EVALUATION OF MULTIPLE FOLIAR APPLICATIONS OF OXAMYL FOR CONTROL OF CITRUS PESTS[1,2]

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Abstract. **A 3-year field study on control of** Radopholus similis **with multiple foliar applications of oxamyl on 15-year-old 'Valencia' orange** (Citrus sinensis) **on rough lemon rootstock** (C. limon) **was conducted from 1976-78. Oxamyl was applied 3 and 5 times annually at 6- or 12-week intervals from May to October. Effects of oxamyl applications on citrus foliar and fruit pests were monitored during the second and third years of the study. Fruit yields were significantly higher from trees receiving treatments in July, September, October, and May, July, October each year than those obtained from untreated controls. Although** R. similis **populations sampled did not reflect sharp treatment differences, oxamyl-treated trees generally were more vigorous and withstood drought stress with less wilting than did untreated trees. Oxamyl also controlled** Phyllocoptruta oleivora **and did not affect scale insect populations or parasite numbers.**

The burrowing nematode, *Radopholus similis* (Cobb) Thorne, is the cause of spreading decline of citrus. Infected trees have approximately one-half as many functional feeder roots as do healthy trees. The optimum feeding zone for the nematode is below 30 inches where 90% of the feeder roots may be destroyed (2, 3). Spreading decline occurs principally in deep, well-drained sands with a 5-7% moisture-holding capacity and a permanent wilting point of about 2.5%. In Florida, low rainfall from January through May puts additional stress on trees weakened by burrowing nematodes. Trees partially recover as a result of summer rains, but never resume the normal growth of healthy trees, primarily because of their depleted root systems. Attempts to eliminate burrowing nematodes from living citrus trees in the field with various chemicals have not been successful (8).

Many groves in Florida have populations of this nematode which reduce tree vigor and yield. Recently, trees in Florida have been treated successfully with certain systemic nematicides that also have insecticidal-acaricidal properties (6, 7). Treatment has improved fruit yields, reduced russeting, and improved growth of trees.

In an earlier report (7) foliar sprays of N′,N′-dimethyl-*N*-[(methylcarbomoyl)oxy]-1-thio-oxamimidate (oxamyl) applied 6 times annually for 3 years reduced *R. similis* populations and increased yields in the second and third years of treatment. Although 6 applications effectively controlled the nematode, fewer applications might provide an effective control without the need for extra costly applications.

In Florida the common armored scale insects Purple scale, *Lepidosaphes beckii* (Newman); Glover scale, *Lepidosaphes gloveri* (Packard); Florida red scale, *Chrysomphalus aonidum* (L.); Chaff scale, *Parlatoria pergandii* (Comstock); and Yellow scale, *Aonidiella aurantii* (Maskell); are under biological control ranging from partial to complete control depending on species (9).

Citrus rust mite, *Phyllocoptruta oleivora* (Ashmead), is the major entomological citrus production problem in Florida and chemical controls are generally required 2-3 times each year (4). Spider mites including citrus red mite, *Panonychus citri* (McGregor) and Texas citrus mite, *Eutetranychus banksi* (McGregor), although common on Florida citrus, are not severe problems in many groves.

Our objectives were to study the effects of 3 or 5 annual foliar applications of oxamyl on numbers of *R. similis, P. oleivora,* spider mites, various scale insects, scale parasites and effects on tree vigor, fruit yield and quality.

Materials and Methods

Applications of oxamyl were begun in 1976 on 15-year-old Valencia orange (*Citrus sinensis*) trees on rough lemon (*C. limon*) rootstock infected with *R. similis, P. oleivora* and scale insects. The trees were growing in an Astatula fine sand (hyperthermic uncoated typic quartzipsamments) common to the Central Ridge area of Florida near Frostproof.

A randomized-block design with 4 replications per treatment in 3-row plots, 9 trees per plot, spaced 12 x 30 ft was used. Each plot, except the control, was separated by a foliar-treated guard row. Three trees in each plot, selected for uniformity and vitality, served as record trees for nematode counts and fruit yield.

Aqueous oxamyl (2 lb ai/gal) was applied to trees at 2 oz in 2.5 gal water/tree. A surfactant (sorbitan monolaurate) at 0.04 oz/gal was used as a dispersing agent. Foliar application was made at 450 psi by a mechanical sprayer. No attempt was made to prevent leaf runoff, drip, or mist from coming in contact with the soil surface. Comparable untreated trees served as controls.

Treatments consisted of 3 or 5 annual applications in 1976, 1977, and 1978. Applications were made at staggered intervals as follows: Treatment 1, three applications at about 6-week intervals in May, June, July; Treatment 2 in July, September, October; Treatment 3, three applications at about 12-week intervals in May, July, October; and Treatment 4, five applications at about 6-week intervals in May, June, July, September, October.

Root samples for *R. similis* were collected to a depth of 32-36 inches from a single site at each tree with a mechanical soil auger. Samples were processed by the root incubation technique (10). After 3 days, roots were rinsed, the nematodes were drawn off, and all life stages of *R. similis* were counted. Roots were weighed moist and numbers of *R. similis* per g of moist root were recorded.

Since oxamyl also is an insecticide-acaricide, the effects of these treatments on some citrus foliar and fruit pests were observed. Because most armored scale insects of citrus in Florida are controlled biologically, it was important to determine the effect of this material on their parasites.

Beginning in April 1977, citrus rust mites and spider mites (citrus red and Texas citrus) were sampled from 25 leaves taken terminally from the last expanded growth

[1]We thank the Animal and Plant Health Inspection Service, USDA and S. E. Simpson, Division of Plant Industry, FDACF, Winter Haven, Florida for collecting and processing burrowing nematode samples during this study. The authors also wish to thank Norman Todd, James Yager and Harold McTeer for their cooperation.

[2]This paper reports the results of research only. Mention of a pesticide in this paper does not constitute a recommendation by the USDA nor does it imply registration under FIFRA.

flush of the center record tree in each plot. Samples were taken before the first oxamyl application each year and at 6-week intervals throughout the season.

Leaves were examined under a binocular microscope in the laboratory. All adult female citrus red mites and Texas citrus mites were counted and recorded. All mature citrus rust mites were counted and recorded from 4 10X fields (2 fields upper and 2 fields lower surface/leaf).

Armored scales and their parasites were sampled from 50 leaf samples from the same trees at the same time as above. Leaves were taken from the basal end of the last mature growth flush.

All third-stage female scales and their respective parasites were counted and recorded. The various scales were turned over and examined to determine if they were alive and if they were parasitized. Parasites could be readily identified by host association, morphological characters, and whether they were external or internal. Scales and their respective parasites included the following: Purple, *Lepidosaphes beckii* (Newman); *Aphytis lepidosaphes*, Compere; Glover, *L. gloveri* (Packard); *Prospaltella elongata* Dozier; Chaff *Parlatoria pergandii* Comstock; *Aphytis hispanicus* (Mercet); and *Prospaltella fasciata* (Malenotti); Yellow, *Aonidiella aurantii* (Coquillett); *Aphytis chrysomphali* (Mercet); and Florida Red, *Chrysomphalus aonidum* L.; *Aphytis holoxanthus* DeBach.

At the end of the 1977 season, we learned that the grower-cooperator had also applied three sprays to the entire block. These included chlorobenzilate (ethyl 4, 4'-dichlorobenzilate) postbloom, ethion (*O, O, O', O'*-tetraethyl *S, S'*methylene bis=(phosphorodithioate) summer and dicofol (4,4'-dichloro-∂-(trichloromethyl) benzhydrol) fall.

The grower-cooperator did not apply any supplemental sprays in 1978, but we treated the border trees in each control plot to reduce rust mite injury. Accordingly, 0.75% oil sprays were applied in June and September. These trees were sampled to measure the effects of the oil sprays on mites and insects.

Fruit yields were recorded annually in April or May for the 1976-77, 1977-78, and 1978-79 crops as the number of boxes (90 lb. of fruit) from each record tree. Fruit samples to fill a 60 lb box were also taken from each treatment of the 1978-79 crop, washed and graded to sizes 252, 200, 163 and <163 which are the number of fruits required to fill a standard box. Fruit was examined for fruit quality based on russeting caused by *P. oleivora*.

Results and Discussion

Radopholus similis numbers were low on the untreated trees (Table 1) and rarely reached higher numbers. After peak populations occur, numbers decline rapidly because of the severe root damage. Equilibrium populations vary greatly, depending on food supply and season, but rarely exceed 100 *R. similis* per g of moist root (1, 5), an infestation sufficient to keep a tree in decline indefinitely. Populations increase rapidly following chemical treatment due to an improved root system, and may *sometimes exceed that* of the control. Thus, multiple applications are needed for maximum tree response. Previously (7), 6 annual foliar applications of oxamyl resulted in control, with subsequent improved yields. This study showed that nematode population suppression (Table 1) with 3 applications appears to be sufficient to increase yields. Time of application also affected yield (Table 2). Although trees improved with all treatments, early applications were not as effective as those that continued later in the season. Three applications were as effective as five, eliminating the need for more treatments.

Table 2. Valencia orange yields from trees receiving 3 or 5 foliar applications annually of oxamyl applied at 6- or 12-week intervals.

Application dates	1976-77	Fruit yield[z] 1977-78	1978-79
1. May, Jun, Jul	4.15	3.94	3.17
2. Jul, Sep, Oct	5.19**[y]	4.16*	4.29**
3. May, Jul, Oct	4.90**	4.95**	4.12**
4. May, June, Jul, Sep, Oct	3.76	3.98*	4.64**
5. Control	3.65	2.45	2.77

[z]Mean number of 90 lb. field boxes from four 3 tree replicates.
[y]Dunnett's LSD comparing means against a control *(P≧0.05), **(≧0.01). Numbers without asterisk are not significantly different.

The highest percentage of larger-size fruit resulted from treatment, while fruit from the untreated trees were generally smaller (Table 3). Improved vegetative growth and subsequent increase in yield and fruit size result in higher quality as well as quantity of fruit.

Table 3. Numbers of Valencia oranges graded into 4 size categories from trees receiving foliar applications of oxamyl during 1978.

Application dates	Size of fruit after foliar treatment[z] 252	200	163	<163
1. May, Jun, Jul	6.0b[x]	40.0bc	29.0ab	15.7ab
2. Jul, Sep, Oct	34.2b	70.7a	10.7bc	0.5b
3. May, Jul, Oct	6.0b	42.5bc	30.2ab	15.5ab
4. May, Jun, Jul, Sep, Oct	1.5b	33.0c	33.2a	21.0a
5. Control	77.5a	43.7bc	5.2c	3.0b
6. Jun, Sep[y]	33.5b	62.7ab	12.7bc	7.2ab

[z]Size refers to the number of fruits required to fill a standard carton.
[y]Oil spray applications for rust mite control only, made to untreated trees next to control (record) trees.
[x]Means followed by the same letter within a column are not significantly different at the 5% probability level according to Duncan's multiple range test.

Table 1. Numbers *Radopholus similis* from roots of Valencia orange trees on rough lemon rootstock receiving foliar applications of oxamyl from 1976-1978.

Application dates	Mean *R. similis*/g root[z] 1976 Sep.	1976 Dec.	1977 Apr.	1977 Aug.	1977 Dec.	1978 Apr.	1978 Sep.	1979 Feb.
1. May, Jun, Jul	0.2b	4.7a	0.8a	0.4a	3.7b	1.6a	0.6b	1.8ab
2. Jul, Sep, Oct	1.5ab	6.9a	0.4a	2.1ab	2.2b	3.1a	0.7b	1.6ab
3. May, Jul, Oct	0.6b	6.3a	0.9a	0.2a	3.7b	3.5a	0.3b	1.3ab
4. May, Jun, Jul, Sep, Oct	0.2b	4.2a	0.4a	0.3a	1.0b	3.5a	0.5b	0.9b
5. Control	2.9a	7.7a	1.2a	3.5b	9.3a	2.9a	1.8a	3.6a

[z]Mean of four 3-tree replicates. Means followed by the same letter within a column are not significantly different at the 5% probability level according to Duncan's multiple range test.

Table 4. *Phyllocoptruta oleivora* populations from leaves of Valencia orange trees before and after receiving foliar applications of oxamyl applied at 6- or 12-week intervals during 1978.

Application dates	Mean No. Citrus rust mites/25 leaves[z]						
	Sample date						
	Mar.[y]	Apr.[y]	Jun.	Jul.	Sep.	Oct.	Dec.
1. May. Jun, Jul	2 abc	0	0	0 b	0 b	0 b	7 b
2. Jul, Sep, Oct	1.7bc	2	13.5	92.2ab	0 b	0 b	0 b
3. May, Jul, Oct	1.5bc	0.5	0	0.2b	0 b	0 b	1.2b
4. May, Jun, Jul, Sep, Oct	0.7c	0	1	1 b	0 b	0 b	0.7b
5. Control	12.7a	1	73.5	181 a	28.2a	58.0a	197.5a
6. Jun, Sep[x]	11.7a	2	39	8.5b	22 a	1.5b	34.2b

[z]One tree/replicate. Means followed by the same letter within a column are not significantly different at the 5% level (Jul, Sep) or at the 1% level (Mar, Oct, Dec) according to Duncan's multiple range test. Columns with no letters are not significantly different.
[y]Pretreatment counts.
[x]Oil spray applications for rust mite control made on untreated trees next to control (record) trees.

Mites, scales and scale parasites were not sampled in 1976. The 3 sprays applied by the grower-cooperator in 1977 masked our ability to measure treatment differences in oxamyl applications. The summer ethion application practically eliminated armored scales from the test area for the remainder of the year. In 1978, samples reflected more accurately responses to the oxamyl applications.

Citrus rust mites were controlled by the oxamyl applications (Table 4). Oil sprays in June and September applied to border trees in each replicate suppressed populations of rust mite adequately, although some russeting occurred prior to the applications (Table 5).

Table 5. Fruit discarded/60 lb. box because of russet caused by the Citrus rust mite, *P. oleivora*, or armored scale.

Application dates	Mean number	
	Russetted fruit[z]	Scale Inf.
1. May, Jun, Jul	6.5 a[x]	1.5 ab
2. Jul, Sep, Oct	0.2 a	3.0 ab
3. May, Jul, Oct	0.7 a	3.5 ab
4. May, Jun, Jul, Sep, Oct	1.0 a	5.2 b
5. Control	29.0 b	1.5 ab
6. Jun, Sep[y]	11.5 ab	0.5 a

[z]More than 25% of fruit surface affected.
[y]Oil spray applications for rust mite control made to untreated trees next to control (record) trees.
[x]Means followed by the same letter within a column are not significantly different at the 5% level according to Duncan's multiple range test.

Citrus red mite did not exceed 20 adult female mites/100 leaves in any treatment in our samples and there were no significant differences among treatments.

Populations of Texas citrus mites reached a maximum of 128 female mites/100 leaves in the treatment receiving 5 applications of oxamyl just before the fifth application. We recorded 71 Texas citrus mites in the untreated control during the same period. These differences were not significant.

Mean numbers of the armored scales and their parasites/sample date are given in Table 6. Armored scale populations were below economic levels in all treatments during the study period. We did note that more fruit was downgraded due to scale in the treatment receiving 5 applications of oxamyl than from the treatment receiving 2 applications of oil. Chaff scale was the most abundant scale recorded. We detected no effects on parasite activity due to the treatments. However, our samples taken about 6 weeks after each application would not have detected possible immediate toxic effects on adult parasites present.

Table 6. Mean numbers of female armored scales and their parasites/200 leaves/sample date 1978 from trees receiving oxamyl applications as shown.

Insect	Treatment					
	1	2	3	4	5	6[z]
Lepidosaphes beckii	9.5	11.8	13.5	6.0	7.7	6.8
Aphytis lepidosaphes	3.2	4.2	4.3	2.2	3.0	1.3
L. gloveri	3.8	5.2	3.3	2.0	5.2	3.5
Prospaltella elongata	2.0	1.5	0.8	0.5	1.5	1.0
Parlatoria pergandii	34.3	13.8	14.8	9.5	6.7	3.5
Aphytis hispanicus	4.1	5.2	1.5	3.7	2.3	1.8
Prospaltella fasciata	1.0	0.5	0.8	1.0	0.7	0.7
Aonidiella aurantii	0.5	0.2	0.2	1.0	2.0	1.0
Aphytis chrysomphali	1.0	0.5	0.2	0.0	1.0	0.3
Chrysomphalus aonidum	0.8	0.7	0.3	1.5	0.5	0.2
Aphytis holoxanthus	0.0	0.2	0.0	1.3	0.2	1.2

[z]June, September 0.75% oil spray.

This study has shown that under Florida conditions, the general condition of a grove infected with *R. similis*, and which shows decline symptoms, can be improved by 3 annual applications of oxamyl. Applications during July, September, October, or May, July, October were most beneficial. These applications also controlled *P. oleivora* under the conditions of this experiment.

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