Citrus Section

PROTECTION OF YOUNG CITRUS TREES FROM FREEZE

GEORGE YELENOSKY[1]

ABSTRACT

We used solid, liquid and gas fuel in appropriate-type heaters to protect young citrus trees during the winter of 1964-1965. Performance characteristics were indicated by thermometers and thermocouples in inverted L-shape shelters 3, 6 and 20 feet above ground level and thermocouples attached to underside of leaves. Also, we took into account the total number of heaters used, spacing of heaters from trees, the ease of lighting and refueling, the occurrence of excessive smoke and fumes, and the cost of installation.

Wind had a telling effect. Leaf-temperature increases were less; and some heaters were difficult to light during windy, freezing nights in contrast to calm freezing nights which are characteristic of radiation-type freezes. Wind had no marked influence on temperatures at 3 different depths in soil banked 18 inches high around tree trunks. Soil temperatures depended on soil depth. Cornstalks were an inadequate substitute for soil banks.

INTRODUCTION

Our primary interest is to protect research trees, especially small, young, citrus trees less than 7 feet tall. We have little information on how well we might protect our young research trees. Most heating work by others has been on much larger trees in commercial-type grove areas, and results are not applicable to our particular situation.

We realized that heating efficiency would be low regardless of type of heater used. Our small trees probably would intercept and absorb only a small portion of the total heat emitted from heaters. Also, our area is much exposed to wind and most of the heat would be blown away easily, since small trees provide little resistance to wind. Loss of heat, regardless of wind, probably would be excessive during cold nights, since small canopies would favor radiant heat loss (10). Instruments indicate one-half as much heat loss in calories second^{-1} from the soil under canopies of large trees. Finally, young trees, likely to be less dormant, will in turn be injured more than old trees by freezing conditions (2).

[1]Crops Research Division, Agricultural Research Service, U. S. Department of Agriculture, Orlando, Florida.

EXPERIMENTAL METHODS

Since the grove environment of young experimental trees is quite different from that of commercial ones, a variety of orchard heating systems, as well as cultural practices, were tested, to determine the best method of protecting valuable young research trees from potential cold injury.

Heaters were installed in 2 groups of four 0.16-acre plots in 10 acres of 4-year-old citrus hybrids 3 to 6 feet tall. Two groups of 4 plots each were about 300 feet apart, north and south, and plots within each group, aligned east and west, were separated from each other by buffer strips 40 feet wide. Each plot, approximately 80 x 120 feet, contained 100 trees in 4 rows and 20 feet apart or 25 trees 5 feet apart by row.

A different type of heater was used on six of the eight plots and each group of four plots included one unheated control area. Trials were conducted during non-freeze and freeze nights and not all heaters were represented equally in all trials. Number of heaters used, and spacing from trees, varied according to heater type. Each of two plots was heated with a different type of propane gas heater (Figures 1 and 2). A paraffin base solid fuel (Figure 3), a solid-fuel-type which uses rubber as fuel (Figure 4), an oil burner without a stack (Figure 5), and conventional return-stack were used each to heat one of the four plots.

Figure 1.—Propane gas heater type I, radiant-convective heat.

Figure 2.—Propane gas heater type II, essentially 100% convective heat.

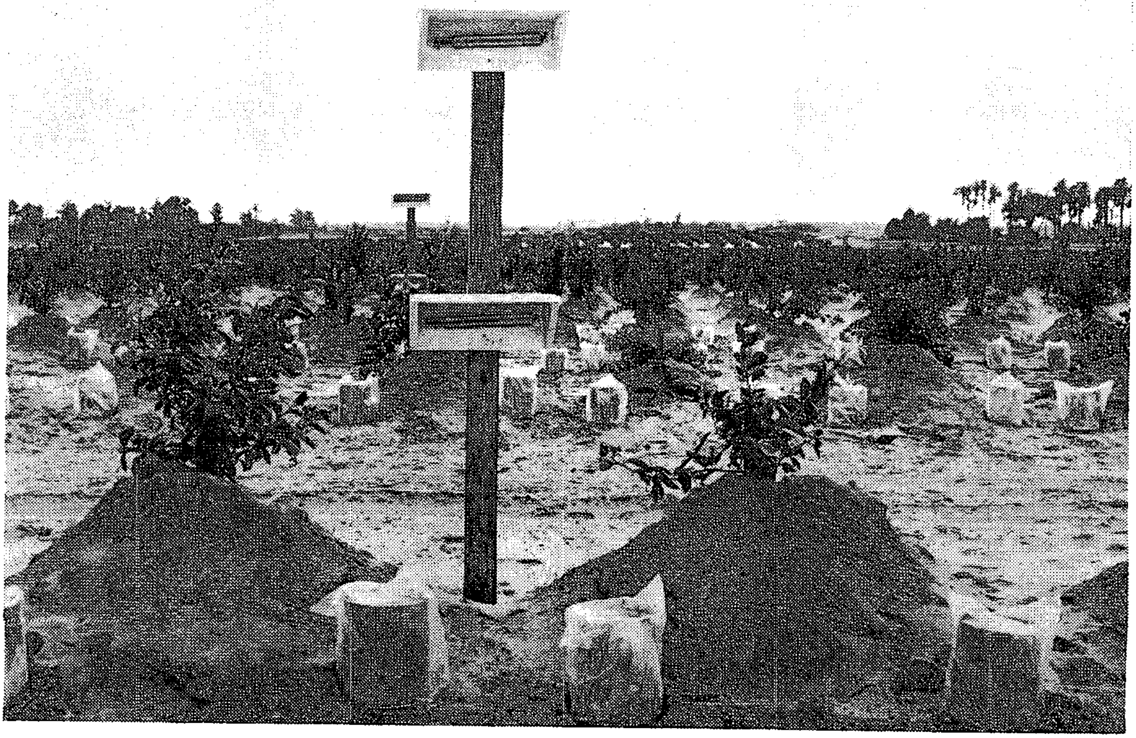

Figure 3.—Paraffin-type solid fuel heaters with plastic covers.

Figure 4.—Solid-fuel-type heater and chopped pieces of rubber in plastic bag as fuel.

Table 1. Undesired features found for various types of heaters

Heater type	Undesired feature
1. Propane gas type I and II	1. High cost of installation.
2. Solid fuel (paraffin base)	1. Commercial packaging of 4 units per cardboard carton hindered quick and efficient handling in the field. 2. Units were often difficult to light, especially in a wind. Moisture was a primary factor.
3. Solid fuel (rubber)	1. Intense smoke and fumes. 2. Inadequate refueling. 3. Unstable heat output curve. 4. Less than 5 hours effective burning time.
4. Return-stack	1. Cumbersome and time consuming.
5. Oil burner without stack	1. Container not sufficiently sturdy. 2. Edges of container too sharp for safe handling. 3. Inadequate control of burning rate. 4. Excessive smoke and flame. 5. Difficult to light if container new. 6. Fuel easily contaminated by rainfall regardless of covers attached.

Table 2. Average lighting time and fuel consumption per heater during various trials of cold protection

Heater Type	Total No. Used	Lighting Tool	Lighting Time (sec) 1 man	2 men	Fuel Consumption per hr
Propane gas					
I	52	Propane hand torch	7.0	2.5	0.60 gal
II	100	" " "	4.4	2.1	0.63 gal
Solid fuel					
paraffin	200	Drip torch and propane hand torch	11.0	-	1.5 lb
rubber	24	(as above)	16.0	-	10.0 lb
Liquid fuel					
Return-stack	50	(as above)	28.0	-	1.0 gal*
Oil burner without stack	50	" "	45.0	-	7.0 gal**

* draft setting of 1 hole

** no cover

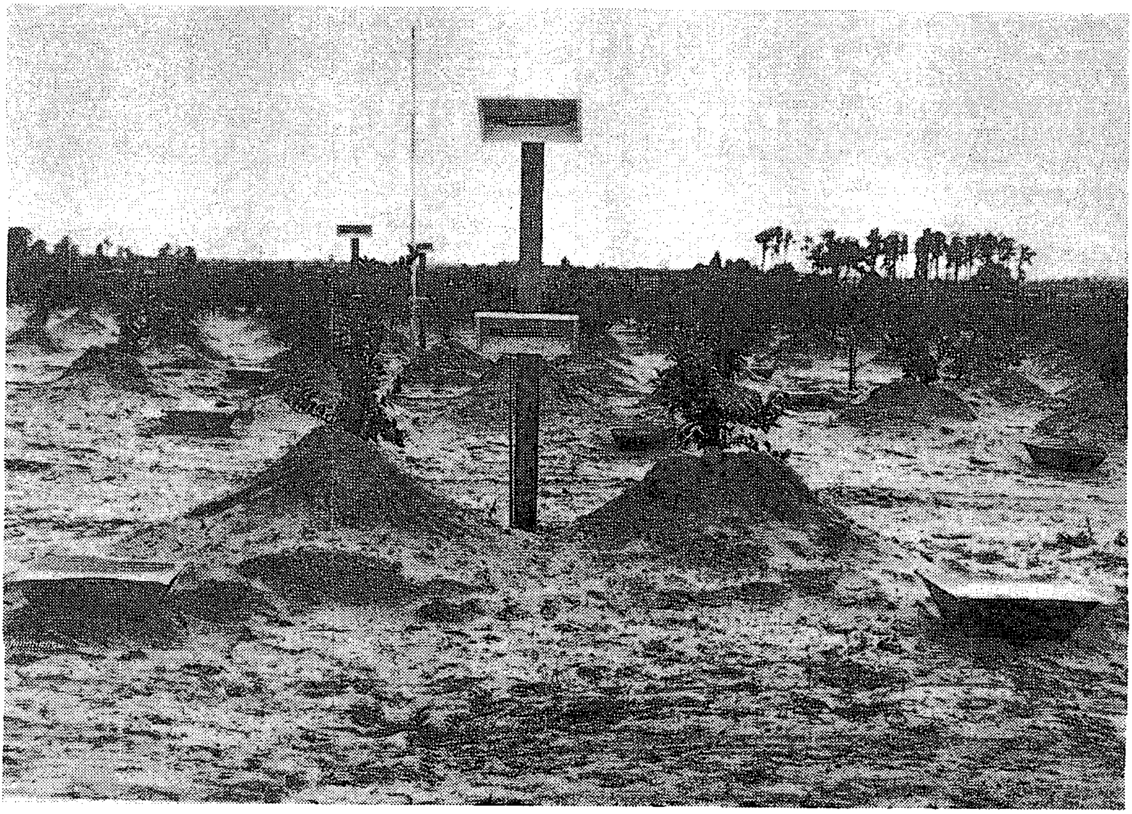

Figure 5.—Oil-burner heaters without stacks.

Leaf temperatures, indicated by thermocouples attached to underside of exposed leaves on the side of trees opposite the heaters, largely determined the effectiveness of heaters. Thermocouples, 24 gauge copper-constantan, were connected to a 24-point potentiometer type recorder. Overall accuracy was calibrated to ±0.5°F. Additional instrumentation included therometers accurate to ±1.0°F and located in inverted L-shape shelters 3, 6 and 20 feet above ground level. A portable battery-operated unit indicated wind speed 6 feet above ground level. Velocity indicator was estimated to require a starting air speed of 3.+ mph. Beaufort's scale was used to approximate wind speeds less than 3 mph.

Soil was piled 18 inches high around the trunks of the trees to provide additional protection. Thermocouples indicated temperatures 6, 12, and 18 inches below the apex of three soil banks and adjacent to the surface of the trunk of the trees.

Results and Discussion

Heat output was less of a problem than workability characteristics of the various types of heaters. Temperatures were raised at least 3°F above ambient freezing temperatures as low as 28°F, regardless of heater type. Some of the undesirable features found among the various heaters are listed in Table 1.

The gas-type heaters lighted quicker and more efficiently than the others (Table 2). The difficulty in lighting solid fuel (paraffin base) can be overcome as demonstrated by another similar solid fuel heater (Figure 6). Lighting time was one second or less, and once lit, it was extremely difficult to blow out. The considerable length of time to light liquid fuel heaters is attributed mostly to new containers. Carbon residue helps quick and efficient lighting of such heaters.

Wind was a major problem encountered in the trials. Low wind speed of < 1 mph, in contrast to 5 to 7 mph, increased heater effectiveness by factors of 2.0 for propane gas-type II, 1.0 for return-stack, and 0.6 for propane gas-type I (Table 3). Data were not obtained for other types of heaters; the symbol delta (Δ) indicates differences in temperature between that heated and its unheated control. Temperature profiles are indicated in Figures 7 and 8. Results suggest that approximately twice as many heaters are needed during an advection freeze, to provide increases in temperature comparable to that obtained during a radiation freeze. The expected large influence of wind on convective-type heaters is apparent with the propane-type II heaters which indicated a 12°F increase in leaf temperatures when wind velocity decreased. However, this does not detract from the effectiveness of convective heat to increase leaf temperature as indicated by maximum Δ T of + 18°F. The expected small influence of wind on radiant-type heaters is indicated by H_k values of 0.6 for propane-gas type I and 1.0 for return-stack. Differences of temperatures among different types of heaters during any one night are attributed mostly to differences in the total number of heaters used and variations in spacing of heaters. Propane gas-type II heaters produced maximum Δ T's of two to three times that of other heater types; but twice as many of these heaters were used in comparison to others and also were spaced 3 to 4 feet closer to trees.

Ambient air temperatures, indicated by thermometers in shelters, were 2°F higher than ambient leaf temperatures during the first night when wind averaged 5 to 7 mph. By comparison, difference between leaf and air temperature was 3°F during the second night when it was relatively calm. In contrast to thermometers in shelters, the more exposed leaves apparently had greater radiant heat loss and were more influenced by wind. Differences of 2°F and 3°F are within expectations, and especially pronounced from low wind speeds of 10 to 0 mph (4).

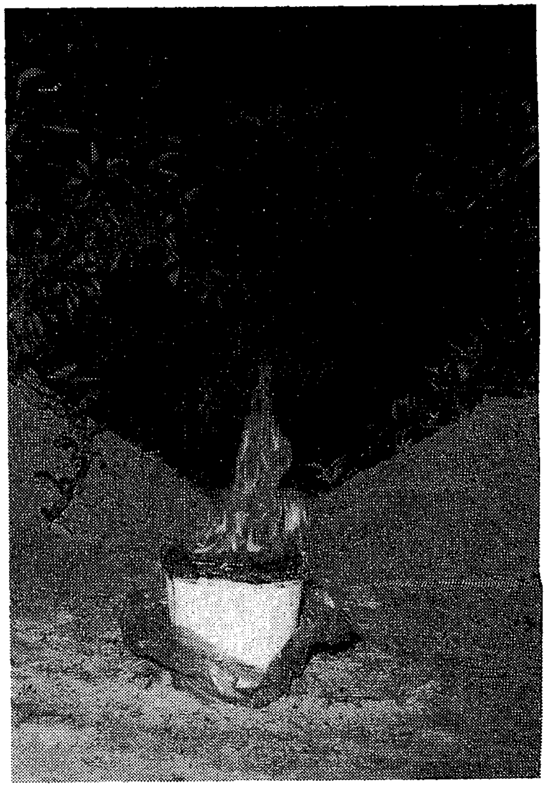

Figure 6.—"Experimental candle," solid-fuel type heater.

Table 3. Effect of wind on heaters as indicated by maximum increases of leaf temperatures in a small-tree citrus grove

Heaters: Type	No. Used	Spacing (feet): From Trees	Spacing (feet): Between Heaters	Max. ΔT_{leaf} At Two Wind Speeds (mph): 5 to 7	1	$T_{(diff.)}$ 1/	H_k 2/
				(°F.)	(°F.)	(°F.)	
Propane Type II	100	3	5	+6.0	+18.0	+12	+2.0
Return-stack	50	7	10	+3.0	+6.0	+3	+1.0
Propane Type I	52	6	10	+3.5	+5.5	+2	+0.6

1/ increase of leaf temperatures attributed to decreased wind speed.
2/ factor index of heater effectiveness attributed to decreased wind speed : $H_k = T_{(diff.)} \div \text{max. } \Delta T_{leaf}$ (5 to 7 mph)

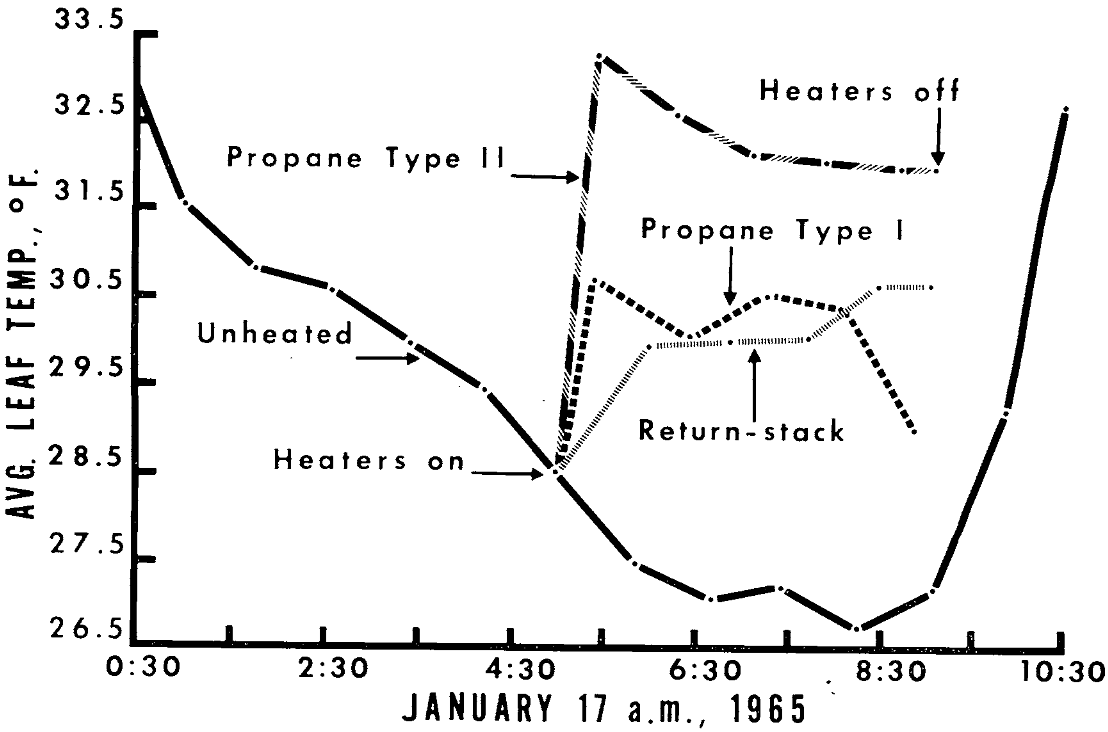

Figure 7.—Average increase in leaf temperatures attributed to various types of heaters during an advective-type freeze night.

Trees were injured slightly during the two freeze nights, although temperature data indicated adequate protection. Some new foliage was killed, primarily at the top of the tree canopies. Leaves were killed on 65% of the trees in the unheated plot which was rated as the most injured (Table 4). Least number of trees injured was 9% of those trees protected by propane gas heater type II; 18% were injured in the plot heated by return-stack; whereas 24% were injured in the plot heated by propane gas heater type I. Differences are attributed partially to the unequal number of heaters used; unequal spacing; and possibly to unequal amounts of new growth per tree per plot.

Wind had no marked influence on soil bank protection in contrast to heaters. Soil temperature patterns were essentially unaffected by wind velocity but strongly dependent on soil depth (Figure 9). Data indicate twice as much pro-

Table 4. Freeze injury in a small-tree citrus grove as a result of low temperatures during January 17 and 18, 1965

Heaters		Spacing (feet)			
Name	No. used	From trees	Between heaters	Trees injured (basis of 100 trees) (%)	Total canopy injured (%)
Propane Type II	100	3	5	9	< 1
Return-stack	50	7	10	18	1 to 10
Propane Type I	52	6	10	24	< 1
Unheated	-	-	-	65	1 to 10

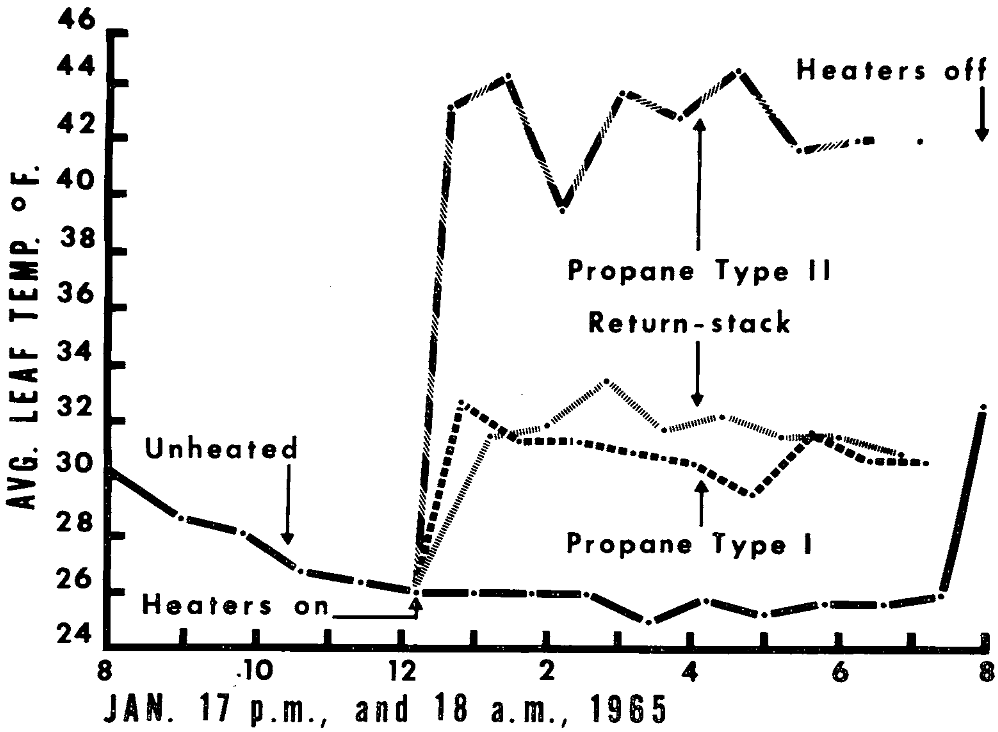

Figure 8.—Average increase in leaf temperatures attributed to various types of heaters during a radiation-type freeze night.

tection at the 18-inch level as at the 12-inch depth, and five times as much as at the 6-inch depth on the basis of extrapolating data to 26°F on January 17, 1965. Additional comparisons suggest that the protection of a 12-inch high soil bank is doubled if the height is increased to 18 inches. As expected, temperatures within soil banks lagged considerably behind air temperatures and to some extent indicate the thermal conductivity properties of the soil banks. Soil temperatures at the 6-inch depth level were approximately 7 hours behind air temperature. Measurements indicated a delay of 17 hours at the 12-inch depth; and indicated twice as much, or 34.5 hours, at the 18-inch depth.

Some work was done on cornstalks as a substitute for soil banks. Cornstalks (Figure 10) were not adequate. Temperatures underneath 2 to 3 inches of cornstalks wrapped around main stems were within 1°F of air temperature in the shelter 1 foot above ground level.

It has been suggested that wind breaks decrease the influence of wind (5). Apparently, *Eucalyptus globulus* trees are recommended highly in some areas (8)). However, wind breaks may increase the hazard of radiation freezes. Other suggestions indicate need of increased humidity as well as heater protection (6). It might be feasible even to consider increasing soil moisture and compacting the soil just prior to the onset of freezes, in order to improve thermal conductance or upward flow of soil heat. Somewhat more extreme methods include some means of tapping solar energy, storing it, and making it available as needed (1). There are no substitutes for the microcosm type of study (9), data accumulation on effectiveness of heaters (7), new formulations of heat requirements (3), and new techniques (4).

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LITERATURE CITED

1. Black, J. F. 1963. Weather control: use of asphalt coatings to tap solar energy. Science 139: 226-227.
2. Cooper, W. C., R. H. Young, and F. M. Turrell. 1964. Microclimate and physiology of citrus: their relation to cold protection. Agric. Sci. Rev., pp. 3-15.
3. Crawford, T. V. 1964. Computing the heating requirements for frost protection. Jour. Appl. Meteor. 3: 750-760.

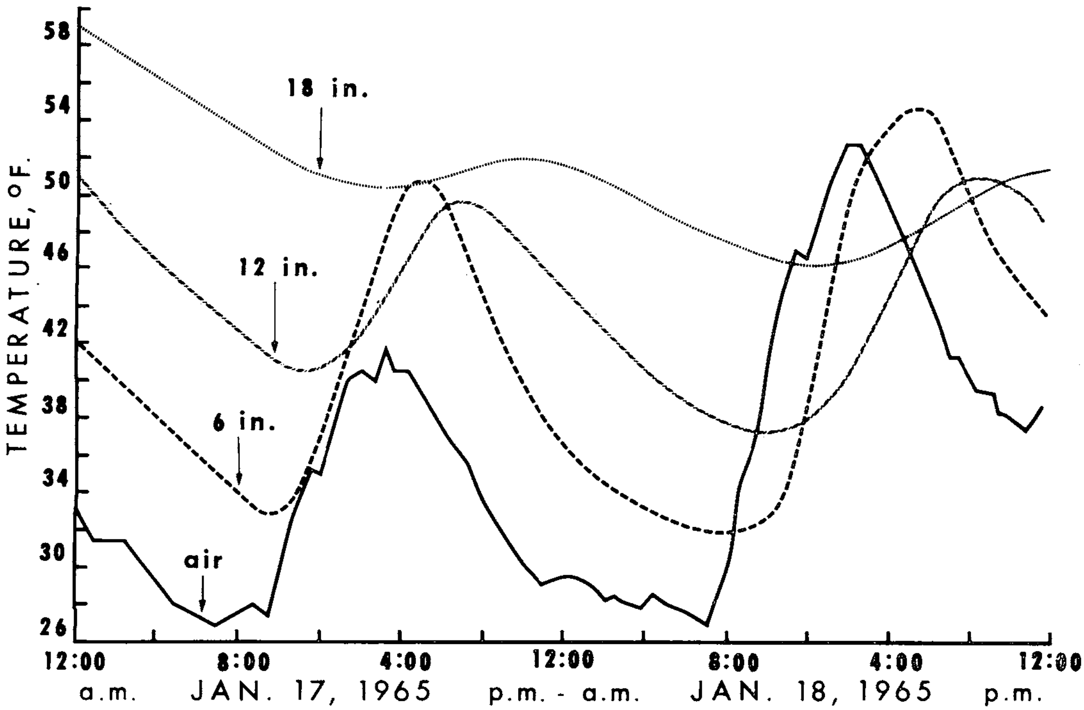

Figure 9.—Temperatures at 3 depth levels in soil banked 18 inches around main stems of young citrus trees and in relation to air temperature in inverted L-shape shelter one foot above ground level.

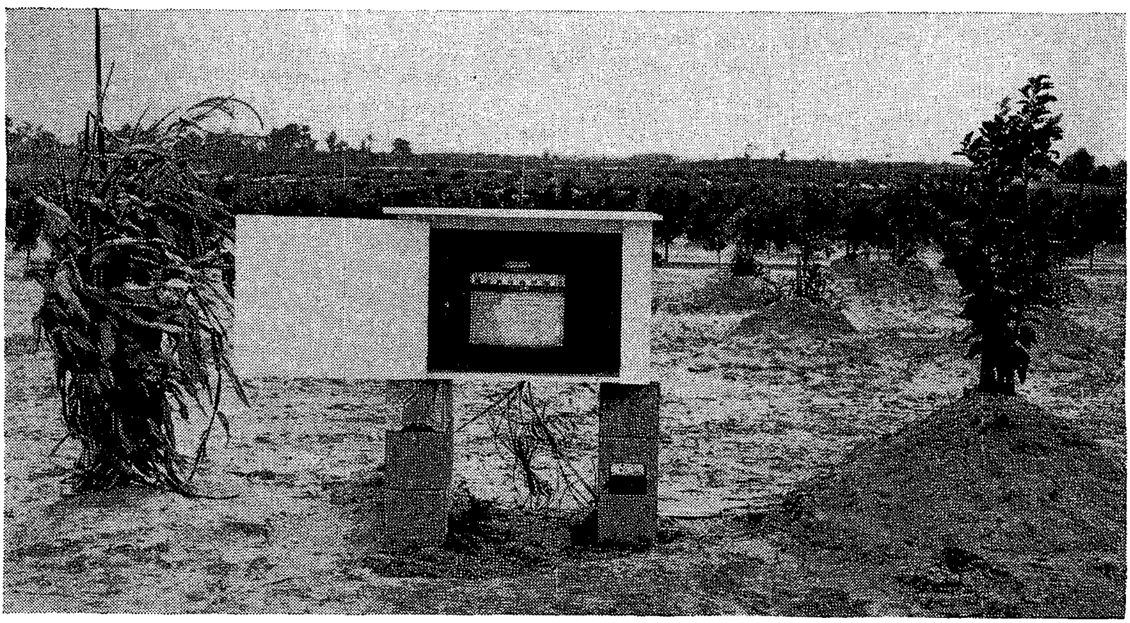

Figure 10.—Thermocouples attached to recorder in center of photo indicate temperatures underneath cornstalks surrounding citrus tree on left of photo and soil bank on the right.

4. Gates, D. M., E. C. Tibbals, and F. Kreith. 1965. Radiation and convection for ponderosa pine. Amer. Jour. Bot. 52: 66-71.
5. Gerber, J. F. 1964. The use of heating devices for cold protection. Proc. Fla. State Hort. Soc. 77: 93-100.
6. Grierson, W. 1964. Grove heating: some thermodynamic considerations. Proc. State Hort. Soc. 77: 87-93.
7. Kepner, R. 1951. Effectiveness of orchard heaters. Univ. of Calif. Agr. Expt. Sta. Bull. No. 723, 30 pp.
8. Pehrson, J. E. 1964. Windbreaks don't take long. The Calif. Citrog. 49: 336.
9. Turrell, F. M., S. W. Austin, and R. L. Perry. 1962. Nocturnal thermal exchange of citrus leaves. Amer. Jour. Bot. 49: 97-109.
10. Turrell, F. M., and S. W. Austin. 1965. Comparative nocturnal thermal budgets of large and small trees. Ecology 46: 25-34.

EFFECTS OF IRRIGATION AND FERTILIZATION ON PRODUCTION AND QUALITY OF 'DANCY' TANGERINE[1]

R. C. J. Koo[2]

A. A. McCornack[3]

Abstract

Results from a 5-year study of 'Dancy' tangerines comparing irrigation vs. no irrigation with 2 rates of nitrogen and potassium showed that fruit production was increased by irrigation. Irrigation resulted in lower soluble solids and acid contents but higher juice ratio as compared to no irrigation. 'Dancy' tangerine maturity date can be advanced in certain years by irrigation.

Additional nitrogen did not increase fruit production but produced fruit of high acid content and thus delayed maturity. Extra potassium resulted in fruit of lower acid content. A fertilizer program based on 200 pounds of nitrogen per acre per year seemed ample for 'Dancy' tangerines.

Two-years' data from post-harvest decay studies indicated supplemental irrigation had no effect on decay, but extra nitrogen reduced the incidence of decay.

Introduction

Tangerines have been grown in Florida for many years, but very little research information is available on cultural practices for this crop. Since tangerines are grown primarily for the fresh fruit market, emphasis has been placed on growing fruit of large size with good color. Thompson *et al.* (12) obtained good fruit color through control of certain insects with spray. Norris (6) reported that hedging of tangerine trees improved fruit color and texture, which resulted in a much higher percent of pack-out. To reduce post-harvest decay, Grierson *et al.* (1, 2, 3) emphasized the importance of picking tangerines only when the fruit is dry and care in post-harvest handling of the fruit.

There are no published results of fertility or irrigation studies of tangerines in Florida. Reitz (7), commenting on fertilization of 'Dancy' tangerines, made the following observations: "An experiment covering a wide range in rates of fertilization failed to significantly affect the size of the fruit produced, and the pack-out of the crop was not consistently influenced. Under most circumstances, it is advisable to use low to moderate fertilizer rates for both good size and color, but as illustrated in this experiment, this kind of program will not always guarantee the desired results."

An irrigation and fertilization experiment was started in the fall of 1959 to obtain information on the influence of soil moisture and fertility on fruit production and quality of 'Dancy' tangerines. This paper summarizes the results obtained between 1960 and 1964.

Experimental Methods

The experiment was conducted on a block of 'Dancy' tangerine trees on rough lemon rootstock at the Citrus Experiment Station, Lake Alfred, Florida. The trees were planted in 1923 on Lakeland fine sand on a 25 x 25 foot spacing or 70 trees per acre. The depth to clay in the block varied from 7 to 9 feet. Treatments included irrigation vs. no irrigation, 2 rates of

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[1]Cooperative research of the Florida Citrus Experiment Station and the Florida Citrus Commission.
[2]Associate Horticulturist, University of Florida Citrus Experiment Station, Lake Alfred.
[3]Assistant Horticulturist, Florida Citrus Commission, University of Florida Citrus Experiment Station, Lake Alfred.
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