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# EFFECT OF HURRICANE ANDREW ON TROPICAL FRUIT TREES

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*Abstract.* **Hurricane Andrew (24 August, 1992) devastated much of the tropical fruit crops acreage in Dade County. Avocado, 'Tahiti' lime, mango, carambola, guava, longan, lychee, mamey sapote, and atemoya orchards were surveyed 10-15 months after the hurricane to determine the percentage of trees that were toppled (tipped over), stumped (reduced to major scaffold limbs), destroyed (blank tree hole or dead tree), or standing (upright tree with major scaffold limbs) after the storm. Three to seven orchards of each fruit crop were surveyed. Orchards were sampled in diagonal corners and in the center and ranged from 1 to 120 acres in area. Trees ranged from 2 to 46 years old, and from 6 to 25 ft in height prior to the storm. A greater percentage of lime (95%), carambola (93%), atemoya (90%), avocado (87%), mamey sapote (84%), and guava (84%) trees survived the hurricane than mango (71%), longan (70%), and lychee (60%) trees. More atemoya (77%) trees were toppled than any other fruit crop, whereas more lychee (40%), longan (30%), and mango (29%) trees were destroyed compared to other fruit crops surveyed. Mamey sapote (44%) trees had the highest percentage of stumped trees while more carambola (76%), guava (69%), avocado (67%), and grafted lime (66%) trees remained standing compared to other fruit crops. The relationship between tree age and height and the percentages of trees that were toppled, destroyed, stumped, standing, and survived varied among fruit crops.**

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On 24 August 1992, Hurricane Andrew made landfall on south Dade County, Florida, devastating the $74 million tropical fruit industry (Mosely, 1990). The National Weather Service reported sustained winds of 145 mph (230 kph) and gusts in excess of 175 mph (280 kph). Only 2 to 4 inches of rainfall were reported during the storm.

Early estimates suggested 40%-45% of the 22,000 acres (8,900 ha) of tropical fruit crops in Dade County were completely destroyed (Crane et al., 1993). Initial observations of tree damage included defruiting, defoliation, breakage of major scaffold limbs, trunk splitting and breakage, tree toppling, extensive bark damage caused by wind-blown rock and debris (sand blasting), and windthrowing (partial and complete uprooting) (Crane et al., 1993). Sunburning of exposed trunks and limbs occurred during the days and months following the storm. More detailed observations of tree damage and post hurricane recovery exposed differences among tree species, cultivars, tree ages (size), tree heights, propagation methods, cultural practices prior to and immediately after the storm, and preplant soil preparation (Campbell et al., 1993; Crane et al., 1994).

The objective of this study was to survey avocado, mango, 'Tahiti' lime, atemoya, carambola, mamey sapote, guava, lychee, and longan orchards and to determine the effect of Hurricane Andrew on the number of trees that were toppled, destroyed, reduced to stumps, and that remained standing after the storm.

## Materials and Methods

Forty-two commercial tropical fruit orchards were surveyed during July to December, 1993 (Table 1). Three to seven commercial orchards of avocado, mango, 'Tahiti' lime, atemoya, carambola, mamey sapote, guava, lychee, and longan were inspected. The orchards surveyed had been trenched before planting (Colburn and Goldweber, 1961) and ranged from one to 120 acres in area. Trees ranged from 2 to 46 years in age and tree heights prior to Hurricane Andrew were from 6 to 25 feet. Forty-eight to 270 trees were inspected per orchard.

Most orchards were surveyed on the southeast or southwest corner, northeast or northwest corner, and in the center with 16 to 150 trees sampled per location (usually 60 trees per location). Some orchards were surveyed in their entirety. Records of tree height and age prior to Hurricane Andrew were obtained from orchard owners. Trees were categorized as having been toppled (tipped over), destroyed (blank tree hole or dead tree), stumped (reduced to trunk or major scaffold limbs during the storm or by pruning after the storm), or standing (upright tree with major scaffolding intact). Data for toppled, stumped, and standing trees were summed to get the percentage of trees surviving the storm for each crop species. Some trees counted as destroyed may have been removed (missing) prior to the hurricane and could not be accounted for in the survey.

The percentages of trees in each category for each species were calculated by orchard location (e.g., southeast, northwest, center) and on a whole orchard basis. Percentage data were arcsine transformed and each fruit crop was analyzed separately by ANOVA to test differences in the percentage of trees that were toppled, destroyed, stumped, standing, and surviving among different locations (i.e., southeast, northwest, center) within an orchard. Differences among orchards of the same crop species could not be statistically tested for a particular attribute due to the impossibility of sampling multiple orchards with identical acreage, tree age, number of trees, and tree height prior to the storm. However, differences among orchards of the same crop were noted.

Differences among crop species in the percent of toppled, destroyed, stumped, standing, and surviving trees were tested using ANOVA and Duncan's Multiple Range Test. The effects of tree age and tree height on the percent toppled, destroyed, stumped, standing, and surviving trees were tested by linear regression.

Table 1. The number of orchards, orchard size range, tree ages, and tree heights of surveyed tropical fruit crop orchards after Hurricane Andrew.

| Crop | Number of orchards sampled | Orchard size range (acres) | Tree ages (yrs) | Prior height (ft)[z] |
|---|---|---|---|---|
| Avocado | 5 | 2-80 | 10-46 | 15-25 |
| Lime | 4 | 40-120 | 10-13 | 10-14 |
| Mango | 4 | 10-40 | 8-35 | 15-23 |
| Mamey sapote | 4 | 5-10 | 6-15 | 12-25 |
| Atemoya | 4 | 3-15 | 3-7 | 8-12 |
| Lychee | 6 | 2-20 | 3-11 | 6-15 |
| Longan | 7 | 1-10 | 5-8 | 10-24 |
| Carambola | 5 | 5-30 | 2-7 | 8-15 |
| Guava | 3 | 1-10 | 10-42 | 7-15 |

[z]Tree height prior to Hurricane Andrew.

## Results

*Orchard location.* There was no significant difference in the percentage of toppled, destroyed, stumped, standing, and surviving trees among grove locations (e.g., northwest, center, southeast) for any of the fruit crops surveyed (data not shown). This was not unexpected because the fruit production area of Dade County lay within the center of Hurricane Andrew and orchards were struck by both the leading and following edge of the storm.

*General crop comparison.* The percentage of trees that were toppled, destroyed, stumped, standing, and surviving varied significantly among crop species (Tables 2, 3, 4). may be attributed to differences among crops in inherent wood strength and flexibility, rooting depth and lateral extension, propagation method, and tree vigor. The range in tree ages, orchard sizes, tree heights, and random storm events (e.g., localized whirlwinds) may have also influenced the amount of tree damage incurred.

Significantly more atemoya trees were toppled (77%) than any of the other crops surveyed (Table 2). The percentages of toppled mango (20%), guava (14%), carambola (13%), and avocado (10%) trees were similar but significantly lower than that of grafted lime trees (25%). Longan (2%), lychee (1%), and mamey sapote (1%) had the fewest toppled trees. Lychee (40%), longan (30%), and mango

Table 2. Effect of Hurricane Andrew on the percentage of avocado, mango, lime, atemoya, carambola, mamey sapote, guava, lychee, and longan trees toppled and destroyed.[z]

| Crop | Percentage of trees toppled (%) | Crop | Percentage of trees destroyed (%) |
|---|---|---|---|
| Atemoya | 77 A | Lychee[x] | 40 A |
| Lime[y] | 25 B | Longan | 30 A |
| Mango | 20 BC | Mango | 29 A |
| Carambola | 13 C | Mamey sapote | 16 B |
| Guava | 14 C | Avocado | 13 B |
| Avocado | 10 C | Atemoya | 10 B |
| Longan | 2 D | Guava | 16 B |
| Lychee[x] | 1 D | Carambola | 7 B |
| Mamey sapote | 1 D | Lime[y] | 5 B |

[z]Mean separation by Duncan's multiple range test, 1% level.
[y]Only grafted lime orchard data used in analysis.
[x]Combined value for 'Mauritius', 'Brewster', and mixed cultivar orchards.

Table 3. Effect of Hurricane Andrew on the percentage of avocado, mango, lime, atemoya, carambola, mamey sapote, guava, lychee, and longan trees that were stumped and standing.[z]

| Crop | Percentage of trees stumped (%) | Crop | Percentage of trees standing (%) |
|---|---|---|---|
| Mamey sapote | 44 A | Carambola | 76 A |
| Lychee[y] | 30 B | Guava | 69 A |
| Longan | 28 B | Avocado | 67 A |
| Mango | 21 B | Lime[y] | 66 A |
| Avocado | 10 C | Longan | 40 B |
| Carambola | 4 CD | Mamey sapote | 39 B |
| Lime[x] | 4 CD | Mango | 30 B |
| Guava | 1 D | Lychee[y] | 29 BC |
| Atemoya | 1 D | Atemoya | 12 C |

[z]Mean separation by Duncan's multiple range test, 1% level.
[y]Combined value for 'Mauritius', 'Brewster', and mixed cultivar orchards.
[x]Only grafted lime orchard data used in analysis.

Table 4. Effect of Hurrican Andrew on the percentage of avocado, mango, atemoya, carambola, mamey sapote, guava, lychee, and longan trees that survived.[z]

| Crop | Percentage of trees surviving (%) |
|---|---|
| Lime[y] | 95 A |
| Carambola | 93 A |
| Atemoya | 90 A |
| Avocado | 87 A |
| Mamey sapote | 84 A |
| Guava | 84 A |
| Mango | 71 B |
| Longan | 70 B |
| Lychee[x] | 60 B |

[z]Combined toppled, stumped, and standing percentages.
[y]Only grafted lime orchard data used in analysis.
[x]Combined value for 'Mauritius', 'Brewster', and mixed cultivar orchards.

Table 5. The overall effect of Hurricane Andrew on the percentage of grafted and air-layered 'Tahiti' lime trees that were toppled, missing (destroyed), stumped, standing and surviving.

| Lime orchard | Percentage of trees | | | | |
|---|---|---|---|---|---|
| | Toppled | Destroyed | Stumped | Standing | Surviving |
| Grafted 1[z] | 29 | 4 | 1 | 66 | 96 |
| Grafted 2[z] | 21 | 7 | 7 | 65 | 93 |
| Air-layered[y] | 8 | 83 | 0 | 9 | 17 |
| Mixed-grafted[x] | 28 | 3 | 3 | 66 | 97 |
| Mixed-layered[w] | 23 | 20 | 3 | 54 | 80 |
| Mixed[v] | 25 | 11 | 3 | 61 | 89 |

[z]Grafted 'Tahiti' lime orchard.
[y]Air-layered 'Tahiti' lime orchard.
[x]Grafted trees in 'Tahiti' lime orchard of alternating grafted and air-layered trees.
[w]Air-layered trees in 'Tahiti' lime orchard of alternating grafted and air-layered trees.
[v]Overall percentages for the 'Tahiti' lime orchard of alternating grafted and air-layered trees.

(29%) orchards had similar percentages of destroyed trees; all other crops had significantly fewer destroyed trees.

Significantly more mamey sapote trees were stumped (44%) due to the hurricane than all other crops surveyed (Table 3). Lychee (30%), longan (28%), and mango (21%) orchards had significantly fewer stumped trees than mamey sapote but more than avocado (10%), carambola (4%), grafted lime (4%), guava (1%), and atemoya (1%). Guava and atemoya orchards had the fewest stumped trees.

Carambola (76%), guava (69%), avocado (67%), and grafted lime (66%) orchards had similar but significantly greater percentages of standing trees than longan (40%), mamey sapote (39%), mango (30%), and lychee (29%), and atemoya (12%) orchards (Table 3). Atemoya orchards had the fewest standing trees after the storm.

Tree survival varied significantly among crops species (Table 4). The percentages of surviving grafted lime (95%), carambola (93%), atemoya (90%), avocado (87%), mamey sapote (84%), and guava (84%) trees were similar and significantly greater than mango (71%), longan (70%), and lychee (60%) trees.

*Lime.* 'Tahiti' lime orchards had dramatic differences in the percentage of trees that were toppled, destroyed, stumped, standing, and surviving, depending upon whether the trees originated as air-layers or were grafted onto a rootstock (in most cases *Citrus macrophylla* L.) (Table 5). The orchard with air-layered trees had many more destroyed trees (83%) than the orchards with grafted (4 and 7%) and mixed (grafted and air-layered trees alternating in-row) trees (11%). In contrast, many more trees remained standing after the hurricane in the orchards with grafted (66% and 65%) and mixed trees (61%) than the orchard with air-layered trees (9%). The orchards with grafted trees had similar percentages of toppled (21% and 29%) and stumped trees (1% and 7%) as the mixed tree orchard (25% and 3%, respectively) whereas few trees were toppled (8%) and no stumped trees were found in the air-layered orchard. Many more trees survived in the grafted (93 and 96%) and mixed (89%) orchards than in the air-layered (17%) orchard.

In the mixed orchard, similar percentages of toppled and stumped trees were found for grafted (28% and 3%, respectively) and air-layered (23% and 3%, respectively) trees. However, more air-layered trees (20%) were destroyed than grafted trees (3%) and fewer air-layered trees (54%) remained standing than grafted (66%) trees. The percentage of air-layered trees surviving in the mixed orchard (80%) was much greater than in the air-layered orchard (17%) and indicated the grafted trees in the mixed orchard afforded some protection for the air-layered trees.

*Lychee.* In lychee orchards, there were dramatic differences in the percentage of destroyed, stumped, standing, and surviving trees among 'Mauritius', 'Brewster' and mixed cultivar orchards (data not shown).

There were few toppled trees in any of the 'Mauritius' (2%), 'Brewster' (0%, one orchard), and mixed cultivar (2%) orchards. In contrast, a greater percentage of 'Mauritius' trees (53%) were destroyed than trees in the 'Brewster' (40%) and mixed cultivar (38%) plantings. Far fewer 'Brewster' (2%) trees were stumped than 'Mauritius' trees (29%) and trees in the mixed cultivar (44%) plantings. Many more trees remained standing in the 'Brewster' orchard (58%) compared to the 'Mauritius' (16%) and mixed cultivar (16%) orchards. Overall, many more trees survived in the 'Brewster' (60%) and mixed (62%) orchards than in the 'Mauritius' orchards (47%).

*Effect of tree age and height.* Significance of linear regression and the magnitude of the coefficients of determination varied among fruit crops for toppling, destruction, stumping, standing, and survival (Table 6, 7). Interpretation of the analysis was complicated by the lack of multiple samples for similar orchard ages and tree heights prior to the hurricane and the many possible other factors involved (e.g., rooting depth and spread, canopy spread and shape, etc.) in determining the fate of a particular tree during the storm.

Multiple linear regression indicated that both tree age and height were correlated with toppling of avocado and guava orchards (Table 6). The percent of toppled avocado and guava trees decreased with tree age and increased with tree height. This was not surprising since older trees generally have more massive trunks and major scaffold limbs which would tend to stabilize the trees compared to younger trees. Taller trees have more wind resistance than shorter trees and are more likely to topple. In contrast to avocado and guava, no significant relationship between tree age or height was found for the mango and mamey sapote orchards sampled. Interestingly, almost no mamey sapote trees were found toppled in our survey.

Table 6. Simple and multiple linear regression equations (non-transformed data) and coefficients of the percentage of trees toppled, destroyed, and stumped as affected by tree age, tree height, and tree age and height prior to Hurricane Andrew.[z]

| Crop | Sign. factor[y] | Sign.[x] | $R^2$ | Equation |
|---|---|---|---|---|
| Toppled | | | | |
| Avocado | age + ht | *,+ | 0.47 | $Y=-7.2 + -0.3X_1 + 1.1X_2$ |
| Mango | —[w] | — | — | — |
| Atemoya | age | ** | 0.55 | $Y=111.3 + -6.2X$ |
| | ht | ** | 0.58 | $Y=102.0 + -2.8X$ |
| Carambola | age | ** | 0.66 | $Y=47.8 + -7.3X$ |
| | ht | ** | 0.78 | $Y=82.0 + -6.0X$ |
| Mamey sapote | — | — | — | — |
| Guava | age + ht | **,** | 0.93 | $Y=-116.6 + -11.4X_1 + 36.2X_2$ |
| Lychee | age | ** | 0.39 | $Y=3.8 + -0.4X$ |
| | ht | ** | 0.41 | $Y=4.5 + -0.3X$ |
| Longan | age | ** | 0.63 | $Y=11.3 + -1.3X$ |
| | ht | ** | 0.42 | $Y=10.3 + -0.5X$ |
| Destroyed | | | | |
| Avocado | — | — | — | — |
| Mango | age + ht | **,* | 0.68 | $Y=-3.3 + -1.5X_1 + 3.1X_2$ |
| Atemoya | age | ** | 0.70 | $Y=-8.8 + 3.5X$ |
| | ht | ** | 0.72 | $Y=-3.3 + 1.6X$ |
| Carambola | — | — | — | — |
| Mamey sapote | age + ht | **,** | 0.42 | $Y=46.6 + 7.6X_1 + -5.7X_2$ |
| Guava | age + ht | **,** | 0.74 | $Y=-126.0 + -10.4X_1 + 35.8X_2$ |
| Lychee | age | ** | 0.42 | $Y=78.8 + -5.5X$ |
| | ht | ** | 0.50 | $Y=98.9 + -4.6X$ |
| Longan | age + ht | +,** | 0.56 | $Y=111.1 + 7.7X_1 + -7.7X_2$ |
| Stumped | | | | |
| Avocado | age + ht | **,+ | 0.56 | $Y=6.1 + -0.3X_1 + 0.5X_2$ |
| Mango | — | — | — | — |
| Atemoya | age | * | 0.24 | $Y=-0.9 + 0.3X$ |
| | ht | * | 0.25 | $Y=-0.4 + 0.2X$ |
| Carambola | age | + | 0.12 | $Y=7.8 + -0.8X$ |
| Mamey sapote | age | ** | 0.61 | $Y=72.3 + -2.7X$ |
| | ht | ** | 0.56 | $Y=80.6 + -1.9X$ |
| Guava | age + ht | *,* | 0.58 | $Y=-11.8 + -1.6X_1 + 4.5X_2$ |
| Lychee | — | — | — | — |
| Longan | age | + | 0.15 | $Y=-4.0 + 4.5X$ |
| | ht | * | 0.26 | $Y=-24.0 + 3.0X$ |

[z]Lime data was not analyzed due to insufficient data.
[y]Significant factor(s); age, tree age; ht, tree height.
[x]Level of signficance; *, P>0.05; **, P>0.01; +, P>0.10.
[w]No significant regression coefficient.

The percentage of toppled atemoya, carambola, lychee, and longan trees were best correlated with tree height or age individually (Table 6). Tree toppling decreased significantly with increasing tree age and tree height. However, the moderate to low coefficients of determination indicate other factors (e.g., tree vigor, rooting depth and lateral growth, microclimate differences during the hurricane) were involved in the percentage of trees that toppled.

No significant relationship between tree age or height and the percentage of destroyed avocado and carambola trees was observed (Table 6). The percentage of mango, mamey sapote, guava, and longan trees that were destroyed due to the hurricane were best correlated with tree height and age together. For mango and guava orchards, the percent of destroyed trees decreased with tree age and increased with tree height. In contrast, the percentage of destroyed trees increased with tree age and decreased with tree height for mamey sapote and longan orchards. The difference between species in the percentage of destroyed trees may have been due to the more common practice of pruning (limiting tree height and spread) of mango and guava orchards than mamey sapote and longan orchards. The larger diameter scaffolding caused by repeatedly reducing the canopy spread of mango and guava orchards results in large diameter scaffolding wood near the edge of the canopy and a reduced canopy area, which presumably would result in a stronger and more wind resistant tree framework.

The percentage of destroyed trees in atemoya and lychee orchards was best correlated with either tree age or tree height individually (Table 6). For atemoya orchards, tree age and tree height were positively related to the percentage of destroyed trees, indicating that older, larger orchards were more vulnerable to tree loss. In contrast, tree age and height were negatively related to destruction in lychee orchards, suggesting that older trees and taller trees were more likely to survive the hurricane. This difference may be due to a more extensive root system of lychee compared to atemoya trees and/or differences in wind resistance between lychee and atemoya trees.

For avocado and guava orchards the percentage of stumped trees were best correlated with tree age (negatively)

Table 7. Simple and multiple linear regression equations (non-transformed data) and coefficients of the percentage of trees stumped and standing as affected by tree age, tree height, and tree age and height prior to Hurricane Andrew.[z]

| Crop | Sign. factor[y] | Sign.[x] | $R^2$ | Equation |
|---|---|---|---|---|
| Standing | | | | |
| Avocado | age + ht | * | 0.47 | $Y=98.9 + 1.0X_1 + -2.4X_2$ |
| Mango | age + ht | ** | 0.67 | $Y=27.6 + 2.0X_1 + -1.5X_2$ |
| Atemoya | age | * | 0.31 | $Y=-1.6 + 2.4X$ |
| | ht | * | 0.34 | $Y=1.7 + 1.1X$ |
| Carambola | age | ** | 0.69 | $Y=33.0 + 9.0X$ |
| | ht | ** | 0.76 | $Y=-8.1 + 7.3X$ |
| Mamey sapote | age | ** | 0.52 | $Y=12.2 + 2.7X$ |
| | ht | ** | 0.60 | $Y=-0.3 + 2.1X$ |
| Guava | ht | ** | 0.43 | $Y=140.2 + -9.1X$ |
| Lychee | age | ** | 0.47 | $Y=-21.3 + 7.0X$ |
| | ht | ** | 0.47 | $Y=-34.9 + 5.0X$ |
| Longan | —[w] | — | — | — |
| Survived | | | | |
| Avocado | — | — | — | — |
| Mango | age + ht | **,* | 0.64 | $Y=93.3 + 1.8X_1 + -2.6X_2$ |
| Atemoya | age | ** | 0.70 | $Y=108.8 + -3.5X$ |
| | ht | ** | 0.72 | $Y=103.3 + -1.6X$ |
| Carambola | — | — | — | — |
| Mamey sapote | age + ht | **,** | 0.43 | $Y=52.7 + -7.7X_1 + 5.6X_2$ |
| Guava | age + ht | *,* | 0.75 | $Y=225.1 + 10.4X_1 + -35.7X_2$ |
| Lychee | age | ** | 0.42 | $Y=19.4 + 5.6X$ |
| | ht | ** | 0.58 | $Y=-0.5 + 4.7X$ |
| Longan | age + ht | +,** | 0.56 | $Y=-9.7 + -8.2X_1 + 8.0X_2$ |

[z]Lime data was not analyzed due to insufficient data.
[y]Significant factor(s); age, tree age; ht, tree height.
[x]Level of significance; *, P>0.05; **, P>0.01; +, P>0.10.
[w]No significant regression coefficient.

and tree height (positively) (Table 6). Thus older orchards where tree height was limited had fewer stumped trees due to the storm than older orchards where tree height was not controlled. No significant relationship between tree age or height and stumping was found for mango and lychee orchards. For stumping, significant coefficients of determination were found for tree age and tree height for atemoya, mamey sapote, and longan orchards. However, while the percentage of stumping was positively related to tree age or tree height for atemoya and longan, it was negatively related to tree age or tree height for mamey sapote. This difference may indicate differences in wood strength and/or limb attachment. Observation of mamey sapote orchards after the hurricane suggested scaffold limbs appeared to break from the main trunk leaving the main trunk intact. This did not commonly occur in atemoya and lychee orchards. Carambola tree age was negatively correlated with the percentage of trees stumped although the low coefficient of determination indicated that other factors were involved.

The percentage of standing trees in avocado and mango orchards was best described by multiple linear regression with a positive correlation with tree age and a negative correlation with tree height (Table 7). Tree age and height were positively correlated to the percentage of trees standing for all other fruit crops except guava. This suggested that more mature trees, even tall ones, remained standing than younger, shorter trees. This may have been due to greater rooting depth and spread and a greater mass of roots and tree trunks of older trees than of younger trees. The percentage of guava trees that remained standing decreased with tree height. This may have been due to greater wind resistance of taller trees and a less extensive root system of guava trees since they are propagated by air layers in Florida.

No relationship was observed between tree survival and tree age or height for avocado and carambola trees (Table 7). Mango and guava tree survival was positively correlated with tree age and negatively correlated with tree height. In contrast, mamey sapote and longan were negatively correlated with tree age and positively correlated with tree height. This difference may reflect the fact that older mango and guava orchards are more routinely topped than mamey sapote and longan orchards, thus decreasing their wind resistance and increasing their stability. In addition, frequent tree size control of mango and guava may have resulted in greater root to shoot ratios compared to mamey sapote and longan which were not routinely topped and hedged. In contrast, perhaps taller mamey trees survived the storm because their limbs easily detached from the trunk whereas taller longan trees survived because of great strength and flexibility of their limbs.

Atemoya tree survival was negatively correlated with tree age and height, indicating that older, taller trees were more susceptible to the high winds and more likely to be completely uprooted than younger, shorter trees. In contrast, lychee tree survival was positively correlated with tree age and height, possibly indicating that tree mass was important in tree survival.

## Discussion

In general, our preliminary field observations after Hurricane Andrew (Crane et al., 1993; Campbell et al.,

1993) were confirmed by the results of this study. Avocado tree survival was high because most orchards consisted of mature trees with large diameter, massive trunks and major scaffold limbs and tree height of 25 ft or less. Preliminary observations indicated that nearly one half of the acreage planted to mangos was destroyed due to the hurricane. However, our survey found about one third of the mango trees were destroyed. Additional losses of mango trees were caused by sunburning of exposed trunks and limbs which was not accounted for in our survey.

Propagation method (i.e., grafting vs. air-layering) was the major factor in orchard survival for 'Tahiti' limes. The large percentage of grafted lime trees that survived the hurricane demonstrate the value of the more extensive root system of grafted trees compared to air-layered trees.

Many atemoya orchards survived the hurricane but most of the trees were toppled. Carambola orchards had the second highest percentage of standing trees after the storm and this may have been due to the reduced wind resistance of the flexible limb structure of the trees. Most mamey sapote orchards survived the hurricane and although older, larger trees lost many of their limbs, few were toppled and few were destroyed. Commercial guava orchards survived the storm well because they are kept topped at about seven to nine feet above the soil line.

In general, about 40% of the acreage planted to lychees was destroyed due to the hurricane. However, the percentage of 'Brewster' trees destroyed was far less than 'Mauritius' trees. Few lychee trees were toppled due to the storm. Most longan acreage survived the hurricane and a large percentage of the trees remained standing.

In conclusion, the type of commercial fruit tree destruction wrought by Hurricane Andrew varied among crops and was influenced by many factors including tree age and height. However, many other factors such as wood strength, limb angle attachment, root depth and extension, row orientation, and cultural practices may have influenced the damage due to the hurricane.

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# IS IT TIME TO DEVELOP A NEW SYSTEM FOR GROWING STRAWBERRIES IN FLORIDA?


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*Abstract.* **The raised bed, plasticulture system currently used to grow strawberries (*F.* × *ananassa* Duch.) in Florida has served the industry well, but its reliance on non-reusable polyethylene mulch, methyl bromide fumigant, and a large labor force to stoop and harvest fruit in the field will likely make it increasingly unworkable if environmental and labor regulations become more stringent.**


The cultural system used to grow strawberries in Florida is called the raised bed, 2-row, plasticulture system. It has been used by Florida strawberry growers for over 30 years (Brooks, 1960). In this paper, we will explain why this system has worked well, but why it might be time to start thinking about developing a new system.

## Current System

Tractor drawn bed presses create semi-confined areas (raised beds) in which to efficiently apply fumigant and fertilizer. Soil drainage within the bed is good because of the bed's elevation above the row middles. This drainage is especially important for strawberries, since large amounts of irrigation water are applied to the crop during the plant establishment period and during freeze events. Raised beds also make hand harvesting easier. The polyethylene mulch, which is used to cover the raised beds, provides excellent weed control and keeps the fruit cleaner than if it were lying directly on the soil surface.

The current system is dependent on a reasonably priced supply of polyethylene mulch and methyl bromide fumigant, and a large labor force willing to stoop and harvest fruit in the field. The future availability of these inputs, however, is uncertain. The use of polyethylene mulch creates a serious solid waste disposal problem. Currently, the mulch film is manually removed from fields at the end of the fruiting season and either burned at the edges of