EFFECTS OF AIR TEMPERATURES ON CITRUS COLD HARDINESS AT DIFFERENT GEOGRAPHICAL LOCATIONS IN FLORIDA

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Abstract. **Freezing points of detached leaves (LFP) were used to evaluate the cold hardiness of 'Temple' orange, 'Hamlin' orange and 'Marsh' grapefruit trees at Gainesville, Leesburg and Dundee during the 1971-72 winter. A portable leaf-freezing unit was used for the LFP determinations. Comparisons were made between changes in LFP and ambient air temperatures during the time studied.**

Significant differences in LFP between cultivars at a single location and between locations were found. Lower temperatures at the more northern locations induced a lower LFP in all 3 varieties. 'Temple' orange and 'Hamlin' orange LFP were decreased more than the LFP of 'Marsh' grapefruit, which was significantly less cold hardy.

Due to mild winter temperatures there was only 1 period during this study when measurably lower LFP were found, indicating only 1 series of low temperatures capable of inducing cold hardiness.

For many years the cold hardiness of citrus has been determined by survival after naturally-occurring cold weather periods or by artificial freezing tests using whole plants. Good agreement is usually obtained between the results of controlled freezing tests and field survival observations (1, 2, 6, 13, 15, 16). However, evaluation of field survival is cumbersome and time-consuming, and the freeze testing of whole plants requires large equipment and the sacrifice of many plants.

Recent Research has indicated agreement between leaf-freezing-points (LFP) and cold hardiness of young citrus trees (4, 7, 8, 9, 10). Previous determinations of citrus LFP have employed large, non-portable equipment (8, 9, 11). This limitation has restricted the use of the LFP technique to a centralized laboratory. In this research a portable leaf-freezing unit was used to determine LFP as influenced by ambient air temperature in 3 different Florida locations.

Materials and Methods

Weekly LFP and daily maximum-minimum air temperatures were determined at 3 locations for the period December 28, 1971 to March 7, 1972. Changes in LFP were then compared to daily minimum and mean air temperatures.

Mature citrus trees were selected at 3 locations in Florida representing areas with a relatively high, intermediate and low frequency of cold hardiness inducing winter temperatures. These locations were the Archer Road Grove on the University of Florida Gainesville campus, A. H. Whitmore Foundation Grove on the USDA property south of Leesburg, and the Estes Grove south of Dundee, respectively.

Two trees each of 'Temple' orange (*Citrus temple* Tanaka), 'Hamlin' orange (*C. sinensis* (L) Osbeck) and 'Marsh' grapefruit (*C. paradisi* Macf.) were selected at each location. Two-tree replication to determine cultivar LFP is less than the 5 tree (11) and 10 tree (8, 9) replication of previous workers. Trees of 'Temple' orange were on 'Cleopatra' mandarin rootstock at Gainesville and Leesburg and sour orange rootstock at Dundee. At Gainesville 'Hamlin' orange trees were on sour orange rootstock. 'Hamlin' orange and 'Marsh' grapefruit trees at Leesburg and 'Marsh' grapefruit at Gainesville were on their own roots, while at Dundee these varieties were on rough lemon rootstock.

Leaf sampling, handling and determinations of leaf-freezing point were the same as described previously by Hutcheson and Wiltbank (7, 8, 9). Leaf-freezing points of 3 randomly-selected, fully-expanded, mature leaves were averaged to give the leaf-freezing point for each tree. Leaf-freezing points for pairs of trees were then averaged to give a mean leaf-freezing point (LFP) for the cultivar. Leaf samples were taken between 10:00 A.M. and 6:00 P.M. to avoid moisture on the leaf surface. Maximum time from leaf detachment to freezing was 1 hour.

LFP values were determined in the field

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using a portable leaf-freezing unit modified from that of Hutcheson (8, 9). This unit was powered by 2 6-volt DC storage batteries connected in series, with an inverter to provide AC power for the recorder. A Norcold MRTF-614 marine freezer was operated directly on 12-volt DC current.

Daily maximum and minimum air temperatures in a weather shelter 5 ft. above ground were obtained from each of the 3 locations. Temperature measurements at Gainesville were taken using copper-constanan thermocouples placed in the canopy of the test trees. These measurements were recorded with a Brown-Honeywell 20-point recorder. Air temperatures at Leesburg were taken with a maximum-minimum thermometer located in the environmental measurement site located in a grove on the USDA property. Air temperature data for the Dundee location were supplied by the Federal-State Agricultural Weather service. This data was taken from survey station 2827A, located in the same commercial planting as the experimental trees.

Compilations and averaging were made on the air temperature data to obtain values for comparison with the weekly LFP values. First, a daily mean was computed using the maximum and minimum air temperature value. A weekly mean air temperature was also computed from the daily means for each of the weeks studied. Second, the number of times night air temperatures dropped below 55°F and 50°F were tabulated, these temperatures being chosen as threshold temperatures at which dormancy and hardiness are induced in citrus (1, 11, 14). Third, in order to evaluate the effect of both the frequency of cold nights and the intensity of the cold exposure, a calculation of hardening units was made. These calculations were made using both daily minimum and daily mean air temperatures in combination with threshold temperatures of 55° and 50°. The hardening units were determined by substracting the temperature parameter (daily minimum or daily mean) from a selected threshold temperature. Thus, 10 hardening units would be acquired when the minimum or daily mean air temperature was 45° and the threshold temperature was 55°. The hardening unit calculations excluded negative values and were established as follows:

(1) HUn = Threshold Temperature - Night Minimum

or (2) HUm = Threshold Temperature - Daily Mean

Comparisons of the data were made in 2 ways. First, a mean LFP of the 3 varieties at each location was calculated and compared with each of the 3 air temperature parameters for a given location. Secondly, the weekly leaf-freezing points for each tree of each cultivar at each location were statistically analyzed to determine if significant changes in LFP had occurred. The statistical design was a 3-factor analysis of location, variety and time. Data for individual cultivars were statistically compared within each location and between the 3 locations.

Results and Discussion

The portable leaf-freezing unit worked satisfactorily under field conditions. The light weight of the freezer box and sensitivity of the thermostatic temperature control added to the convenience of the unit. The DC to AC inverter which supplied AC current for operation of the recorder also performed to expectations. No difference was noted in recorder performance or sensitivity when using the portable power source as compared to line power. The use of 2 trees per replication instead of the previously used 5 (11) or 10 (8, 9) trees to determine LFP gave greater statistical precision than previous analysis of this type.

The analysis of variance of data showed several significant differences. First, there were significant (0.05 level) differences between mean LFP values for the different locations (Table 1). The location mean of the weekly LFP values was 19.1° at Gainesville, 19.4° at Leesburg and 20.3° at Dundee. The lower LFP values obtained at the more northern location can be attributed to the lower air temperatures experienced (Fig. 1). Weekly mean LFP values at Gainesville (Table 2) were consistently lower than those at Dundee because air temperatures at Dundee during this study were not low enough to induce measurable lowering of LFP. Weekly mean air temperatures at Dundee were never below 55°, the temperature below which dormancy and cold hardiness are induced in citrus. Further, mean LFP values at Dundee were similar to dormant but unhardened trees (11). Second, there were significant differences between LFP values of the 3 cultivars within each location, and by LFP the relative cold hardiness of the 3 cultivars to each other was similar at all 3 locations (Table 1). Third, there were significant decreases in the weekly mean LFP at a given location (Table 2), although these occurred over 2-to 3-week periods rather

Table 1. Eleven-week LFP and mean LFP for 3 cultivars and 3 locations.

Location	Temple orange	Hamlin orange	Marsh grapefruit	Mean[y]
Gainesville	18.7a[z]	18.7a	19.9b	19.1a
Leesburg	18.7a	19.1b	20.4c	19.4b
Dundee	19.8c	19.8c	21.2d	20.3c
Mean[y]	19.1a	19.2a	20.5b	

[z]Cultivar means within a given column or row not followed by the same letter are significantly different at the 5% level by Duncan's Multiple Range Test.

[y]Means not followed by the same letter are significantly different at the 5% level by Duncan's Multiple Range Test.

than from 1 week to the next. However, no significant decrease in weekly mean LFP occurred at Dundee and the weekly mean LFP of trees at Gainesville and Leesburg significantly decreased only in February. This decrease corresponded to the only weekly mean air temperatures below 55° (Fig. 1).

Table 2. Weekly mean LFP[z] and statistical comparison between sampling dates within location.

Date	Gainesville	Leesburg	Dundee
12/28/71	18.4e[y]	19.1c	19.7d
1/4/72	18.6cde	19.4abc	20.4abcd
1/11/72	19.1abcde	19.1c	20.2abcd
1/18/72	19.4abc	19.6abc	20.6abc
1/25/72	19.5ab	19.2bc	20.2abcd
2/1/72	19.7a	19.1c	20.2abcd
2/8/72	19.3abcd	20.0ab	20.3abcd
2/15/72	18.8bcde	19.6abc	19.7d
2/22/72	18.7bcde	19.4abc	20.6ab
2/29/72	19.1abcde	19.2c	20.7a
3/7/72	19.1abcde	20.0a	20.4abcd

[z]The weekly mean LFP is the mean of the LFP of 3 varieties at that location.

[y]Means within locations (columns) followed by the same letter are not significantly different at the 5% level by Duncan's Multiple Range Test.

The 11-week means of air temperatures at the 3 locations were 61.9° at Gainesville, 62.9° at Leesburg and 65.5° at Dundee. The difference in these mean air temperature was smaller between Gainesville and Leesburg than the difference between Leesburg and Dundee and was reflected by 11-week mean LFP differences of 0.3° and 0.9°, respectively (Table 1).

Table 3. Weekly and total frequency of night and daily mean air temperatures at or below 55° and 50°F.

Date	Gainesville Night 55°	Gainesville Night 50°	Gainesville Means 55°	Gainesville Means 50°	Leesburg Night 55°	Leesburg Night 50°	Leesburg Means 55°	Leesburg Means 50°	Dundee Night 55°	Dundee Night 50°	Dundee Means 55°	Dundee Means 50°
12/28/71	5	0	0	0	2	0	0	0	2	0	0	0
1/4/72	1	0	0	0	2	0	0	0	1	0	0	0
1/11/72	4	4	2	2	3	3	1	1	3	3	1	0
1/18/72	4	4	3	2	4	4	4	3	3	3	2	1
1/25/72	3	0	0	0	3	0	0	0	2	0	0	0
2/1/72	2	0	0	0	1	0	0	0	0	0	0	0
2/8/72	6	6	3	2	5	4	2	1	5	3	2	2
2/15/72	7	5	4	1	7	6	3	1	6	4	2	0
2/22/72	7	5	4	3	6	4	3	3	6	4	3	2
2/29/72	4	2	0	0	5	2	0	0	6	2	0	0
3/7/72	5	3	1	0	5	2	1	0	4	3	0	0
Total	48	29	17	10	43	25	14	9	38	22	10	5

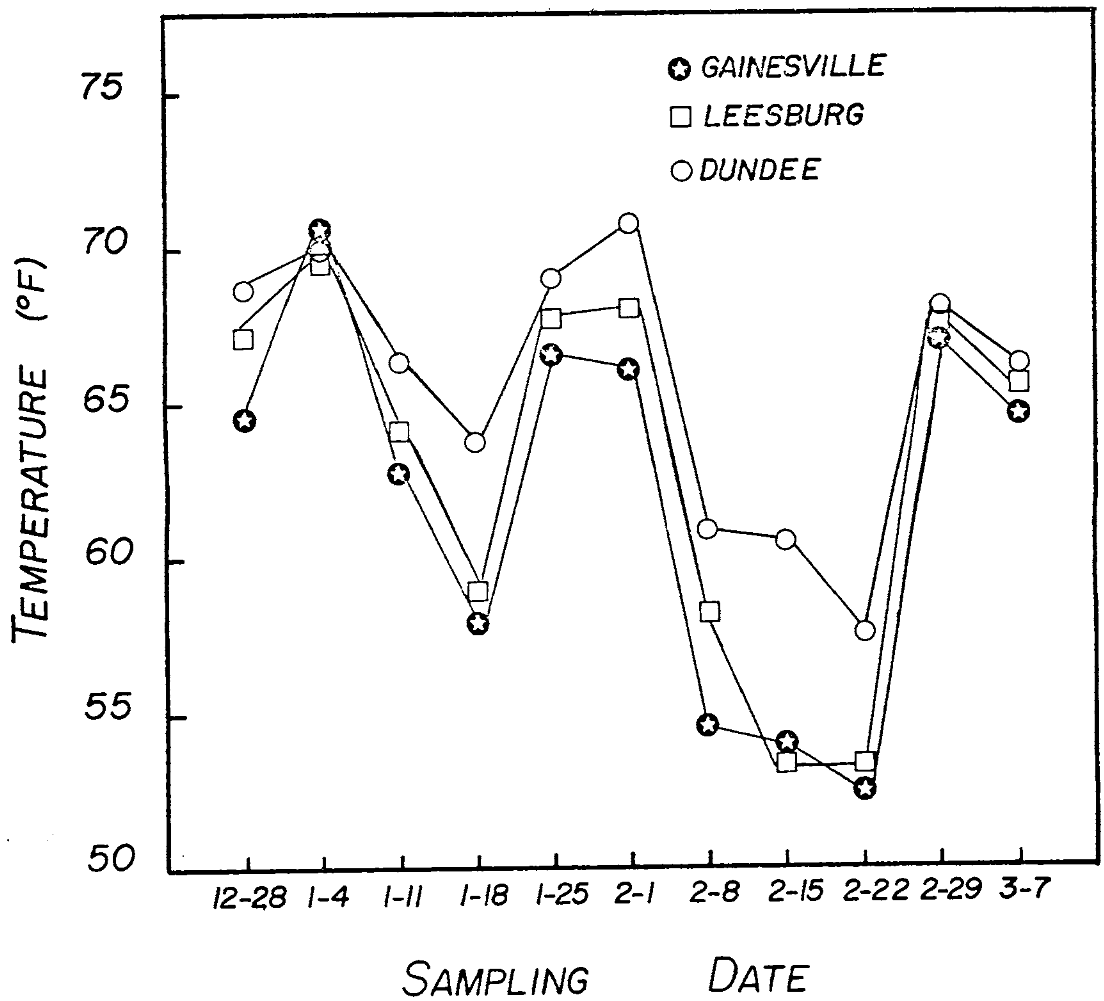

Fig. 1. Weekly mean air temperatures for 3 locations in Florida.

The number of nights that air temperature reached 55° and 50° or below at each location was tabulated (Table 3). The total number of nights air temperature reached 55° or below was 48 at Gainesville, 43 at Leesburg and 38 at Dundee, the warmest location. The number of nights air temperature reached 50° or below was 29 at Gainesville, 25 at Leesburg and 22 at Dundee. The number of times daily mean air temperatures were 55° and 50° or below at each location was also tabulated. Daily mean air temperatures at or below 55° occurred 17 times in Gainesville, 14 in Leesburg and only 10 in Dundee. Daily mean air temperatures at or below 50° occurred 10 times at Gainesville, 9 times at Leesburg and only 5 times at Dundee.

The frequency of cold temperatures at Gainesville using both minimum night and daily mean air temperatures and both threshold temperature levels indicated that hardiness could have been induced in mid-January and mid-February. However, the mean LFP values did not indicate any induced cold hardiness in January as they did in February (Table 2). This might be explained by evaluating the length and intensity of the 2 cold periods. It was for this reason that hardening-unit analysis of the environmental data was made.

Hardening units were calculated using both minimum night and daily mean air temperatures and threshold temperatures of 55° and 50° (Table 4). Using night air temperature and threshold 55° (55N), Gainesville acquired 466 hardening units, Leesburg 382 and Dundee 286. With night air temperature and threshold 50° (50N), Gainesville received 279 hardening units, Leesburg 231 and Dundee, 152. When using daily mean air temperature and threshold of 55° (55D), Gainesville had 115 hardening units, Leesburg, 86 and Dundee, 42. By using daily mean air temperature and threshold of 50° (50D), Gainesville received 49 hardening units, Leesburg, 31 and Dundee only 6.

When using hardening units or the frequency of cold hardening temperatures based on minimum night or daily mean air temperatures with both threshold levels, the hardiness-inducing temperature patterns were similar. Two low temperature periods were identified. However, hardening units indicated that slightly lower temperatures occurred in mid-January than mid-February, but for a shorter time. The possibility is presented that with unusually mild winter temperatures prior to mid-January, preconditioning of the trees did not occur. Thus the 1-week period of cool temperatures in January was not sufficient to induce measurable hardiness and lower LFP. The 3-week cool period in February was sufficient to lower the mean LFP values at Gainesville (Table 2). Further, only during the mid-February cool period did weekly mean air temperatures decrease to below 55° (Fig. 1).

Table 4. Weekly and total hardening units.[x]

Date	Gainesville				Leesburg				Dundee			
	55N	50N	55D	50D	55N	50N	55D	50D	55N	50N	55D	50D
12/28/71	9	0	0	0	2	0	0	0	2	0	0	0
1/4/72	1	0	0	0	0	0	0	0	1	0	0	0
1/11/72	57	37	12	2	38	23	8	3	30	15	4	0
1/18/72	78	58	31	18	63	43	27	11	41	26	10	3
1/25/72	6	0	0	0	3	0	0	0	6	0	0	0
2/1/72	5	0	0	0	4	0	0	0	0	0	0	0
2/8/72	83	53	25	13	70	48	9	4	49	34	11	1
2/15/72	72	40	20	5	75	42	17	2	39	17	4	0
2/22/72	99	71	26	11	82	59	26	11	65	42	13	2
2/29/72	18	5	0	0	15	4	0	0	24	6	0	0
3/7/72	39	15	3	0	30	13	0	0	29	12	0	0
Total	466	279	115	49	382	231	86	31	286	152	42	6

[x]

Hardiness Unit Calculation	Abbreviation
1. 55°F minus night minimum air temperature	55N
2. 50°F minus night minimum air temperature	50N
3. 55°F minus daily mean air temperature	55D
4. 50°F minus daily mean air temperature	50D

Statistical comparisons were made of cultivar means without regard to location (Table 1). These comparisons showed 'Temple' orange acquired similar hardiness to 'Hamlin' orange as no significant difference was found between the LFP of these cultivar means. This is not in agreement with previously published observational data (3, 5) which ranks 'Temple' orange as less cold hardy than 'Hamlin' orange. Rootstocks may be the reason for part of this disagreement. However, it is in agreement with previously reported leaf-freezing points (7) which indicated that the difference in cold hardiness of 'Temple' and 'Hamlin' orange may not be as great as previously reported from observational data. Significant differences in cultivar mean LFP were present between 'Temple' orange and 'Marsh' grapefruit, and between 'Hamlin' orange and 'Marsh' grapefruit. In both comparisons 'Marsh' grapefruit was definitely less cold hardy as measured by leaf-freezing points.

The LFP of 'Temple' and 'Hamlin' orange were not significantly different at the Gainesville or Dundee location, but were significantly different at Leesburg. LFP of 'Marsh' grapefruit during the period studied were consistently higher than the other citrus varieties within each location. This agrees with published observational and previous leaf-freezing point data on variety cold hardiness. Although LFP of 'Temple' and 'Hamlin' orange at Gainesville and Dundee were not significantly different within a given location, the LFP of 'Temple' and 'Hamlin' orange at Gainesville were significantly lower than LFP of 'Temple' and 'Hamlin' orange, respectively, at Dundee. This was expected because Gainesville received more hardiness-inducing temperatures than Dundee. At Leesburg the LFP value for 'Temple' orange was significantly lower than the LFP value for 'Hamlin' orange. The reasons for this were not apparent from this or previously published data. During this study LFP values of 'Hamlin' orange at Gainesville were significantly lower than those at Leesburg, which were significantly lower than those at Dundee.

It is concluded that both frequency of low temperatures and hardening units with both 55° and 50° threshold can be used to identify periods when citrus cold hardiness will be acquired. Therefore, for future studies the available weather data of minimum night or daily mean air temperatures can be used to determine when sufficient cold temperatures have occurred to induce cold hardiness in citrus. The lack of hardiness-inducing temperatures during this study did not permit adequate comparison of the 2 threshold temperatures. Under conditions of a more typical Florida winter identification of cold-hardiness inducing periods might be better defined by one or the other threshold temperature. In this study the accepted threshold temperature of 55° was found satisfactory. Although 'Temple' orange is considered to be a less cold hardy variety than 'Hamlin' orange by published observational data, this and other research with leaf-freezing points indicates that 'Temple' and 'Hamlin' orange can acquire similar degrees of hardiness if adequate pre-conditioning temperatures are experienced. Citrus cold hardening temperatures of 55° and 50° occurred more frequently at Gainesville, least frequently at Dundee, and with intermediate frequency at Leesburg. The LFP values increased in a highly significant manner as hardiness-inducing temperatures decreased from Gainesville to Dundee.

Literature Cited

1. Cooper, W. C. 1959. Cold hardiness in citrus as related to dormancy. **Proc. Fla. State Hort. Soc.** 72:61-66.
2. Cooper, W. C., B. S. Gordon and S. D. Tayloe. 1954. Freezing tests with small trees and detached leaves of grapefruit. **Proc. Amer. Soc. Hort. Sci.** 63:167-172.
3. ————, Jack Hearn, Gordon K. Rasmussen, and Roger H. Young. 1963. The Florida freeze. **Calif. Citrograph.** 48:217-220.
4. Gerber, J. F. and F. Hashemi. 1965. The freezing point of citrus leaves. **Proc. Amer. Soc. Hort. Sci.** 86:220-225.
5. Hearn, C. J., **et al.** 1963. Influence of variety and rootstock upon freeze injury to citrus trees in the 1962 Florida freeze. **Proc. Fla. State Hort. Soc.** 76:75-81.
6. Hendershott, C. H. 1962. The responses of orange trees and fruits to freezing temperatures. **Proc. Amer. Soc. Hort. Sci.** 86:244-252.
7. Hutcheson, C. E. 1970. Leaf freezing points and cold hardiness of citrus. Master's Thesis. Univ. of Fla., Gainesville.
8. ————, and W. J. Wiltbank. 1970. Cold hardiness of selected citrus varieties as determined by freezing detached leaves. **Fla. State Hort. Soc.** 83:95-98.
9. ————, and ————. 1972. The freezing point of detached leaves as a measure of cold hardiness of young budded citrus plants. **HortScience.** 7(1):27-28.
10. Jackson, L. K. and J. F. Gerber. 1963. Cold tolerance and freezing point of citrus seedlings. **Proc. Fla. State Hort. Soc.** 76:70-74.
11. Lindsey, R. J. 1971. Environment and citrus cold hardiness. Master's Thesis. Univ. of Fla., Gainesville.
12. McCown, J. T. 1958. Field observations of Florida citrus following the 1957-58 freezes. **Proc. Fla. State Hort. Soc.** 71:152-157.
13. Sites, J. W. 1960. Preconditioning of plants in relation to cold tolerance. Fla. Agr. Exp. Sta. Ann. Rept. 1960: 120.
14. Young, Roger. 1969. Cold hardening in citrus seedlings as related to artificial hardening conditions. **J. Amer. Soc. Hort. Sci.** 94(6):612-614.
15. Young, R. H., and A. Peynado. 1961. Effects of artificial freezing on Red Blush grapefruit. **J. Rio Grande Valley Hort. Soc.** 15:68-74.
16. ————, and A. Peynado. 1962. Growth and cold hardiness of citrus and related species when exposed to different night temperatures. **Proc. Amer. Soc. Hort. Sci.** 81:238-243.

LIGHTNING AND DECLINE OF CITRUS TREES IN FLORIDA GROVES

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Abstract. **Each year lightning either directly or indirectly causes considerable tree loss in Florida citrus groves. One to many trees may be affected by one or more lightning strikes in any grove at one time. The number of trees affected by one strike depends on the size of the discharge area and the planting distance of the trees. The largest number of trees known to have been killed by lightning during one storm was 1,177 trees in 90 acres of a flatwoods grove. Usually, 1 or 2 trees may be killed when the strike occurs and others will be affected to a lesser degree progressing from the center of the strike to the periphery of the discharge area. Frequently, some of the more severely affected trees near the center of the strike area decline gradually and die from what appears to be root rot, heart rot, or foot rot within 1 to 3 years after the strike. The less affected trees on the periphery of the discharge area generally do not decline or die. The secondary effects of lightning strikes on citrus trees may have the appearance of a disease spreading through the grove. The symptoms of lightning injury differ from those of rough lemon decline and other declines; but when lightning injury is superimposed on some other condition, the causes of the decline and loss of trees may be obscure.**

Lightning is a spectacular and frequent phenomenon in citrus groves of Florida. Some of the effects of lightning on citrus trees were

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