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PEST AND YIELD RESPONSES OF CITRUS TO ALDICARB IN A FLATWOODS GROVE[1]

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Abstract. **Commercial applications of Temik® brand aldicarb were made 2 successive years at 13, 20 and 33 lb/ac to replicated double-bed plots in a large block of mature Hamlin oranges in southern Hendry County. Suppression of citrus rust mite *Phyllocoptruta oleivora* (Ashmead) was seen both years until approximately 6 months after application, and a reduction of culled fruit was detected the second year. Significant improvements in yield, but not juice quality, were also detected the second year from Temik treatments, although no significant differences among rates of Temik were seen. Most Temik in excess of 13 lb/ac was applied outside the drip line, so the apparent failure to improve responses with higher rates may have been a function of application method.**

Control of nematode and arthropod pests and increased yield are both well documented responses of Florida citrus to aldicarb (Childers et al. 1987, Wheaton et al. 1985, Bullock 1980, 1989, Knapp et al. 1982). Rates used in these studies were 5 or 10 lb ai/ac, equal to the maximum or twice the maximum now allowed. However, it has not always been clear if yield responses observed were due to pest suppression or direct effects of aldicarb on tree growth and vigor. Knapp et al. (1982) observed decreased russeting and increased yield and °Brix following aldicarb application in a Lake Wales grove but did not provide information on nematodes. The study was conducted on commercial acreage but harvest data were not complete enough to allow for statistical analysis. Wheaton et al. (1985) documented increased fruit size the first year and increased yield the second year of a 2-year study on small replicated plots in 4 Florida groves. Pest populations were reported in a separate paper (Childers et al 1987) indicating that both nematode and arthropod pest populations had been suppressed by aldicarb so that it was not possible to attribute yield increases to any particular cause.

Lowering prices in an increasingly competitive citrus market require that all management costs be justified by even greater returns. What benefits could a citrus grower expect from applications of aldicarb at different rates? Only a commercial scale test could provide a reliable answer to this question. The present study provided an opportunity to evaluate the effects of aldicarb concentration on the citrus rust mite (CRM) population and horticultural factors of yield and fruit quality in a large commercial citrus trial with replicated blocks. The objectives were the following:

1) Quantify the rate response to Temik in citrus for canopy growth, fruit yield, and juice quality factors, and

2) Evaluate rate-dependent response to Temik of CRM populations and rust mite induced fruit injury.

Materials & Methods

The test was carried out in a 57 acre commercial grove block on ALICO, Inc. property near Felda, Florida. Trees were 'Hamlin' sweet orange (*Citrus sinensis*) on Cleopatra mandarin (*C. reticulata*) rootstock planted in August 1986 on 2-row beds typical of flatwoods groves in the area. Tree spacing was 15 feet in row and 27.5 feet between rows, 106 trees/acre. Trees had been managed using standard citrus cultural practices which the grower believed adequate for either the processed juice or fresh fruit market. Temik had been applied to the 10 rows on the west side of the planting in 1988 at a rate of 33.0 lbs. per acre. Temik had been applied to the entire grove in 1991 at a rate of 20 lbs/acre. Two summer oil sprays were made to the grove in 1992, one in June and the other in August, and one in July 1993. Irrigation was by a microsprayer system with an emitter at each tree.

The experimental design was randomized complete block with 4 replications per treatment except for the control which had 8 replications. Plots consisted of 2, 2 row beds (4 rows of 68 trees/row = approximately 272 trees). Aldicarb was applied at the following rates:

1.) 2 lb ai/ac = 13.2 lbs/A Temik 15G (T13)
2.) 3 lb ai/ac = 19.8 lbs/A Temik 15G (T20)
3.) 5 lb ai/ac = 33.0 lbs/A Temik 15G (T33)
4.) Control no Temik (T0)

Temik applications were made on 9 March 1992 and 10 February 1993 to both sides of the tree using a tractor-drawn applicator equipped with 3 double-disk furrow openers placed at 12 inch spacing. A metering wheel controlled release of granules from a single hopper and a PTO-powered blower delivered the granules to the furrows though 5 delivery tubes. Two tubes fed into each of the 2 outside furrows (those furthest into the canopy) with the fifth opening into the remaining furrow closest to the center. Furrows were then closed by a press wheel. Tree skirts reached the ground which the applicator believed limited his ability to penetrate the canopy without damaging limbs. The 13 lb rate was applied through the 2 tubes of the first double disk opener, 6 - 12 inches inside the dripline. The 20 lb rate was achieved by the addition of a third tube through the second double disk opener, so that only the 33 lb rate required the third opener, thus employing all 5 tubes emptying into the 3 furrows.

Rustmite. A commercial scouting service (Glades Crop Care), was contracted to sample CRM populations at intervals varying from once a week in spring and summer to once a month in winter. The sample consisted of 96 lens fields per plot (1,920 lens fields per sample date). Presence of other arthropod pests was observed and noted. Rust mite induced damage was evaluated in 1993 by visual estimation of CRM damage, wind scar, and damage from other causes for each

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[1]J. Noling at the IFAS Citrus Research Station in Lake Alfred provided advise on nematode sampling and nematode analysis and Dean Poole made Temik applications. Excellent cooperation was received from J. D. Alexander and his staff.

culled fruit and for a random sample of 50 number 1 grade fruit per plot.

Growth and yield. Tree growth was evaluated by measuring tree canopy volume at the beginning and end of each growing season on the same 4 uniformly representative trees per plot. Canopy width was measured in a north-south and east-west direction at the widest point and averaged to determine mean diameter (d). Tree height (h) was also measured and canopy volume estimated by the formula for an oblate spheroid, $V=0.5236d^2h$.

The block was harvested during December and January and fruit yield calculated from the total weight obtained from each 4-row plot. Fruit weight was converted to standard 90-pound-field-boxes for reporting yield. Four uniform trees from each plot were harvested, graded into commercial size categories, and analyzed for juice quality in 1992. In 1993, a 5-box-sample of fruit from 20 trees in each of the north and south end of each plot was taken as a representative sample to estimate juice quality and packout in a packinghouse run. Juice quality was determined from a 1 bushel fruit sample of each plot harvested for the packinghouse run. Fruit sizes and packout were determined from the packinghouse run of 2 samples of 5 boxes each harvested from each plot, and from each bulk trailer load of fruit taken to the juice plant during harvest of the whole grove. Juice quality factors included °Brix, total acid, juice content, and pound solids/box. Packout was determined in 1993 by running a fruit sample from each plot through a commercial packing line at the Citrus Research and Education Center (University of Florida) in Lake Alfred. Fruit size determinations were made in conformance with USDA size categories.

Nematodes. A soil sample consisting of 10 subsamples per plot was taken in 1992 and analyzed for citrus nematode *Tylenchulus semipenetrans* and burrowing nematode *Radopholus citrophilus* by standard procedures.

Results

All nematode samples were negative for both the citrus nematode and burrowing nematode (J. Noling, unpublished data). Infestations of non-rust mite arthropod pests were light and not considered to be economically damaging.

Rust mite and russeting. Temik-treated plots had significantly lower CRM counts than the untreated controls both year. Plots treated with Temik at all rates reduced mite counts for 5 months in 1992 (Table 1). Mite counts were reduced with each increased rate of Temik. Percent lens-fields infested lined up with Temik rate in the expected order, and the regression of infested lens-fields with rate was highly significant ($P = 0.0001$, $R^2=0.4$).

In 1993 the first post-treatment sample showed significantly fewer rust mites per leaf on Temik-treated trees compared to the control (Figure 1). Although the analysis of

Table 1. Rust mite counts as percent infested lens-fields 5 months after treatment with various rates of Temik, 1992.

Treatment	Infested lens-fields (%)
Untreated control	9.50 a[1]
Temik 13 lbs/A	4.25 b
Temik 20 lbs/A	2.13 b
Temik 33 lbs/A	1.75 b

[1]Means in the same column followed by the same letter are not significantly different (LSD P< 0.05).

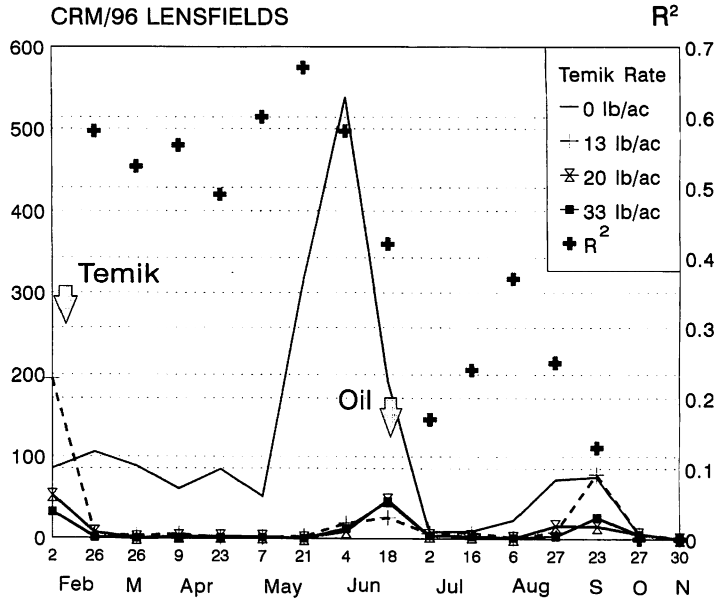
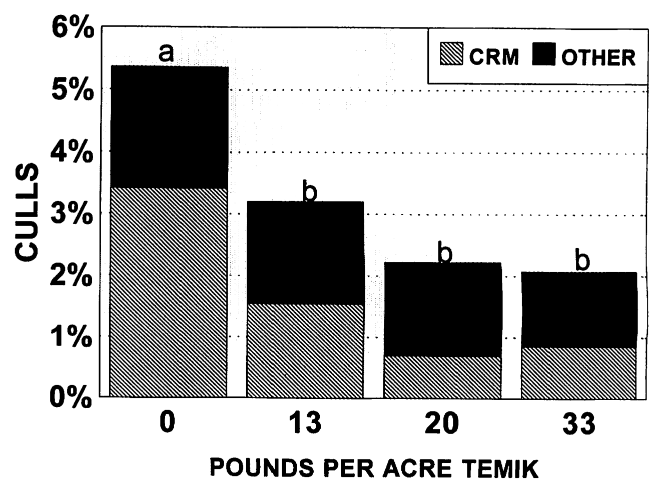


Figure 1. Number of citrus rust mites per 96 lensfields and R^2 values from regression of CRM numbers against aldicarb concentration in 1993.

variance did not show significant differences between rates, there was a highly significant effect of aldicarb rate on CRM counts when analyzed by regression. Subsequent leaf samples and then fruit samples showed the same trends through 2 July when differences were obliterated by an oil spray. However, significant differences reappeared in the following week and continued through the end of August. These results closely mimicked those of the previous year.

Temik treatments also had a significant effect on number and percent culls (Figure 2). Again, analysis of variance did not separate means between individual rates of aldicarb but regression analysis showed significant rate responses. Rust mite damage and wind scar accounted for most of the damage observed on culled fruit. Russeting caused by CRM accounted for a significantly greater percentage of blemishes



R^2 (% culls) = 0.45, R^2 (% russet) = 0.2.

Figure 2. Percentage of sample harvest culled and portion of surface blemishes due to CRM damage or other causes (mostly windscar) in 1993.

on untreated fruit compared to treated fruit. Also, there was also significantly more rust mite damage observed on untreated number one grade fruit compared to treated number one grade fruit (data not shown).

Yield. The first year (1992) there were no significant yield differences among any treatments (Table 2). Mean yield ranged from 5.9 boxes/tree for the control and T33 to 6.2 boxes/tree for T13. Yield efficiency (fruit per unit area of tree canopy volume) was slightly greater for trees in the control and T13. Tree canopy volume of these trees was also slightly greater.

In contrast to year 1, yield increased significantly year 2 in Temik-treated trees above the untreated control. Mean yield ranged from 5.4 boxes/tree for the control to 6.3 boxes/tree for T13. Yield efficiency (fruit per unit area of tree canopy volume) was greater for trees treated with Temik and greatest with T13. Tree canopy volume was not statistically different among treatments.

There were no significant differences the first year in pounds solids per box or per tree basis among any of the treatments (Table 3). Pounds solids per box ranged from 5.89 for T33 to 6.22 for T13. Pounds solids per tree ranged from 34.57 for T33 to 38.71 for T13

There were also no significant differences in pounds solids per box in 1993. Pounds solids per box ranged from 5.66 for the untreated controls to 5.79 for T20. However, total pounds solids per tree was greatest for T13 at 36.07 which was significantly different from the control of 30.59.

In 1992 and 1993 there were no significant differences among any of the treatments in juice quality factors of percentage juice per fruit, °Brix, or acid (Table 4). In 1992 there was a significantly higher Brix/acid ratio of juice from the T20 and T33 treatments. This was apparently the result of less acid in the juice of these 2 treatments, although the difference was too slight to be statistically significant. No difference in ratio resulting from lower acid was detected in 1993.

There was a significant difference in number and percentage of fruit in the standard commercial carton sizes (Table 5). The first year, treatment with 33 lbs/acre of Temik resulted in less of the smaller size 163 fruit and increased the percentage of size 100 fruit. No other significant differences were found among the other fruit size categories in 1992.

There was little difference the second year in number and percentage of fruit in the standard commercial carton sizes. Treatment with 13 lbs/acre of Temik resulted in more of the size 125 fruit as compared to the untreated control (Table 6). The shift from undersize to commercially desirable mid-size fruit seen with Temik the first year was not evident in 1993. No other significant differences were found among the other fruit size categories.

Table 2. Tree yield, canopy volume, and yield efficiency.

Treatment	Yield (boxes/tree) 1992	Yield 1993	Canopy volume (m^3) 1992	Canopy volume 1993	Yield efficiency[1] (lbs. frt/m^3) 1992	Yield efficiency 1993
Untreated control	5.9	5.4 b[2]	45.6	52.0	7.7	9.3
Temik 13 lbs/A	6.2	6.3 a	47.5	51.8	7.7	10.9
Temik 20 lbs/A	6.0	5.8 ab	43.2	49.5	7.2	10.5
Temik 33 lbs/A	5.9	5.8 ab	43.2	50.4	7.3	10.4
	ns		ns	ns	ns	ns

Statistics by LSD at the 5% level of significance.
[1]Yield efficiency based on 90 pound box of fruit produced per cubic meter of tree canopy. One pound of fruit/m^3 equals efficiency value of 1.0, higher values mean greater yield per unit of tree canopy volume.
[2]Means in the same column followed by the same letter not significantly different (LSD P< 0.05).

Table 3. Pounds Solids of sugars in juice on a per box and per tree basis

Treatment	Solids/box (lbs) 1992	Solids/box 1993	Solids/tree (lbs) 1992	Solids/tree 1993
Untreated control	5.92	5.66	34.93	30.59 b[1]
Temik 13 lbs/A	6.22	5.72	38.71	36.07 a
Temik 20 lbs/A	6.05	5.79	36.75	33.61 ab
Temik 33 lbs/A	5.89	5.76	34.57	33.40 ab
	ns	ns	ns	

[1]Means in the same column followed by the same letter are not significantly different (LSD P < 0.05).

Table 4. Juice quality data.

Treatment	Juice (%) 1992	Juice (%) 1993	TSS(°Brix) 1992	TSS(°Brix) 1993	Total acid 1992	Total acid 1993	TSS/acid ratio 1992	TSS/acid ratio 1993
Untreated control	50.9	51.4	10.1	11.1	0.56	0.66	18.1	16.9
Temik 13 lbs/A	51.0	51.2	10.1	11.2	0.56	0.66	18.0	16.9
Temik 20 lbs/A	50.3	50.9	10.1	11.4	0.54	0.67	18.9	17.0
Temik 33 lbs/A	50.8	50.9	10.2	11.4	0.54	0.65	19.7	17.5
	ns	ns	ns	ns	ns	ns	ns	ns

Statistics by LSD at the 5% level of significance

Discussion

Second year results confirmed and extended those of the first year. In both years similar levels of CRM control lasting over 5 months were observed, and in the second year we were able to demonstrate rate-dependent reductions in rust mite damage on fruit and consequently in total and percentage culls. This level of damage might be of economic importance in a fresh fruit market, but should not impact the value of fruit destined for processing (Allen 1981). Although significant rate responses were demonstrated through regression analysis, yet the failure of analysis of variance to separate means within aldicarb rates indicated that increased levels of performance with rates above 13 lb/acre could not be clearly demonstrated. This failure may have been at least partly due to application method. The 13 lb rate was applied furthest in-

Table 5. Percent size distribution of fruit sampled in 1992 and 1993.

Temik Rate (lb/acre)	1992 Fruit size (%) 80	1992 100	1992 125	1992 163	1993 Fruit size (%) 80	1993 100	1993 125	1993 163
0	4	27 b[1]	37	30 a	1	15 a	53 b	31
13	5	28 b	37	28 a	0	8 a	83 a	9
20	5	32 b	38	23 ab	0	5 a	68 ab	27
33	8	41 a	34	15 b	0	5 a	68 ab	27
	ns		ns		ns			ns

[1]Means in the same column followed by the same letter are not significantly different (LSD P < 0.05).

terior under the canopy, and thereby may have been the most effective application. Additional material to make up the 20 and 33 pound rates was applied outside the canopy dripline. Thus material in excess of 13 lbs was not as favorably positioned as the first 13 lbs and so could not be expected to provide the same level of control.

A clear yield response to aldicarb was observed the second year, in contrast to the first year when differences were not statistically significant. Fruit yield the second year was greatest with the low Temik rate (13 lbs/acre) and yield efficiency of trees treated with Temik appeared to be greater than untreated controls, although juice quality was not influenced significantly. The pattern of increased fruit size the first year and significant yield increases the second year of aldicarb application was also observed by Wheaton et al. (1985), although with higher rates of aldicarb.

In summary, year 2 results confirmed and extended those of the previous year. In both years we saw CRM control extend from March through August and in the second year we documented significant reduction in rust mite damage on fruit and consequently in total and percentage culls. In year 1 we observed increased fruit size, and in year 2 we were able to detect significant increases in yield of fruit and pound solids. However, we have not been able to demonstrate tangible benefits from aldicarb applied above the 13 lb/acre rate. This failure may be due at least partly due to the application procedures as mentioned above.

What do our results tell us about the economic benefits of aldicarb in process fruit? Pound solids/tree for years 1 and 2 were 34.93 and 30.54 for the untreated control, and 38.71 and 36.07 for the 13 pound/acre rate of Temik, respectively, an increase of +3.78 and +5.53 lbs solids/tree, an average of +4.66 lbs solids/tree/year. At 106 trees/acre this resulted in an increase of 400.68 and 586.18 lbs solids/acre for trees treated at the low rate over the 2 years, an average of +493.43 lbs solids/acre/year. The average cost of Temik 15G is $3.58/lb or $47.26/acre for 13.2 lbs, plus $14.33/acre application cost gives $61.59/acre (Muraro et al. 1994). Using the above figures as a best scenario, the break-even pounds solids price for the 13 lb rate of Temik at present would be $61.59/acre divided by +493.43 lbs solids/acre increase = 14.1¢/lb solids. Put another way, as long as the market price paid for pounds solids was above 14.1 cents it would be profitable to use aldicarb at the 13.2 lb/acre rate, given our results. Assuming a conservative current market price of 70 ¢/lb solids, expected yearly acreage benefit from 13.2 lb of aldicarb would be ($493.43 x 0.70) - $61.59 = $283.81/acre.

We have demonstrated a case of direct yield benefits from aldicarb to healthy, productive Hamlin orange in the absence of economically damaging infestations of nematode or arthropod pests. While these results may not be directly applicable to all citrus in Florida, the large size of our replicated plots and the assessment of total yield make us confident that treatment differences we observed were real.

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UPDATE ON CONTROL OF THE CITRUS LEAFMINER[1]

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Abstract. **Since November 1993, 4 different trials were conducted on lime, *Citrus aurantifolia* to determine the efficacy of pesticides against the leafminer (CLM), *Phyllocnistis citrella* Stainton. The performance of Sevin, Temik, Agrimek, Dimilin, Malathion, Align, RH5992, RH2485, Admire, Disyston, Payload and Orthene is discussed. Drench rates of 34 fl oz/acre of imidachloprid significantly reduced CLM populations for approximately 60 days. The mixture of Agri-Mek + Dimilin plus oil (1%) significantly reduced CLM mines per leaf for approximately 27 days after treatment.**

Citrus leafminer (CLM), *Phyllocnistis citrella* Stainton (Lepidoptera: Gracillariidae) invaded Florida in May 1993 (Heppner 1993) and since then it has spread throughout the state, and has also invaded Louisiana and Texas. The leafminer affects all citrus cultivars. Several different chemical families have been used by researchers to control this pest (Batra & Sandhu 1981, Catling et al. 1977, Stansly & Knapp 1993, Peña & Duncan 1993). While foliar spraying is the most common method of application, soil treatments have been used by researchers (Bullock 1993) with success in the control of this pest.

The objective of these experiments was to evaluate chemicals with different formulations and methods of application for control of the citrus leafminer on limes in Florida.

Materials and Methods

Experiment 1. Insecticides for control of CLM were evaluated Fall 1993 through Winter 1994 in 2 year old Tahiti limes located at the University of Florida's Tropical Research and Education Center, Homestead, Florida. Insecticides 3, 4, (Ad-

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[1]Chemicals used for research purpose only. No endorsements or registration implied herein.