Lightning--A Predator of Citrus Trees in Florida[1]

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INTRODUCTION

LIGHTNING is a spectacular and integral part of the environment in citrus groves of Florida. The potential for lightning in Florida is great because atmospheric conditions are virtually ideal for convection type thunderstorm formation. Such thunderstorms are very common and frequently produce great amounts of lightning activity.

Much of Florida was once covered with relatively open pine forests. Since 1900, extensive segments of these pine forests, as well as oak hammocks, have been replaced with modern forests of citrus. These new forests are unique in that they constitute pure stands of fruit trees covering thousands of hectares artificially maintained by man.

The remnants of the once vast, open pine forests are lightning-fire oriented ecosystems that depend on the regular occurrence of fires for their existence. Lightning-ignited fires still occur frequently

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in these forests but in the adjacent citrus groves of similar magnitude there are no fires. The absence of lightning-ignited fires in citrus groves does not indicate that thunderstorms do not occur there. Summer convection thunderstorms take place just as frequently over citrus groves as over adjacent pine forests. Lightning discharges also occur with equal frequency over citrus groves and pine woods. Like pine trees, citrus trees become the ground terminals for lightning discharges.

Lightning injury to citrus trees was identified and described first by Stevens in 1918 (Stevens 1918a). Since then lightning has been recognized as being a destructive agent in citrus groves and is the cause of considerable tree loss (Stevens, 1918b, Waldron, 1923, and Rhoads and DeBusk, 1931). In grove surveys to determine the kinds of citrus decline and extent of tree loss, it was found that 4.4 percent of the groves inspected had suffered damage caused by lightning (Suit and DuCharme, 1947). Each year lightning strikes more citrus trees and continues to be the cause of more tree loss than is generally recognized or even suspected (DuCharme and Suit, 1964, and DuCharme, 1972).

Effects of lightning strikes on citrus trees is usually clearly defined but frequently the injury may not be readily apparent. Not all trees in a strike area have visible symptoms of having been struck and the consequences of the obscure injuries are slow to appear. Such trees decline and die long after the strike has occurred. Then the most recent problem involving citrus trees or perhaps the use of a new pesticide, herbicide, or even fertilizer materials may be blamed for the decline condition. It is also commonplace to have lightning injury confused with the decline and loss of trees caused by known factors. Because this confusion can and does occur, it was considered appropriate to assemble and bring up-to-date data and information on the kinds, extent, and importance of lightning injury to citrus.

CHARACTERISTICS OF LIGHTNING INJURY ON CITRUS

Lightning strikes on citrus are not characterized by explosive violence as often happens when lightning strikes other kinds of trees.

There is no obvious mechanical damage to citrus at the time of the strike and no fires are started. Branches are not wrenched from the struck trees and bark is not explosively torn from the trunk and branches by the forces associated with lightning strikes.

There are two types of effects on citrus trees struck by lightning. There is immediate damage and sequence of visible symptoms within 30 days of the strike, and secondary effects that appear 1 to 3 years after the strike has occurred.

Usually, the first symptom that becomes evident after a strike is wilting of tender branch terminals and foliage. Wilting may start within 4 hours after a strike. A few days after the discharge, leaves of severely injured branches, as well as entire trees, become permanently wilted and leaves start to turn yellow. This is followed by abscission between the leaf blade and the winged petiole and defoliation begins. Petioles may remain attached to the slender stems for a few days but eventually drop. Death and drying of the foliage may be so rapid at times that the leaves curl, turn brown, and remain attached for several weeks before being shed. Such trees superficially appear to have been damaged by fire or cold. These foliar symptoms may occur on all or part of the tree depending upon how much of the tree was injured.

One of the most characteristic symptoms to appear on trees struck by lightning is the injury to young green terminal shoots and twigs. Small round to large irregularly shaped patches of green bark between the leaf nodes are killed and become tannish gray to brown but the bark surrounding the buds, leaf bases, and thorns apparently is not damaged and remains green, Figure 1. These irregular shaped patches of injured bark may girdle the small stems or twigs, coalesce into larger areas, but the buds and thorns remain green and isolated by brown, dead bark. Leaves also remain green and appear to be healthy on such injured stem tips. Frequently drops of gum collect on the surface of the dead bark.

The green bud surrounded by dead bark is a transitory symptom and appears only on the small green twigs or shoots where the discharge occurred. This symptom develops 7 to 10 days after the strike and is visible for only a few weeks. Then the green buds and

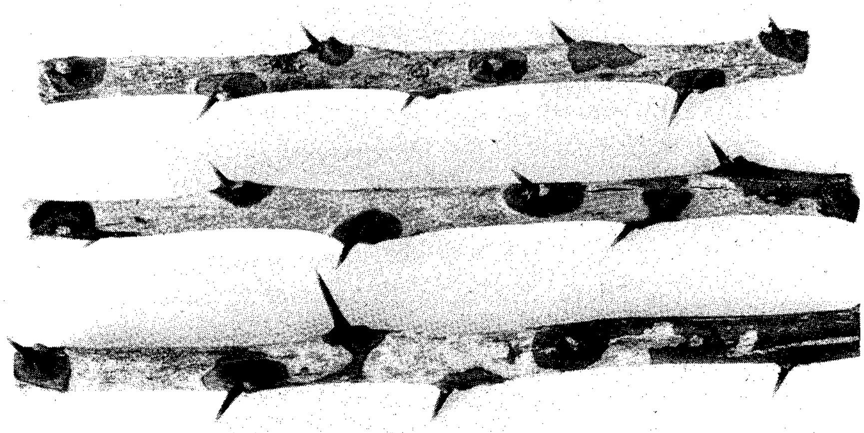

FIG. 1. Lightning injury to citrus twigs showing the killed tender bark and green undamaged bark around leaf bases, buds, and thorns.

adjacent bark gradually fade to gray-brown as the injured stems die. Leaves also die, turn brown, and remain attached for a few weeks before falling. On trees slightly affected by a lightning strike, there may be only one or two terminal twigs killed and these stand out in sharp contrast to the normal green foliage.

This "green-bud-island" symptom has not been observed on trees affected by any other disorder and is considered specific for lightning injury. Damaged terminals most commonly occur at the top of the trees but may be observed at any place on the canopy, especially on stem terminals in contact with the soil or herbaceous cover crop.

Patches of bark may be killed on the trunk, main scaffold, and small branches in the pathway of the discharge. Occasionally, a continuous strip of bark or all of the bark on the trunk and one or more main branches will be killed from below the soil surface to the top of the tree. Within a few days, the injured bark develops a water-soaked appearance and becomes somewhat darker than the adjacent bark. Sometimes inconspicuous narrow slits may be observed in damaged or killed bark on large branches, trunk, and crown roots 7 to 10 days after the strike. Wood and inner bark in the affected areas becomes somewhat yellow and gum may begin to accumulate between the wood and inner bark. Severely injured bark is softened and gradually becomes granular as it dries and blackens. Killed bark blackens, crumbles readily when rubbed, splits longitudinally as the disintegration and drying proceeds, separates from the wood, and often falls from the trunk. The size of the dead patches and amount of bark killed in struck trees varies with intensity of the discharge. Patches of dead bark on trees not killed by the stroke become points of entry for wood rot organisms.

Injured bark and wood become points of entry for several species of Scolytids such as "shot hole borers" and flatheaded borers. Shot hole borers usually enter killed tissues on branches and trunks within 8 to 10 days after the strike has occurred; but if penetration takes place, a few days after the strike a small drop of gum will accumulate on the surface of the bark over the entrance hole. Areas of bark and wood killed by the discharge are detected frequently by slender cylinders of white to gray wood detritus protruding from the small holes made by shot hole borers as they penetrate. These slender columns of detritus are approximately 1/16 inch in diameter and up to 1/2 inch long. A flatheaded borer, *Chrysobothris chryseola*, commonly invades and feeds only on dead inner bark, phloem, and cambium.

Roots of trees struck by lightning may be killed, severely damaged, or not affected, depending upon the intensity of the discharge. If damage is severe, death of roots is immediate and bark decay and disintegration take place rapidly. Bark on killed roots soon becomes soft, water-soaked, turns brown and granular, and finally black. If the discharge strike is relatively mild and only weakens the tree, root rot develops slowly and such trees may die of root rot 1 to 3 years later.

Another symptom frequently observed on trees struck by lightning is a band of injured bark 1 to 2 inches wide just under the soil surface. This band of dead bark is often present even though no other bark damage can be detected on the tree or trees struck in the discharge area. This narrow band of killed bark may be made up of a series of small areas on one side of the tree or may completely girdle the trunk as a continuous band of dead bark. If the damage is not extensive or too severe, new wood and bark may be regenerated, covering the wounds, and the trees recover. Exposed wood may also become infected by wood invading fungi such as *Fomes* spp. and *Ganoderma* spp. which cause further trunk destruction. Trees in later stages of lightning induced trunk decay might be erroneously diagnosed as a tree decline initially caused by wood rot and foot rot organisms.

The secondary effects on lightning struck trees become evident 1 to 3 years after the discharge occurred. Trees only mildly affected by a discharge may be only weakened and predisposed to secondary

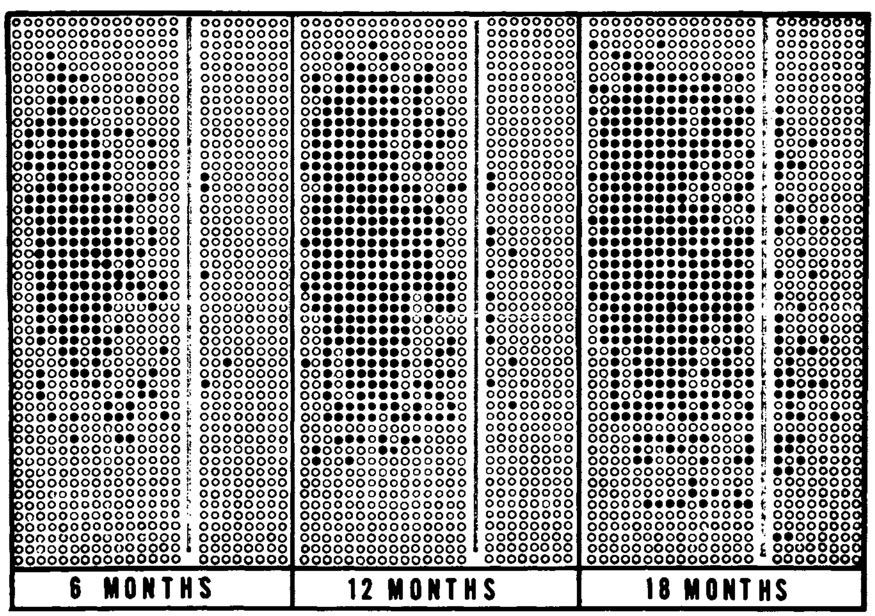

FIG. 2. Loss and decline of citrus trees in a lightning discharge area 6, 12, and 18 months after the lightning activity occurred.

infection by bark, wood, and root rot fungi. Growth of trees slows and in time the trees remain somewhat stunted and when under stress wilt sooner than healthy trees. Eventually, foliage becomes chlorotic as the root system deteriorates. These trees decline and die, first near the center of the strike, then progressively towards the periphery of the discharge area. Decline and loss of trees in such areas may continue for 1 to 3 years and could be interpreted as a disease spreading in the grove.

Not all trees in a strike area are visibly damaged. Some are only slightly injured and suffer little or no permanent damage and some might have no external indictions of having been struck. Such trees are not noticed until they decline. In two blocks of a grove, 39 and 19 trees were classified as dead, severely injured, or only had twig symptoms 6 weeks after a strike. Six months later 124 and 119 trees respectively were removed from these blocks because they were either dead or in advanced stages of decline (Table 1, blocks 55 and 56).

In another grove of 350 trees, 2 years old, 2.02 hectares (5 acres) were struck during one thunderstorm and every tree had at least one terminal with symptoms typical of lightning injury. No trees were killed at the time and none were reported to have died during the following 10 years. Some trees recover and may be struck again at some later date. It is, therefore, possible that lightning could strike the same tree or trees more than once.

NUMBER OF TREES STRUCK

The number of trees struck by one lightning bolt depends on the size of the discharge area and the tree spacing. The number of trees recognized as struck by lightning in a grove during one storm has ranged from 1 to 3,225 (Table 1). Usually less than 20 trees are affected in discrete discharge areas with only one to three trees killed and the others damaged. Strike areas in a grove may range from one to several, depending on frequency and intensity of lightning discharges (Fig. 3).

The area of known lightning discharge sites has varied from one young tree space, an area less than 3 meters square, to as much as

TABLE 1. NUMBER OF TREES, 4 YEARS OLD, KILLED OR VISIBLY INJURED BY LIGHTNING IN 13 BLOCKS OF A FLATSWOODS TYPE GROVE DURING A STORM IN MID-AUGUST, 1972

	3 weeks after storm	6 weeks after storm			6 months after storm		
Block No.	Dead or severe injury	Dead or severe injury	Twig injury	Total affected	Pulled	Percent loss	Total trees in block
50	447	487	191	678	535	59.4	900
51	128	279	307	586	171	19.0	900
52	0	1	2	3	0	0.0	900
53	1	1	0	1	33	3.6	900
54	46	70	113	183	115	12.7	900
55	15	23	16	39	124	13.7	900
56	19	8	11	19	119	12.2	973
57	83	83	104	187	174	15.8	1,100
58	218	218	110	328	311	34.2	909
59	165	225	80	305	232	25.7	900
60	58	100	53	153	71	7.8	900
61	144	203	105	308	158	17.5	900
62	225	309	156	465	284	31.5	900
Total	1,549	2,006	1,249	3,255	2,327	19.4	11,982

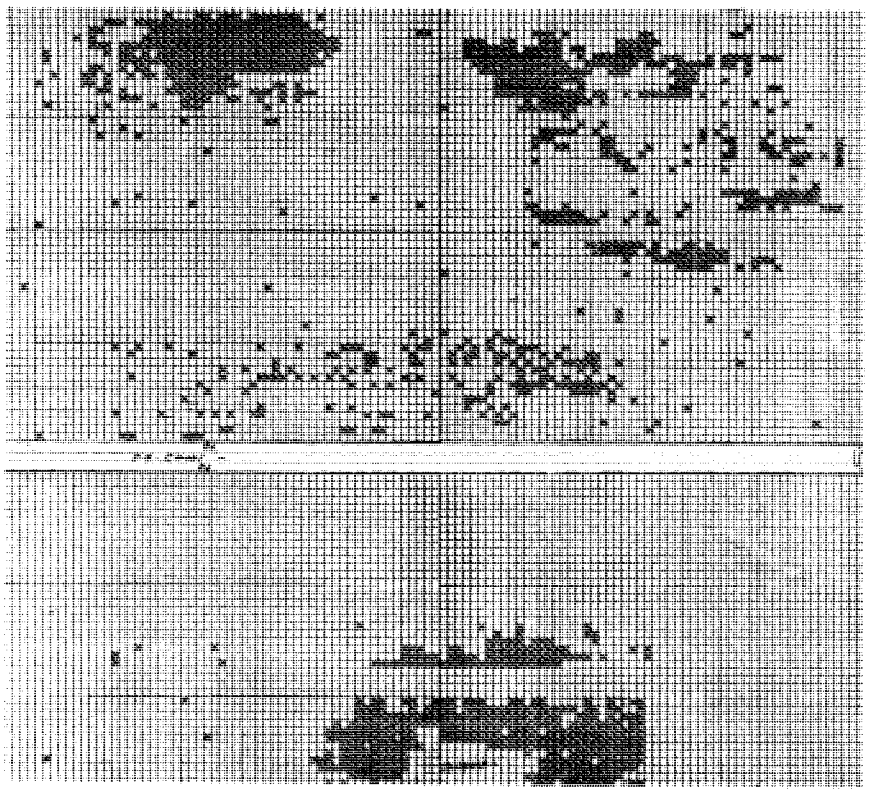

FIG. 3. Trees killed in four lightning discharge or cluster strike areas in 36.5 hectares (90 acres) of a citrus grove 7 years old in a flatwoods area during one storm, August, 1971.

10.6 hectares (26 acres) (Table 2). Measurements of discharge areas are possible because of regular spacing of trees and blocks of trees in citrus groves and visible symptoms of the trees struck. The largest single discharge area recognized in a citrus grove was 458 meters long by 298 meters wide (Table 2). Another larger strike area seemed to involve two continguous strike areas that overlapped one another and involved 24.2 hectares (60 acres), a superficial area 550 meters by 458 meters (1,840 feet by 1,500 feet). There were 5,500

TABLE 2. DIMENSIONS AND SURFACE AREA OF 10 LIGHTNING CLUSTER STRIKES OR DISCHARGE AREA IN CITRUS GROVES OF FLORIDA.

	Meters			Equivalent	Location
	Length	Width	Hectares	acres	
1	206	176	2.8	6.9	Flatwoods
2	320	229	5.7	14.1	"
3	330	145	3.7	9.1	"
4	200	176	2.7	6.6	"
5	458	176	8.1	20.0	"
6	458	199	9.1	22.5	"
7	458	298	10.6	26.0	"
8	458	214	9.8	24.2	"
9	69	58	.25	.6	Sand Ridge
10	183	106	1.5	3.7	" "

trees planted in this area and of these 1,230 were pulled within 6 months after the strikes occurred.

The greatest tree loss and tree injury occurred in one grove from lightning activity generated by one August thunderstorm which involved 52.5 hectares (130 acres) in 13 contiguous 4.04 hectare (10 acres) blocks of 900 trees each, Table 1. Three weeks after the storm, 1,549 trees were dead or severely injured and after 6 weeks 2,006 trees were dead or in decline and 1,249 had twig symptoms, Table 1. Six months after the strikes, 2,327 trees were pulled from the affected blocks. According to the grouping of trees killed or injured, there were at least four principal discharge areas. In addition, affected trees were observed in other blocks of trees adjacent to the 13 blocks where most of the damage occurred.

SHAPE OF DISCHARGE AREAS

The shape of discharge areas, as reflected by distribution of killed and injured trees, has been variable but the usual shape of a strike area has been either an irregular circle or oval to somewhat pear shaped. Occasionally, the area involved has been almost lenticular. A large and unusual distribution of injured trees, in a strike area suggestive of damage caused by a "cluster strike" or several strikes

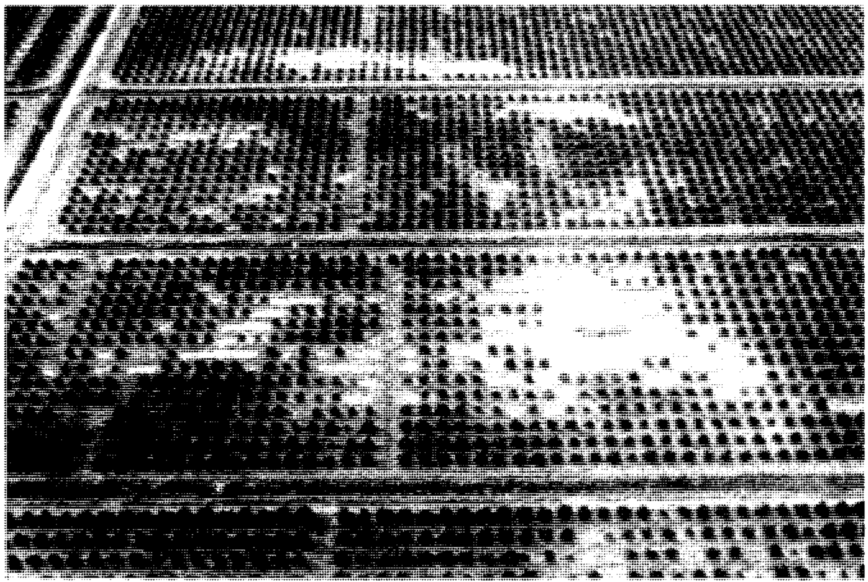

FIG. 4. A lightning discharge area in a flatwoods grove of trees 7 years old. The strike or strikes took place during a storm, August 7, 1971, and the photograph was taken November 23, 1971 after some of the affected trees had been pulled.

in one discharge area, occurred in a flatwoods grove of citrus trees, 7 years old (Fig. 4).

Citrus tree damage due to lightning strikes has been observed in all areas of Florida where citrus is grown. It is difficult to determine where most lightning injury to citrus has occurred because not all strikes are detected and only relatively few are reported. Groves where large discharge areas have occurred recently are mostly in flatwoods groves in the southwestern quadrant of the state. Smaller strike areas involving 1 to 20 trees are typical of strikes in the sandhill ridge area of central Florida.

Trees along roads, wide middles, and borders of groves next to open areas seem to be hit more frequently than those in the interior of groves. Perhaps this is only apparently so because these trees are seen most frequently. Trees seem to be struck with equal frequency on hillsides as well as on the crest of hills.

Trees struck are not necessarily the tallest ones in the grove. Citrus trees in a given grove are approximately the same size. Modern cultural practices of hedging and topping currently in use maintain all trees in a given grove or block of trees to the same conformity and height.

TIME AND PERIODICITY OF LIGHTNING STRIKES

Lightning may occur at any time during the day as well as during the year. Commonly, citrus trees have been struck more frequently during the afternoon and evening, from June through October, than at other times. Peak activity, especially for strikes affecting large numbers of trees, has been from mid-July through mid-September. Five unusually large strikes recorded occurred in August.

Lightning strikes in citrus groves seem to occur more frequently in some years than in others but a cyclic pattern has not been demonstrated because of limited data. Not all strikes are detected and only a few are reported. Komarek (1967) observed that there seems to be a 2 to 3-year cycle between periods of increased frequency. This observation might be supported with observations from strikes in citrus groves. There have been more strikes in citrus groves reported during the summer of 1970, 1971, and 1972 than from 1966 to 1969.

Depth of the root system does not seem to be a determining factor as to whether a tree will be struck. Trees 1 meter tall become terminals for lightning strikes as well as trees 12 meters tall. There may be a possible relationship between the depth of rooting and the number of trees affected in a discharge area. Conditions in the flatwoods-type groves where root systems are shallow, soil layer is thin, and trees closely spaced may be conducive to horizontal diffusion of the ground terminal and account for large discharge areas in these groves. On the deep-sand, central ridge, deep rooted trees may function as more efficient ground terminals and thus result in smaller strike areas.

Lightning is an important factor in the ecology and agriculture of citrus trees and groves of Florida. This importance is directly related to tree loss and tree health but not to fires or a fire oriented grove ecology. Lightning ignited fires from citrus trees have not been a factor in the artificially maintained environment in citrus groves.

Lightning injury to citrus trees is perhaps a much more important precursor of tree diseases than has been generally realized. Not all symptoms associated with struck trees necessarily occur on any one tree in a strike area. Likewise, not all trees struck are killed outright or decline immediately and die within a few months. Not all trees in a discharge area show outward signs of having been affected by the strike. Many trees in the discharge area slowly decline and ostensibly die from root rot, foot rot, and heart rot. In these cases, the wood rot is secondary and not the initial cause of the tree mortality.

Although there are no precise data available, there are virtually thousands of citrus trees that are directly killed or indirectly die from secondary causes following unrecognized lightning injury. It is common knowledge that there is a constant mortality of trees in citrus groves. Some of these losses, though unexplained, are considered normal regardless of cause. When lightning and some disease simultaneously affect trees in either a block or a grove of trees, decline and death of trees can be devastating and the cause or causes of decline might not be readily apparent and separable.

There seems to be no way to avoid lightning damage in citrus other than possibly equipping each with a lightning rod. It can be expected that lightning will continue to cause substantial tree losses annually. Some years there will be more damage than in other years. Lightning constitutes an integral component of climatic factors in Florida citrus groves and there seems to be no prospect that these losses will diminish in the future, especially in flatwoods areas. In a manner of speaking, lightning is a natural predator and a recurring phenomenon constantly taking its toll of citrus trees in Florida groves.

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