symptom development (Table 1) (7). However, it is possible that reducing Zn levels prior to plug formation may delay disease onset (Fig. 1).

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EFFECTS OF ALDICARB ON YIELD, FRUIT QUALITY, AND TREE CONDITION OF FLORIDA CITRUS

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Abstract. **The effects of aldicarb on production, fruit quality, and tree growth were observed in 4 citrus groves for 2 years. Aldicarb treatments applied at 5 and 10 lb. a.i./acre were compared to a foliar miticide-insecticide spray treatment and an untreated control. Aldicarb treatment had little effect on yield or fruit quality the first year after application. However, treatment significantly increased yield and Brix in most blocks the second year. Fruit size was increased in only 1 grove the first year. External fruit color was improved by aldicarb in 1 grove the first year and in most groves the second year. Leaf P and Ca were increased in several instances. No differences in trunk growth, flowering, or vegetative growth characteristics due to aldicarb treatment were observed. Trees receiving aldicarb suffered less severe freeze damage than control trees in 1 grove during the Jan. 1985 freeze.**

The use of aldicarb in Florida citrus has rapidly increased. In 1985, over 200,000 acres were treated, representing approximately 30% of Florida citrus. Its efficacy for control of nematode, mite, and insect pests of citrus has been recognized in Florida and elsewhere. Less is known, however, about the effects of aldicarb on fruit yield, fruit quality, and tree condition. Some experiments demonstrated clear benefits of aldicarb on yield and fruit size, while others showed no advantage (1, 3, 5, 6, 8, 9). The purpose of this study was to obtain information on the effects of aldicarb on yield, fruit quality, nutritional status, and growth responses of Florida citrus over a 2-yr period.

Florida Agricultural Experiment Station Journal Series No. 7070.

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Materials and Methods

Treatments were applied in 1983 and 1984 to 4 citrus groves located in Polk and Hardee Counties. Grove characteristics are listed in Table 1. Plots were arranged in a randomized block design, and consisted of 20-tree plots in the Valencia experiment and 5-tree plots at the other locations. Treatments were replicated 8 times at each location in 1983. In 1984, replications were reduced to 5 in experiment 3, and to 7 in experiment 4 due to additional restrictions placed on aldicarb use. For Table 2, analysis of variance was performed separately for each grove and each year. The response curves in the figures showing average increase over all groves for the 1984/85 season were calculated by the analysis of covariance with grove as the covariate.

The 4 treatments applied at each location were: 1) aldicarb at 5 lb. a.i./acre, 2) aldicarb at 10 lb. a.i./acre, 3) foliar sprays for mite control, and 4) a control treatment. Aldicarb (Temik 15G) was applied in 1983 in a 4-ft band 2 to 3 inches deep under the tree canopy on 2 sides parallel to the row using a 4-chiseled, powerfed granular applicator. In 1984, aldicarb was applied using a granular applicator with 8 tubes spaced 6 inches apart, gravity-fed from a Gandy box, and incorporated by discs directly behind the delivery tube. Soil moisture was judged adequate

Table 1. Characteristics of plantings.

Characteristics	Experiment No. 1	2	3	4
Variety	Valencia	Hamlin	Duncan	Hamlin
Stock	Rough lemon	Sour orange	Sour orange	Sour orange
Tree age	22	22	15	18
Location	Davenport	Bowling Green	Bowling Green	Bowling Green
Spacing (ft)	25 x 25	15 x 30	25 x 25	20 x 28
Aldicarb application (1983)	29 Mar.	30 Mar.	29 Mar.	30 Mar.
Aldicarb application (1984)	2 Apr.	5 Apr.	3 Apr.	5 Apr.
Harvest (83/84)	27 Jan.	22 Dec.	7 Jan.	13 Dec.
Harvest (84/85)	5 Feb.	19 Dec.	18 Jan.	8 Jan.

and irrigation was not necessary following application either year.

Both treatments 3 and 4 were controls. Treatment 3 received summer sprays as required for mite control. In 1983, a summer oil (FC435-66) plus late summer amitraz, mancozeb (Dithane M-45) and oil was applied. The 1984 treatment was a summer application of hexakis distannoxane (Vendex) and oil. Treatment 4 received no summer miticide sprays.

All 4 treatments (aldicarb 5 lb., aldicarb 10 lb., foliar miticide-insecticide and control) received a summer copper spray for greasy spot control each year (chlorobenzilate was inadvertently included in the 1983 application to the Valencias in experiment 1). All treatment plots at each location also received a miticide application of hexakis distannoxane in Nov. 1984.

Trees were selected for uniform size and appearance prior to beginning the experiment. Yield was determined by weighing fruit harvested from 2 to 3 trees in each experimental plot. At the time of harvest, a random sample of 60 to 100 fruit was taken from each plot for determination of average fruit size (measured as average fruit weight), external fruit color, percent juice, juice Brix (soluble solids), acidity, and Brix/acid ratio. External fruit color was determined on a 20-fruit sample using a Hunter Color Difference Meter. This instrument provides a color index for light reflected from the fruit surface. The a/b color index is negative for green fruit, approximately 0 for yellow fruit, and has increasing positive values for orange and red coloration. Juice quality factors were determined using the standard automatic extraction and computerized test equipment found in Florida processing plants.

The effects of treatments on tree condition were determined by regularly observing the trees for vegetative growth, flowering, and fruit set. Trunk circumference measurements were made when the experiment was initiated and at yearly intervals to determine trunk growth. Visual freeze damage ratings were made each season to determine damage following the severe December freeze in 1983 and the January freeze of 1985. The rating scale ranged from 0 for no damage to 5 for trees with major scaffold limbs killed.

Effects of treatments on nutritional status of the tree were studied by sampling 60 leaves (spring flush, nonfruiting twigs) from all plots both years in Aug. or Sept. and analyzing these for major and minor elements. Leaf nitrogen was measured using the standard Kjeldahl method. Other elements were measured by inductively coupled plasma atomic emission spectrometry in 1983 and by flame atomic absorption spectrometry in 1984. The analyses included N, P, K, Ca, Mg, Mn, Cu, Zn, Fe, Na, and Al. Average leaf size was also measured from these leaf samples in some experiments.

Results

Aldicarb application influenced yield, juice quality, external fruit color, leaf composition (Table 2), and freeze damage. A few of these results were observed the first year after application, but more differences were found the second season. The freezes of Dec. 1983 and Jan. 1985 severely damaged the trees and fruit in experiment 1 but there was no wood damage at the other locations. Freeze stress may have been partially responsible for yield reduction the second season in experiments 2 and 3. Because of the freeze damage, Valencias in experiment 1 were harvested well before normal maturity and harvest dates.

Fruit yields in 1983/84 were not significantly affected by aldicarb treatments at any of the locations. Fruit yields were in the range of 700 to 900 boxes/acre for Hamlin, 1000 boxes/acre for grapefruit, and 250 boxes/acre for Valencias. In 1984/85, yields were lower in most experiments, but aldicarb treatments significantly increased yield compared to controls in all experiments. The Valencia grove, which traditionally had not yielded well, showed the greatest response to aldicarb. Production in the 2 Hamlin groves also increased from aldicarb treatments the second year. Yield in the Duncan block dropped overall to the 300-box/acre range the second season. Nevertheless, aldicarb treatment increased yield compared to the controls. Average increase in boxes/acre resulting from the 2 rates of aldicarb for 1984/85 is shown in Fig. 1. Yield increase was calculated relative to the foliar arthropod treatment; i.e., yield increase equals yield of aldicarb plots minus yield of treatment 3 foliar spray control. This figure shows an average yield increase for all 4 experiments of 50 boxes/acre for the 5-lb. rate and 100 boxes/acre for the 10-lb. rate.

Average fruit size was increased by aldicarb in only 1 instance, but effects on juice quality were more common. There was neither a consistent effect of treatments on percent juice nor juice acidity either year. Juice Brix (total soluble solids) was increased by aldicarb treatments in most experiments the second year resulting in an increase in lb. solids/box. Average Brix for all 4 experiments in 1984/85 increased linearly with aldicarb rate about 0.3 units for the 5-lb. rate and 0.6 units for the 10-lb. rate (Fig. 2).

External fruit color was improved (more orange) by aldicarb treatments at 2 locations the first year, and at 3 locations the second year. For the 1984/85 season, average

Table 2. Effect of aldicarb treatments on yield, Brix, acidity, pounds solids/box, fruit size, external color, leaf P, and leaf Ca. Treatments were aldicarb 5 lb. a.i./acre, aldicarb 10 lb. a.i./acre, foliar spray, and a control.

Cultivar	Treatment	Yield (box/A)	Brix (%)	Acid (%)	Solids (Lb./Box)	Size (g)	Color (a/b)	Leaf P (%)	Leaf Ca (%)
				1983/84 Season					
Valencia Exp. 1	Aldicarb 5[z]	294	11.3b[w]	1.32b	4.8ab	225a	0.63a	0.14	1.88
	Aldicarb 10[z]	252	11.2b	1.30b	4.7bc	224a	0.64a	0.14	1.84
	Foliar[y]	266	1.11b	1.28b	4.5c	196b	0.54b	0.14	1.75
	Control[x]	238	11.7a	1.46a	4.9a	174c	0.53b	0.14	1.67
Hamlin Exp. 2	Aldicarb 5	902	11.4a	0.89a	6.0a	131	0.44a	0.14a	4.58a
	Aldicarb 10	941	11.5a	0.90a	6.0a	140	0.43a	0.13a	4.42ab
	Foliar	931	10.8b	0.80b	5.5b	142	0.39b	0.11b	4.44ab
	Control	902	11.5a	0.91a	5.9a	131	0.40b	0.10c	4.21b
Grapefruit Exp. 3	Aldicarb 5	945	10.9	1.60	5.1a	395	0.12a	0.12b	3.78
	Aldicarb 10	1078	10.7	1.59	4.9b	435	0.10ab	0.12ab	3.74
	Foliar	1022	10.8	1.59	4.9b	436	0.11ab	0.13a	3.75
	Control	1022	10.7	1.60	4.9b	443	0.09b	0.12b	3.67
Hamlin Exp. 4	Aldicarb 5	819	11.4	0.90	6.1	128	0.36	0.13	4.51
	Aldicarb 10	780	11.6	0.87	6.1	127	0.38	0.13	4.63
	Foliar	741	11.2	0.85	5.9	132	0.37	0.14	4.36
	Control	733	11.5	0.88	5.9	118	0.40	0.13	4.50
				1984/85 Season					
Valencia Exp. 1	Aldicarb 5	224a	12.0a	1.18a	5.3a	226	0.72b	0.13a	1.54
	Aldicarb 10	227a	12.2a	1.13ab	5.4a	226	0.77a	0.13a	1.60
	Foliar	103b	11.4b	1.08b	4.9b	216	0.61c	0.12b	1.36
	Control	128b	11.5b	1.19a	5.1b	220	0.59c	0.12b	1.47
Hamlin Exp. 2	Aldicarb 5	447ab	11.8ab	0.89	6.2b	230	0.50a	0.13	2.64
	Foliar	353b	11.6b	0.90	6.2b	221	0.36c	0.13	2.71
	Control	402ab	11.7b	0.89	6.2b	237	0.42b	0.13	2.71
Grapefruit Exp. 3	Aldicarb 5	349ab	10.0	1.32	4.3	649	–0.02ab	0.16	2.41a
	Aldicarb 10	423a	10.3	1.31	4.5	649	0.01a	0.16	2.45a
	Foliar	293b	9.7	1.32	4.0	704	–0.06b	0.16	2.19b
	Control	290b	9.9	1.38	4.0	720	–0.03ab	0.17	2.21b
Hamlin Exp. 4	Aldicarb 5	743a	12.0ab	0.72	6.7a	191	0.60b	0.15	3.14ab
	Aldicarb 10	745a	12.2a	0.70	6.7a	190	0.68a	0.14	3.53a
	Folair	678a	11.7c	0.72	6.5ab	197	0.62b	0.15	2.95b
	Control	671b	11.7bc	0.75	6.4b	197	0.59b	0.14	2.91b

[z]Aldicarb at 5 lb. or 10 lb. a.i./acre.
[y]Foliar spray control as described in text.
[x]Untreated control.
[w]Mean separation for column and experiment by Duncan's multiple range test, 5% level.

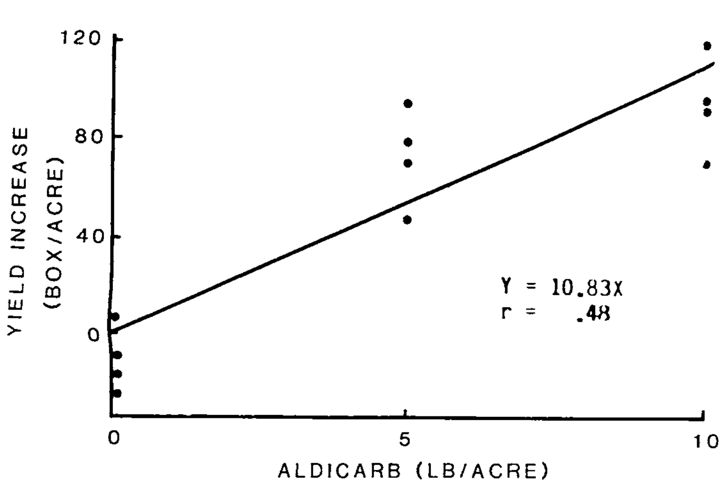

Fig. 1. Average yield increase (Y) response to aldicarb rate (X) for all 4 experiments during the 1984/85 season.

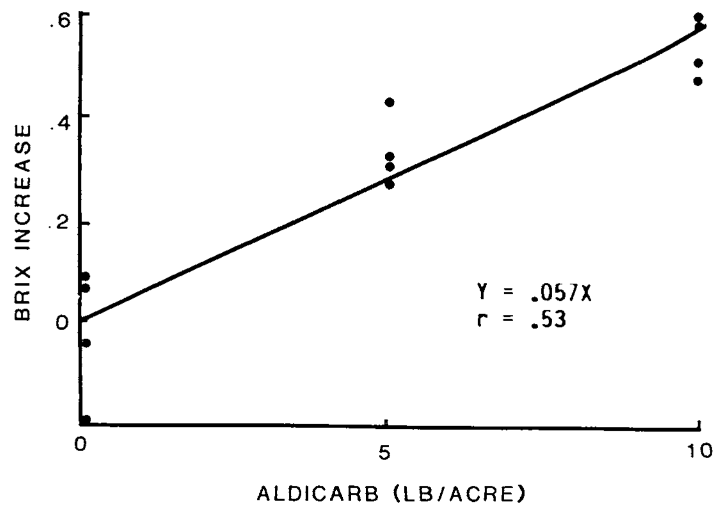

Fig. 2. Average Brix increase (Y) response to aldicarb rate (X) for all 4 experiments during the 1984/85 season.

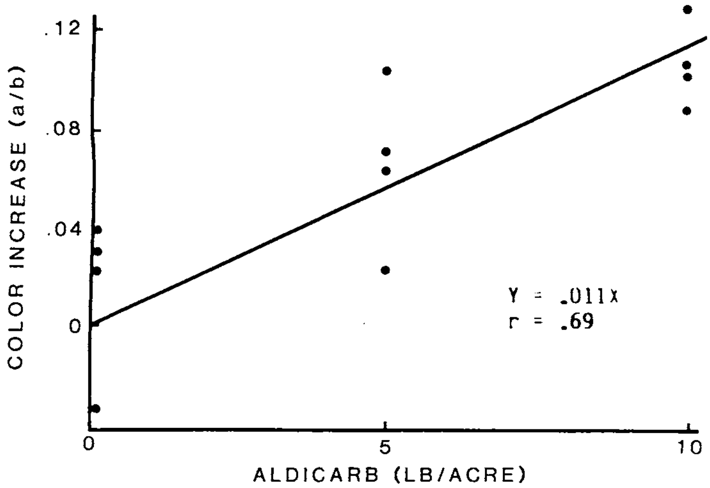

Fig. 3. Average fruit color increase (Y) response to aldicarb rate (X) for all 4 experiments during the 1984/85 season.

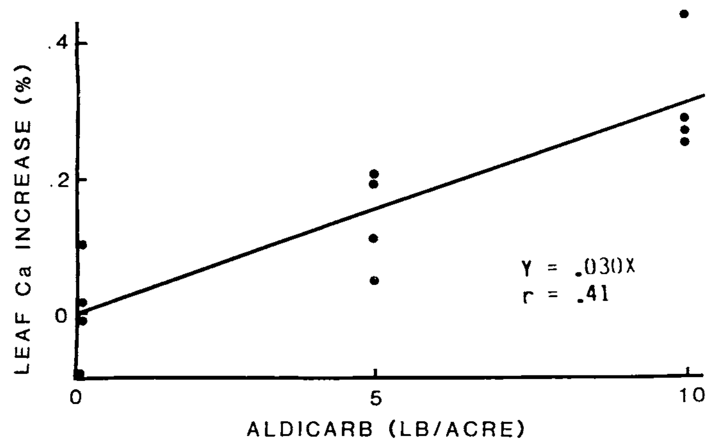

Fig. 4. Average leaf Ca increase (Y) response to aldicarb rate (X) for all 4 experiments during the 1984/85 season.

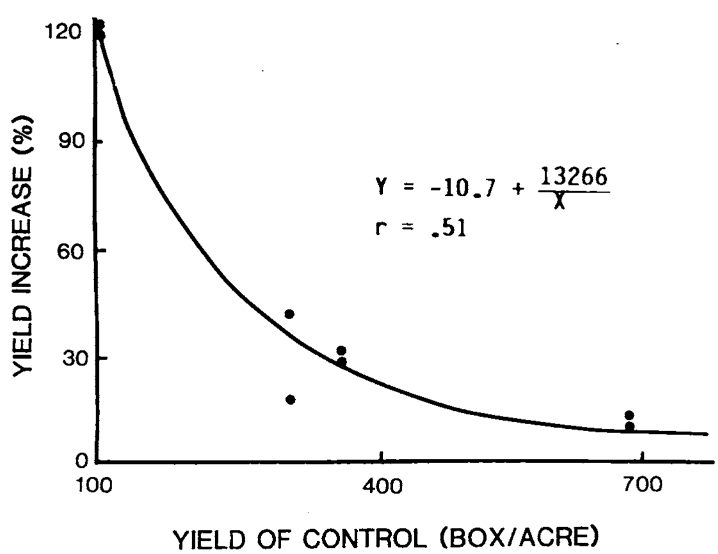

Fig. 5. Relationship between percent increase in yield due to aldicarb (both rates) (Y) and yield of control (X). Aldicarb increased yield more in groves with lower yields of control plots.

increase in fruit color for all 4 experiments was about 0.05 a/b units for the 5-lb. rate and 0.1 units for the 10-lb. rate (Fig. 3). This color increase was linear with increasing aldicarb rate.

Aldicarb was associated with increases in levels of some elements in leaf samples. However, there was no consistent pattern of accumulation of any element associated with aldicarb treatment over both years. Leaf N was not affected by treatment in any experiment. Leaf P was increased by aldicarb treatment in a Hamlin block the first year and in the Valencia block the second year. Similarly, leaf Ca was higher. For the 1984/85 season, average leaf Ca for all 4 experiments increased approximately 0.15% for the 5-lb. rate and 0.3% for the 10-lb. rate (Fig. 4). Several other elements also showed occasional treatment response in 1 or 2 experiments but no pattern was observed.

Trees were observed regularly and visually rated for bloom, vegetative flush, freeze damage, and trunk growth. No treatment effect on quantity or timing of bloom was found nor were differences in time or characteristics of vegetative growth observed. Average leaf size was not influenced by aldicarb. Tree trunk circumference increased during the 2 seasons, but no differences due to aldicarb were found. Freeze damage to trees in the Valencia block was not related to aldicarb treatments following the Dec. 1983 freeze, but was substantially reduced following the Jan. 1985 freeze. The freeze damage rating was 2.0, 1.8, 3.6, and 3.5 for the 5-lb., 10-lb., foliar, and control treatments, respectively. The lower ratings for the aldicarb treatments indicate substantially less freeze damage to these plots. Wood killed by the freeze was generally 0.3 inches in diameter or less and there was no loss in canopy size. In foliar and control plots, 1- to 2-inch wood was killed with consequent reduction in overall canopy. The other groves were not severely damaged by either freeze.

Discussion

Previous reports indicate aldicarb may or may not increase yield. In Australia, aldicarb did not improve yield of Valencia oranges (6), nor were benefits observed on Valencias in an experiment in South Africa over a 6-yr period where aldicarb was applied every third year (5). In California, increased yields were reported (1). Studies in Texas showed a yield increase the second year following treatment in one experiment (3), a yield increase occurring 1 out of 3 yr in another experiment and increases both years in a third experiment (10). In a previous Florida study, aldicarb applied 3 yr substantially increased third year yield at one location but had no effect at another. Yield data were not reported for the first 2 yr (8). Aldicarb also increased yield of Meyer lemon (9). In our present study, no yield response was observed the first year at any location, but substantial increases were observed the second year. This pattern of a delayed response has been observed previously (3), and may result from a cumulative effect of treatment. Date of application may also be important in determining time required to observe a response. Our application date near Apr. 1 each year may have been too late to obtain a current season response the first year. Earlier application dates should be evaluated in future studies, both for yield response and pest control.

Yield increases induced by aldicarb were greatest for the Valencia block which had the lowest yield. The percentage increase in yield over the foliar control for all blocks decreased with increasing yield of the control (Fig. 5). These results indicate aldicarb may increase yield to a greater extent in groves producing well below their potential.

The increase in juice Brix observed in the present study appears to be an added benefit of aldicarb treatment. The increase, though not large, translates into an additional 0.14 lb. solids/box for the 5-lb. aldicarb rate or approximately 70 lb. solids/acre for a 500 box/acre crop. An increase in Brix was not reported in previous studies.

Reports on the effects of aldicarb on fruit size and quality have varied with increased fruit size observed in some studies (1, 5, 8, 10) but not in others (7, 10). In South Africa, Valencia fruit size is a problem. Aldicarb improved fruit size (2), but was no better than increasing K fertilization (5). In our experiments, an increase in fruit size was observed only the first year in the Valencia experiment. Generally, heavier crop loads are associated with smaller fruit size. The 2 Hamlin blocks had very heavy crops the first year which may have precluded size increases due to aldicarb. General increases in yield induced by aldicarb the second year may have inhibited fruit size increases.

The improved external fruit color is of particular value for the fresh fruit market. Since there was no treatment effect on juice acidity or ratio, it appears the effect on external color is unique and not related to earlier fruit maturity. Improved fruit color has been observed by Florida growers but this effect of aldicarb has not been quantitatively presented previously.

Effects of aldicarb on leaf mineral composition have been studied previously. In one report from South Africa, aldicarb plus a K fertilizer was no more effective in increasing leaf K than the fertilizer alone (5). In another report, a trend toward higher P, K, and Ca resulted from aldicarb treatment (2). In Egypt, application of aldicarb to citrus seedlings grown in the presence of citrus nematodes increased leaf Mn and Zn levels, alleviating deficiencies of these elements (4). Our results also indicated some effects of aldicarb on the nutritional status of the tree. Although results for many elements were variable, increases in leaf P occurred in 2 groves the first year and 1 grove the second year. The increase in leaf Ca with increasing aldicarb rate is clearly observed in Fig. 4.

Improved freeze tolerance associated with aldicarb treatment has not been reported previously.The improved tree condition for aldicarb treatment in the Valencia experiment following the January 1985 freeze will result in more rapid recovery of production in future years. Some of the aldicarb responses observed for the 1984/85 crop may be due to unmeasured differences in freeze damage among treatments for the December 1983 freeze. However, no visible differences in canopy condition were detected by visual rating after that freeze.

Results from these experiments can be useful in determining the potential value of aldicarb in Florida citrus production. Substantial benefits from application of aldicarb at 5 and 10 lb. a.i./acre were observed during the second year of application. Although differences between the aldicarb rates were usually not significant in analyzing individual experiments, regression analyses of average increase in response over all experiments showed the 10-lb. rate was superior. Measured responses to aldicarb increased in a linear fashion with increasing aldicarb rate in this study. However, additional experiments with more rates and conducted over longer time periods will be required to establish optimal rates for aldicarb in Florida citrus.

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