. C., and J. H. O'BANNON. 1974. Postplant fumigation with DBCP for citrus nematode control in Florida. J. Nematol. 6:41-48.
15. TIMMER, L. W. 1974. Suppression of populations of the citrus nematode, Tylenchulus semipenetrans, with foliar applications of oxamyl. Plant Dis. Rep. 58:882-885.
16. TIMMER, L. W. 1975. Efficacy of DBCP treatment of clay soils for control of citrus nematode. Proc. Am. Phytopathol. Soc. 2:45(Abstr.).
17. VAN GUNDY, S. D., F. J. FOOTE, R. L. RACKHAM, and A. RINKOV. 1960. Studies on methods of application of emulsifiable DBCP around living citrus trees. Plant Dis. Rep. 44:830-833.