A Resource for the State of Florida

HURRICANE LOSS REDUCTION
FOR
HOUSING IN FLORIDA:

Section 7

Effects of Pruning on Trunk Movement in Wind

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Introduction

This study was conducted at the University of Florida by Dr. Ed Gilman in coordination with Dr. Forrest Masters from the International Hurricane Research Center (IHRC) at Florida International University. The goal was to determine how different pruning techniques effect trunk movement on 20 ft. live oaks. The three pruning treatments studied were thinning, reducing, and raising of the canopies. There were five replications of each treatment, including the control with no pruning, for a total of 20 trees tested. The trees were blown by a wind generator with a maximum wind speed up to 120 mph, maintained for three minutes. Each tree was instrumented with three Microstrain 3DM-GX1 orientation sensors at set heights along the trunk to measure its deflection in all three axes. A significant difference in trunk movement between the control and the three pruning treatments was observed. This implies that pruning trees reduces trunk movement, and thus reduces the risk of tree failure under high wind speeds.

Objectives

The objective of the study was to determine how tree trunk movement is impacted by applying different pruning treatments to the canopy. More specifically, the objectives were to: (1) Determine the amount of total trunk deflection for each pruning treatment and (2) Compare how different pruning techniques impact trunk movement.

Background

This experiment was the first of its kind using a wind generator powerful enough to simulate hurricane force winds and trees of this magnitude in an attempt to study pruning treatment impact on trunk movement. The experiment was conducted at the Environmental Horticulture Teaching Lab at the University of Florida in May of 2006. The trees that were tested were *Quercus virginiana* 'Cathedral' cultivar and were 5 years of age and 5 inches in caliper (Fig. 1). This species was selected because it is a commonly used tree in urban landscapes and because the trees were clones that were propagated from cuttings. The dose of each pruning treatment applied to each tree, i.e. the amount of foliage removed, was 33% of the total canopy. This amount was chosen because it is above and beyond the ANSI A300 pruning standard of 25% for the maximum amount of foliage that should be removed from a tree in any one growing season. The three pruning treatments and the control are as follows:

- **Thinning**: Foliage was removed from throughout the canopy and was added up until the diameters reached 1/3 of the total canopy.
- **Reducing**: Foliage was removed from the top of the canopy down until 1/3 of the total canopy was removed.
- **Raising**: Foliage was removed from the bottom of the canopy upwards until 1/3 of the total canopy was removed.
- **Control**: No pruning.

Materials and Methods

In order to accurately remove 33% of the foliage from each tree, a relationship had to be determined between branch height and diameter and its foliar weight. This relationship was calculated by dissecting three trees, measuring the height and amount of foliar weight of each branch along the length of the trunk. Five branches were selected at random from the bottom, middle, and top third of the canopy. The branches were then placed on a grid and pruned in increments of 15%, 25%, 33%, and 40%. The amount of foliage removed each time was weighed, as was the remaining foliage. A curve relating branch diameter to foliar weight could then be created to determine the amount of branches necessary to remove the desired percentage of foliage (Fig. 2). Dissecting the three trees gave the total foliar weight of the canopies from which an average was calculated. Once the total weight of the canopy's foliage was determined, the amount of foliage necessary to remove 33% could then be calculated. In the field, the trees were pruned one branch at a time and the diameter of the pruned branch was recorded. Branches were pruned one by one and their squared diameters were added up. Pruning stopped once the sum of the squared diameters reached the point on the curve that was equal to the desired foliage weight to be removed. There were five total blocks in the experiment, and each block contained one replication of the three pruning techniques plus the control. Pruning treatments were randomly assigned to the twenty trees in the plot.

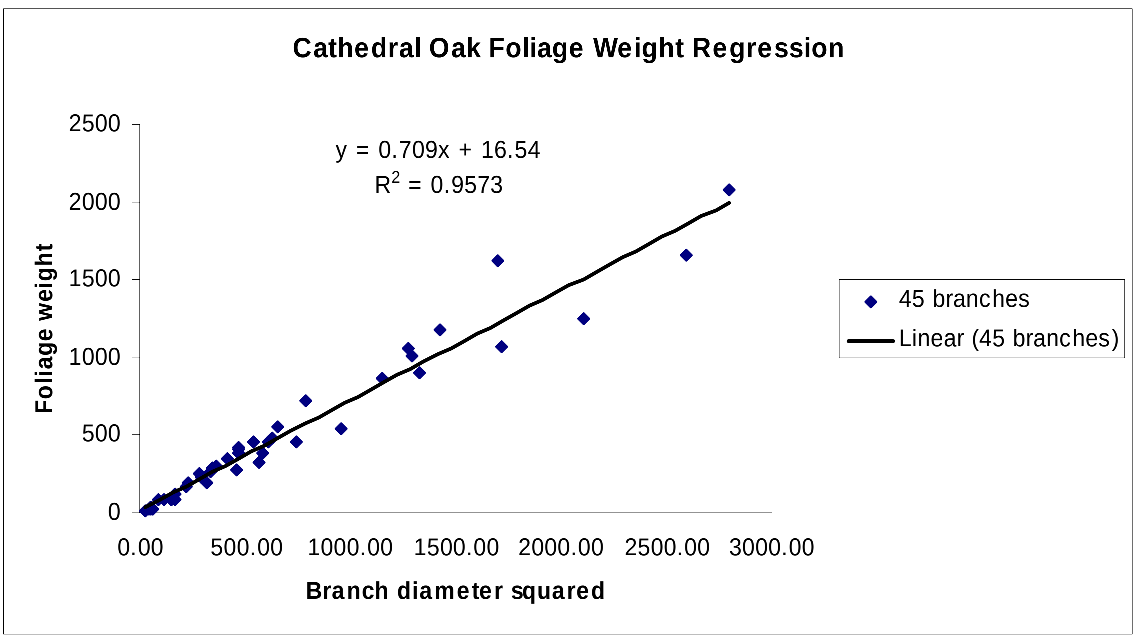

Fig. 2

The soil was brought to field capacity within a 10 ft. diameter circle beneath each tree so that the soil conditions would be the same for each tree tested. This was done by calculating the amount of water required to bring such a volume of soil to field capacity (384 gal.) and then applying that amount of water prior to testing each tree. A period of six hours had passed between the time the irrigation stopped to the time the trees were tested. This allowed the water to percolate into the inter-pore space of the soil and thus bringing it to field capacity.

Orientation sensors were used to measure trunk deflection (Fig. 3). The three orientation sensors were mounted at the same three fixed points along the trunk of every tree. The highest mounting position was at 104 in. from ground level. The second highest mounting position was at 72 in. at the average center of mass, which was calculated by using the data collected from the three dissections. The lowest was at 42 in. above ground level. The data collected from these three points enabled a curve to be constructed, simulating the bend in the trunk of the tree, when subjected to high wind speeds (see Appendix).

The wind generator was designed and manufactured by Diamondback Airboats, Inc. It is comprised of a two-fan array mounted to a trailer for mobility. Driving each fan is a Chevrolet ZZ402 big block engine housed in an outer steel frame. Wind is generated by means of two 80 inch counter-rotating airboat propellers mounted to each engine.

Each tree was subjected to the same wind loading sequence of a constantly increasing wind speed until the target top wind speed of 120 mph was reached. The sequence was applied to each tree by computer software that monitored and controlled wind speed by controlling the throttles on the wind machine remotely. This allowed each tree to be subjected to the exact same test procedure in order to isolate the effect the pruning technique had on trunk movement.

A wind tunnel was constructed to create a more uniform flow from the wind generator and to lessen the effects of diffusion (Fig. 4). The tunnel also blocked out external winds which could have influenced the upwind flow field. The wind tunnel was 12 ft. in length and 12 ft. high, and was placed so that it was 5 ft. from the trunk of the tree being tested. Wind speeds were recorded using a RM Young wind monitor. Behind the tree being tested was a wind deflector which was used to protect the next tree in line to be tested.

Results

At 110 mph, the average maximum angle of deflection for the topmost inclinometer on the unpruned trees was 45.8°. As expected, the control trees with no foliage removed had the greatest amount of trunk deflection. This was the anticipated result because it was assumed that the trees with the biggest canopies, and thus the largest exposed frontal area, would catch the most wind and cause the trees to bend over the most. Of all the twenty trees tested, the one that had the most trunk deflection was a control tree that bent over 64.2° from its original position (Fig. 5).

The trees that were raised showed the second most trunk deflection with the average maximum reading from the top inclinometer of 30.8°. The thinned trees showed the third most deflection having an average maximum angle of 23.1°. Lastly, the reduced trees showed the least amount of deflection with an average maximum angle of 16.9°. A summary of the data is shown in the table below:

Control	45.8°	A
Raised	30.78°	A B
Thinned	23.14°	B C
Reduced	16.86°	C
Treatments denoted with the same letter are not significantly different.		

Foliage lost as a result of the wind occurred with all three treatments including the control, however the raised trees appeared to have had the least amount of leaf loss. The thinned trees had more damage from limbs rubbing against each other than any other treatment. There were very few branches that broke between the treatments, the amount being consistent among all treatments and the control.

Conclusions

Pruning trees reduces trunk and canopy movement which, in turn, reduces the risk of damage to trees at high wind speeds. Removing foliage from the canopy of a tree increases its porosity and the method in which the foliage is removed is directly related to how the sail area will react to wind loading.

The raising and reducing techniques are similar in that they concentrate the remaining foliage of the canopy into a smaller area than before the tree was pruned. However, the data shows that trees pruned in these two way will react to wind loading much differently. The raised trees had their canopies concentrated at the top of the trunk, giving them a longer moment arm. The reduced trees' canopies were concentrated at the lower region of the trunk, giving them a shorter moment arm. This key difference is why the raised trees bent over, on average, almost twice as much as the reduced trees.

It should be noted that the extent of deflection for the raised trees could have been larger than what was encountered in testing. The reason for this is that the wind generator's wind field extended 16 ft. above ground level, and the raised trees stood at nearly 23 ft. so their canopies were not entirely within the wind field (although deflection under loading lowered the heights of the tree to 20 ft). Despite this limitation, the trees still responded to wind loading in a predictable manner. The control and thinned trees' canopies were also not completely within the wind field prior to testing, however once the wind began to blow the trees, it caused them to reconfigure their branches and bend over. Once bent over, the trees were within the wind field. Even if the wind field were tall enough to encompass every tree's canopy, it is assumed that the results would be very similar to the results of this experiment and thus it was determined that these differences are negligible.

The thinned trees, with 33% of their foliage removed, bent over almost half as much as the control trees. Thinning a tree does not reduce the frontal area of a canopy to the extent of the other two treatments, however it does reduce its porosity. Interestingly, reducing the canopy by a third reduced trunk deflection by a half. The difference in trunk deflection between the thinned and reduced trees was not statistically significant, nor was the difference between the control and the raised trees.

The damage inflicted on the thinned trees was primarily due to branches rubbing against each other. This phenomenon was not encountered with the raised or reduced trees to the extent it was with the thinned trees. The reason for this is that a tree's canopy acts as a buffer to dampen the force of the wind. When the canopy was pruned, the canopy's ability to dampen the wind force was reduced, thus allowing the branches to move around more. The increased movement of the branches within the canopy allowed the branches to rub against each other to the point of bark removal at the site of the rubbing.

In conclusion, pruning trees minimizes canopy movement, thus reducing the risk of tree failure during high wind speeds. Trunk movement was minimized with the thinning and reducing treatments. More research is warranted in this area of research, including the testing of different species, different pruning doses, and testing the effect of wind speeds for different durations.

Fig. 1

Fig. 3

Fig. 4

Fig. 5

Test Num	Tree		Height (in)	Before Roll	Before Pitch	Before Yaw	Peak Min Roll	Peak Max Roll	Peak Pitch	Peak Min Yaw	Peak Max Yaw	After Roll	After Pitch	After Yaw	Sensor Number
1	Tree 29	Top	106.5	-1	-1	56.8	-2.6	2.3	-28.8	49.0	57.9	1	-4	55.6	2675
	Thinned	Middle	74.5	0	0	49.2	-0.8	2.6	-19.3	46.1	49.9	0	-2	49.6	2586
	5/31/06 #1	Bottom	41.5	0	0	-23.0	-0.6	2.0	-13.1	-30.7	-22.8	0	-1	-24.4	2585
2	Tree 27	Top	102	-1	-2	52.9	-5.3	3.6	-51.1	40.1	55.2	-1	-5	49.2	2675
	Unpruned	Middle	72.75	0	-1	49.5	-9.4	0.6	-41.0	47.6	54.1	0	-7	50.4	2586
	5/31/06 #2	Bottom	41.75	0	0	-21.0	-6.5	0.4	-31.8	-29.1	-21.0	0	-8	-26.5	2585
3	Tree 25	Top	102.25	1	-1	55.5	-13.3	0.9	-41.7	51.3	60.7	0	-5	55.4	2675
	Raised	Middle	72	0	-1	47.1	-2.9	0.6	-26.2	46.1	50.0	0	-3	48.0	2586
	5/31/06 #3	Bottom	42	0	0	-19.3	-3.8	0.3	-15.8	-29.2	-19.0	0	-2	-21.9	2585
4	Tree 30	Top	107.25	1	-1	48.5	-1.0	4.7	-37.3	38.3	51.0	0	-4	50.5	2675
	Unpruned	Middle	73.5	0	0	43.2	-0.9	3.2	-26.9	39.4	45.5	0	-3	45.4	2586
	5/31/06 #4	Bottom	43	0	0	-22.4	-8.7	0.9	-19.9	-33.8	-2.9	-1	-3	-5.3	2585
5	Tree 32	Top	102	1	-1	53.2	-2.4	3.7	-26.4	43.4	54.4	1	-2	53.1	2675
	Thinned	Middle	73	0	0	48.2	0.0	5.0	-20.2	44.0	49.2	0	-1	47.7	2586
	6/1/06 #1	Bottom	42	0	0	-25.3	-0.6	2.8	-14.5	-31.6	-24.6	0	-1	-26.3	2585
6	Tree 32	Top	102	1	-1	54.4	-3.8	2.0	-13.8	50.4	60.1	0	-3	51.5	2675
	Thin Half	Middle	73	0	0	48.9	-1.8	2.1	-9.8	46.5	52.5	0	-1	46.9	2586
	6/1/06 #2	Bottom	42	0	0	-24.2	-1.9	1.3	-7.9	-28.4	-21.2	0	-1	-26.4	2585
7	Tree 34	Top	102.5	0	-1	50	-1.3	2.4	-17.0	47.8	54.7	0.7	-5.9	50.7	2675
	Reduced	Middle	73.25	0	0	48	-2.5	1.0	-15.1	47.0	51.0	-0.2	-4.3	48.7	2586
	6/2/06 #1	Bottom	42.75	0	0	-19	-2.2	1.0	-12.7	-24.6	-19.1	-0.1	-3.3	-21.2	2585
8	Tree 35	Top	101.5	1	-2	55	-19.9	0.6	-64.2	42.4	57.1	-1	-14	46.4	2675
	Unpruned	Middle	71	1	0	44	-2.3	3.9	-55.9	33.4	44.6	1	-12	39.1	2586
	6/2/06 #2	Bottom	41.25	0	0	-23	-7.8	0.2	-46.2	-32.6	-22.0	-1	-10	-31.0	2585
9	Tree 35	Top	101.5	-1	-14	53.6	-25.1	-1.2	-45.4	52.8	69.2	-1	-11	54.8	2675
	Unpruned Half	Middle	71	1	-12	44.6	-8.6	0.5	-39.7	43.6	51.2	0	-8	44.7	2586
	6/2/06 #3	Bottom	41.25	-1	-10	-25.1	-8.6	-0.5	-32.2	-28.2	-21.1	-1	-8	-27.6	2585
10	Tree 18	Top	107	1	-1	53	0.0	4.7	-17.6	47.9	56.1	1	-2	53	2675
	Reduced	Middle	77	0	0	46	-0.4	3.7	-15.8	41.7	47.7	0	-2	46	2586
	6/2/06 #4	Bottom	41	0	0	-24	-1.8	5.3	-12.6	-43.1	-21.1	0	-1	-26	2585
11	Tree 18	Top	107	1	-2	53	-2.3	2.0	-8.5	51.2	60.0	0	-2	53	2675
	Red Half	Middle	77	0	-2	46	-2.9	0.6	-7.7	44.7	51.6	0	-2	46	2586
	6/2/06 #5	Bottom	41	0	-1	-26	-4.4	2.9	-6.0	-37.2	-13.0	0	-1	-26	2585
12	Tree 16 Thinned	Top	104.5	1	-1	52	-1.1	3.8	-25.5	48.6	58.6	0	-3	52	2675
		Middle	73.5	0	0	46	-1.3	1.7	-20.2	41.9	46.7	0	-2	45	2586
	6/2/06 #6	Bottom	42	0	0	-24	-2.4	2.9	-14.6	-35.3	-22.6	0	-2	-25	2585
13	Tree 20 Reduced	Top	103	1	-1	53	-3.7	1.4	-17.2	48.4	58.3	1	-3	53	2675
		Middle	72	0	0	46	-3.6	0.7	-15.3	42.7	52.7	0	-2	46	2586
	6/2/06 #7	Bottom	41	0	0	-24	-3.1	0.4	-12.1	-32.5	-22.9	-1	-2	-24	2585
14	Tree 24 Thinned	Top	103.5	1	-1	52	-1.5	2.5	-17.9	49.1	55.5	0	-4	52	2675
		Middle	72.5	0	0	45	0.0	3.9	-13.2	43.2	46.4	2	-2	46	2586
	6/2/06 #8	Bottom	42	0	0	-19	-3.5	1.5	-9.8	-31.3	-15.8	0	-2	-20	2585
15	Tree 10 Raised	Top	102	1	-2	53	-5.9	2.2	-37.0	46.6	57.0	1	-6	54	2675
		Middle	72	0	0	44	-4.1	2.7	-26.1	42.2	48.5	0	-3	45	2586
	6/3/06 #1	Bottom	41	0	0	-22	-1.4	3.2	-26.1	-32.5	-19.0	1	-1	-24	2585
16	Tree 10	Top	102	1	-6	54	-4.3	2.2	-20.3	53.4	63.3	0	-5	54	2675
	Raised Half	Middle	72	0	-3	45	-2.8	2.5	-13.4	43.9	50.7	0	-3	45	2586
	6/3/06 #2	Bottom	41	1	-1	-24	-2.6	3.5	-7.5	-32.3	-16.1	0	-1	-24	2585
17	Tree 8	Top	105	1	-1	53	-2.8	2.7	-17.1	49.6	58.5	1	-2	53	2675
	Thinned	Middle	71.5	1	0	47	-3.0	3.4	-15.3	42.0	53.3	0	-1	47	2586
	6/3/06 #3	Bottom	41	0	0	-23	-1.7	1.6	-9.8	-27.7	-23.2	0	-2	-23	2585
18	Tree 6	Top	104.5	1	-1	52	-0.4	3.2	-15.2	48.7	54.9	1.4	-4.3	51.2	2675
	Reduced	Middle	75.5	0	0	47	-2.6	0.4	-12.6	45.7	49.9	0.1	-2.3	47.3	2586
	6/3/06 #4	Bottom	41.5	0	0	-15	-4.6	1.5	-10.1	-21.6	-15.3	-0.2	-2.7	-17.0	2585
19	Tree 11	Top	108	0	-2	51	0.3	14.8	-48.3	27.4	51.7	2	-10	50	2675
	Unpruned	Middle	74	0	0	44	0.1	11.3	-39.5	29.3	44.7	1	-7	44	2586
	6/4/06 #1	Bottom	42	0	0	-19	-0.4	5.1	-31.8	-33.5	-19.6	1	-7	-22	2585
20	Tree 13	Top	1035	1	-1	52	-4.7	2.8	-22.5	48.6	48.6	1	-2	52	2675
	Raised	Middle	72.5	0	0	46	-2.3	1.4	-16.4	43.0	48.4	0	-1	46	2586
	6/4/06 #2	Bottom	41	0	1	-20	-2.0	1.1	-10.1	-26.3	-19.6	0	-1	-20	2585
21	Tree 15	Top	102.6	1	-1	49	-0.3	4.6	-17.3	45.9	53.8	1	-2	49	2675
	Reduced	Middle	71	0	0	45	-1.2	2.9	-14.8	41.2	48.8	0	-1	46	2586
	6/5/06 #1	Bottom	41.6	0	0	-20	-3.7	1.3	-11.8	-25.2	15.0	0	-1	-20	2585
23	Tree 1	Top	105	1	-1	52	-2.0	2.6	-19.2	48.8	54.4	1	-2	51	2675
	Raised	Middle	74	0	0	48	-1.8	1.3	-13.1	46.6	50.3	0	0	48	2586
	6/5/06 #3	Bottom	42	0	0	-23	-1.8	0.6	-8.6	-29.4	-21.8	-1	-1	-23	2676
24	Tree 3	Top	106	1	-1	52	-5.3	0.6	-28.1	45.9	53.7	0	-6	52	2675
	Unpruned	Middle	75	0	0	44	-3.7	0.4	-22.9	41.7	45.3	-1	-5	45	2586
	6/5/06 #4	Bottom	42	-1	0	-22	-5.3	-1.3	-16.7	-31.1	-24.0	-2	-4	-23	2676
25	Tree 5	Top		1	[illegible]	50	-4.3	3.9	-33.5	40.0	51.4	0	-3	50	2675
	Raised	Middle		0	0	45	-3.8	1.6	-22.4	41.5	47.9	0	-1	45	2586
	6/5/06 #5	Bottom		0	-1	-22	-3.4	0.9	-14.3	-29.4	-21.8	0	-2	22	2676

Appendix