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THE IMPACT OF FOUR HURRICANES IN 2004 ON THE FLORIDA CITRUS INDUSTRY: EXPERIENCES AND LESSONS LEARNED

L. GENE ALBRIGO,* RICHARD S. BUKER, JACQUELINE K. BURNS, WILLIAM S. CASTLE, STEPHEN FUTCH, CLAYTON W. MCCOY, RONALD P. MURARO, MICHAEL E. ROGERS, JAMES P. SYVERTSEN AND L. W. TIMMER
University of Florida, IFAS
Citrus Research and Education Center
Horticultural Sciences
700 Experiment Station Road
Lake Alfred, FL 33850

JOHN ATTAWAY
Florida Citrus Consultants International, Inc.
P.O. Box 205
Winter Haven, FL 33882

KIM BOWMAN
U.S. Horticultural Research Laboratory
2001 South Rock Road
Ft. Pierce, FL 34945

K. W. HANCOCK
P.O. Box 12463
Ft. Pierce, FL 34979

MARK A. RITENOUR
University of Florida, IFAS
Indian River Research and Education Center
Department of Horticultural Sciences
2199 South Rock Road
Ft. Pierce, FL 34945

PETER D. SPYKE
Arapaho Citrus Management Inc.
13300 Okeechobee Road
Ft. Pierce, FL 34945

R. C. VACHON
Packers of Indian River
5700 Midway Road
Ft. Pierce, FL 34981

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Abstract. **Florida citrus areas were affected by four severe hurricanes (three direct hits) within a 6-week period in August and September 2004. All segments of the Florida citrus industry were impacted either directly or indirectly. Citrus nurseries suffered extensive losses and bearing trees were uprooted, broken or lost leaves and fruit. Compared to the 2003-04 season, the orange crop was reduced by 31% while grapefruit yields were reduced by 68%. Re-establishing grove operations and water management practices were major tasks for growers affected by the hurricanes. Tree damage, survival, and recovery depended on pre-existing pest pressures, cultivars, tree canopy size, grove architecture, cultural practices, and the hurricanes' forces in the specific areas and blocks. For example, in young rootstock trials there was more tree blow-over apparently attributable to larger canopy volume relative to rooting, lack of rooting symmetry, and previous root weevil damage. Evaluation of different hedging and topping recovery practices indicated that early fall timing reduced return bloom in 2005. Some pest populations increased on the heavy fall flush in 2004 following mature leaf loss. This article brings together some useful information about hurricane preparedness and recovery practices for citrus production.**

UF/IFAS, cooperating scientists, and citrus growers conducted on-going evaluations of the health, recovery, and future potential of Florida citrus. Episodic catastrophic weather events like hurricanes are unpredictable and offer limited opportunities to observe and conduct experiments to assess their impacts. Nonetheless, there is a need to assist producers, harvesters, and the post-production components of the citrus industry in making appropriate, informal decisions about recovery of trees and the overall industry. Extension activities were conducted to keep growers informed of tree and grove conditions, provide advice on best management practices for potential problems and grove hurricane recovery.

Economic decisions and investments in disaster recovery must be made with realistic expectations. The aftermath of three severe hurricanes within a 6-week period in Aug. and Sept. 2004, provided a unique opportunity to bring together the lessons learned about hurricane preparedness and recovery practices for citrus production. The purpose of this article is to summarize the experiences, what we may know and what we don't know about the short- and long-term impacts of the hurricanes in 2004 in case similar events were to occur again.

Hurricane Comparisons

Over the past 60 years, the Florida citrus industry has experienced several destructive hurricanes (Table 1). Major hurricanes devastated the industry in 1944, 1945, 1947, and 1949 (Attaway, 1999). The 1944 and 1949 hurricanes were particularly severe, but no previous season can compare with

Table 1. Hurricanes of major impact prior to 2004 in the past 60 years in Florida (after Attaway, 1999)

			Wind speed		Losses	
Year	Name	Path	Sustained	Gusts	Or	Gpf
1944	NN[z]	SW-N	80	100	18	38
1945	NN	SE-N	125	150	10	30
1947	NN	E-W[y]	100	110	6[x]	
1949	NN	SE-NW	125	150	5	30
1960	Donna	SW-NE	92	120	10	30

[z]NN = not named hurricanes.
[y]Path was south of most citrus production.
[x]Orange and grapefruit losses not separated.

*Corresponding author; e-mail: albrigo@ufl.edu

the four 2004 major hurricanes, of which Charley, Frances, and Jeanne ravaged the industry with both rain and hurricane force winds, and Ivan added to the major flooding in the Indian River (IR) District (Table 2). All four hurricanes which struck Florida in 2004 originated off of Cape Verde, Africa. The state escaped any 2004 hurricanes of Caribbean and Gulf of Mexico origin. The initial damage rivaled that of major freeze years such as 1962, 1983, 1985, and 1989 (Attaway, 1997).

The hurricanes which have been the most destructive to the Florida citrus industry tended to follow one of two general tracks. Hurricane Charley followed what could be called the U.S. Highway 17 track. Hurricanes which followed this path will often make a northeast turn in the Gulf and come ashore between Naples and Punta Gorda, after which they "follow" U.S. Hwy. 17 through Lee, Charlotte, DeSoto, Hardee, Highlands, Polk, Osceola, and Orange Counties before exiting into the Atlantic along the Northeast Florida Coast from Volusia County to Jacksonville. An unnamed destructive hurricane in Oct. 1944 and Hurricane Donna in Sept. 1960, both took a similar course with devastating results.

Hurricanes Frances and Jeanne followed an IR track, coming ashore near or slightly north of Stuart in Martin County and moving across the state to reach the Gulf of Mexico north of Tampa near Pasco County. The storm surge in Frances affected coastal properties but did not push into many citrus groves. The storm surge in Jeanne was projected to be 4-6 ft higher than it was in Frances, but it was low tide when the eye approached, reducing its impact. Jeanne came on shore at nearly the same point as Frances, and the paths of the north eyewall—the most intensive part of the storm—were similar. The difference between the two storms was that Jeanne traveled 13 mph instead of 3 mph for Frances, and Jeanne's sustained winds were about 125 mph instead of 105. There wasn't nearly as much rain out of Jeanne, but the wind damage and coastal storm surge were more severe. Frances, which occurred on 4 Sept. and Jeanne on 25 Sept. brought tremendous sustained wind and rain. Jeanne had wind gusts clocked at 156 mph west of Ft. Pierce. Extensive flooding did occur, particularly in the IR District.

An unnamed hurricane which followed this IR course in Aug. 1949 was arguably the most destructive single hurricane to hit this citrus area in recorded history. This hurricane came ashore on 26 Aug. 1949 at Jupiter Light with 153 mph sustained winds. Stuart felt 125 mph sustained winds with gusts to 150 mph. Dr. Herman J. Reitz noted that "not a leaf was left on a single tree at the IR Field Laboratory," (Attaway, 1999). Winds exceeding 100 mph were also felt at Lake Placid and Bartow as the hurricane extended its damage into Highlands and Polk Counties.

Table 2. Hurricanes affecting Florida citrus area in 2004.

	Charlie	Frances	Ivan	Jeanne
Dates	13 Aug.	5 Sept.	15 Sept.	26 Sept.
Path	SW-NE	SE-NW	S-N	SE-NW
Wind[z]	125	105	40 (TS[y])	120
Rain	4-8 inches	12+ inches	10 inches	10+ inches
Landfall	Charlotte	Martin	TS	Martin

[z]Wind as sustained wind at landfall.
[y]TS = tropical storm strength in citrus areas, no defined land fall in citrus area.

In 2004, hurricanes affected most citrus producing areas in Florida except the Immokalee-LaBelle area. Extensive, repeated damage occurred in the IR and south central citrus areas as hurricane-force winds followed the same paths or crossed over major portions of the citrus production areas two or three times from different directions (Fig. 1). Some central Florida areas reported rainfall in excess of 10 inches associated with Hurricanes Charley, Frances, and Jeanne. In the IR District, Ivan deposited an additional 10 inches of rain as it passed on the west coast toward the panhandle of Florida and looped around again from the northeast. Along with rainfall from the other two East Coast storms, the IR District accumulated about 40 inches of rain in the month of September. Standing water has the potential to damage roots and predisposed them to soil-borne disease and insect losses. Opportunities for leaching of minerals and nutrients accompanied widespread flooding, potentially leaving surviving crops short of the nutrients necessary for recovery.

Dealing with the Storms

Infrastructure

Almost every citrus operation in the path of the storms had to deal with office, shop and/or barn damage (Spyke, 2004). Multiple hurricanes compounded damage initiated by earlier storms. Many roofs failed and needed replacing. Blue tarp covers on offices and homes were the rule for most of Florida throughout the winter as re-roofing materials and crews were insufficient. Metal covered buildings were stripped of covering, including many well pump houses. Heavy duty expanded metal or hardware cloth may be a better option where rain is not a concern. Citrus nurseries lost greenhouse, other structures, and trees. Hurricane preparedness guidelines for nurseries are available (Yeager, 2001). In the IR District, most packinghouses were damaged to the point that the ability to operate was delayed and only about 20 opened. There operation also was limited because of a shortage of suitable fruit. Some packinghouses on the east coast that plan to run during the 2005-06 season still had not been fully repaired as of June 2005. Although damage was widespread, houses in the center of the state generally experienced less damage than those on the east coast. Harvesting and packing in the center of the state was generally delayed a couple of weeks as repairs were finished and power restored, but operation of east coast houses was often delayed a month or more even were damage was not so severe. Several processors suffered building damage from at least one storm, and in most cases it was pre-fabricated insulated panels that were blown from tank storage areas or larger metal buildings used for dry storage. This happened at two plants after Charley and an additional two plants on the East coast after Frances and Jeanne. One processor sustained severe tank farm damage and had to move several million gallons of Frozen Concentrated Orange Juice (FCOJ) to outside storage while repairs were made. It appears that packinghouses, tank farms and other structures should be evaluated for structural strength to survive hurricane force winds and appropriate reinforcement applied and better construction be used in the future.

Re-establishment of infrastructure damaged by the hurricanes was a necessary and top priority to resume normal grove operations. Damaged irrigation pumps and structures, and drainage system components, damaged farm operations

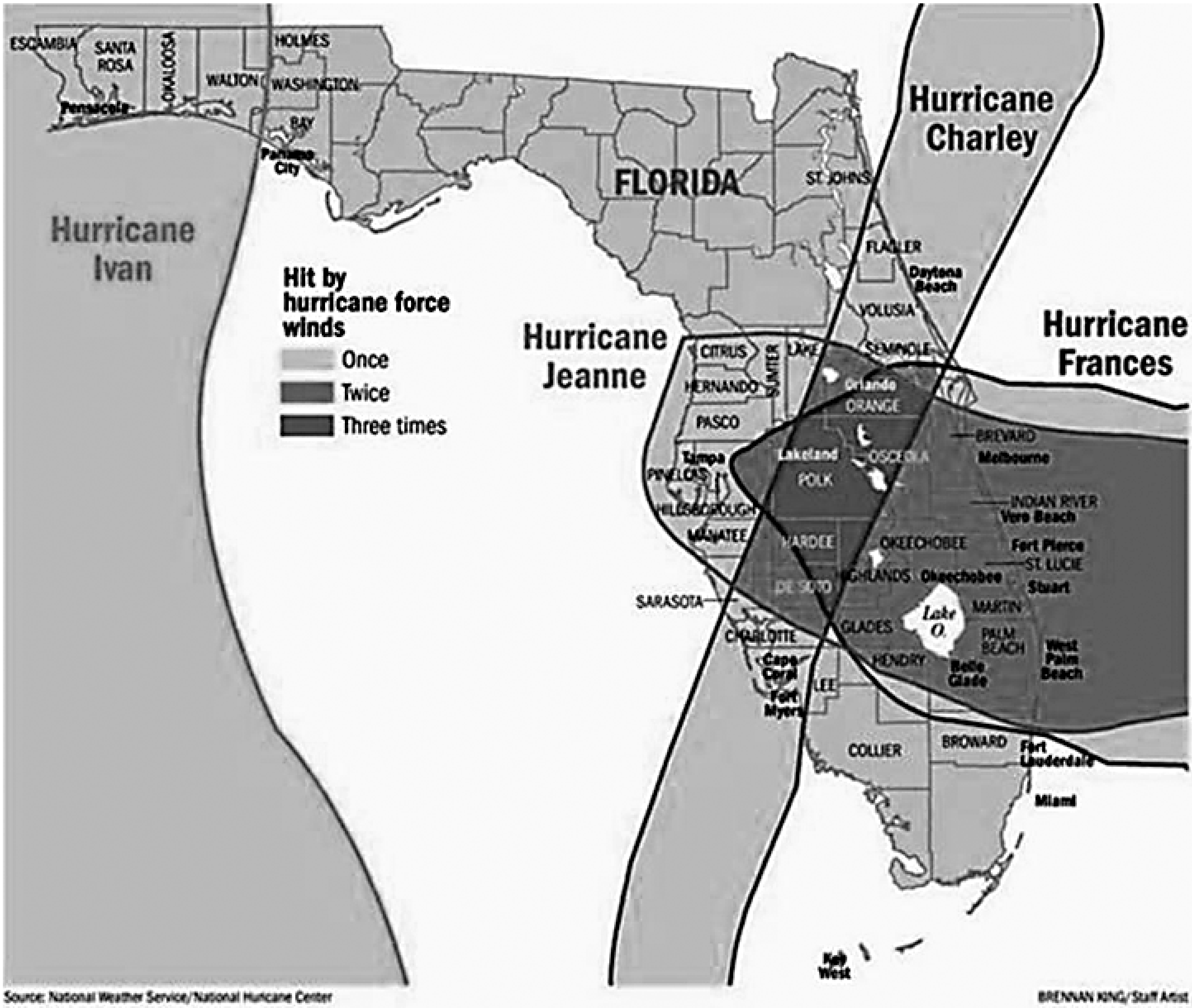

Fig. 1. Paths of four hurricanes that hit Florida in 2004 and the cross over patterns through Florida's citrus areas (Gray and Klotzbach, 2004).

sites, pesticide mix/load sites, and equipment facilities were priorities as growers completed clean-up and resumed normal operations.

Operations

All operations experienced extended periods without electricity from one or more storms. Most growers did not have adequate generating capacity to run their minimal office needs and maintain stable power environments for computer operations (Spyke, 2004). Notebook computers with car battery adapters should be available to lessen some of this deficiency, but would not help immediately where servers are an integral part of the office environment. There are only a few processors who have backup power on-site since the cost is high and the need is, up until last season, relatively rare. Processors evaluated backup electrical requirements with differences primarily depending on FCOJ or Not From Concentrate (NFC) storage. FCOJ is already stored below 32 °F (0 °C) allowing it to go without power for a day or two while backup is brought in. NFC is more critical since it is stored aseptically at a higher temperature, and those storages need backups in place. Most processors have addressed these needs based upon their individual production and made appropriate adjustments.

Any pumps that were electrical, particularly drainage lift pumps, were out of operation for extended periods. East Coast processors and packinghouses often had excess water problems exacerbated during the widespread power failures by only having electric pumps for water removal. Many offices at all industry levels had water intrusion. The extended period without air conditioning to dry out wet insulation and walls led to serious mold development that required major renovation.

Grove equipment was damaged either in collapsed shelters or from wind driven debris. Phone systems were out and cell phone use was limited due to tower damage, lack of backup power, and heavy traffic demands on a strained system. Lack of normal communications during the initial recovery period was particularly stressful.

Planning for the hurricanes was limited, partly due to 40 years without a major hurricane throughout the citrus industry of Florida. Boarding up windows was one universal step, but few if any operations had precut shutters with built in anchorage that would have saved time. Some guidelines were available from experience with Hurricane Andrew's effects on tropical fruit trees (Crane et al., 1993, 1994; Rouse, 2001a, b). Most of the planning was done after the hurricanes started. Administrative, office and equipment repairs, finding needed but scarce supplies, drainage, grove access, and uprighting toppled trees were the highest priorities in that order. Water furrow drains in bedded groves were often plugged with fallen fruit. Screen covers over these pipes would have saved time in keeping these drain pipes open from the decaying fruit in water furrows. This was particularly frustrating because water removal took most of the time and resources initially available in most operations.

All of these activities went on for several weeks, while growers were dealing with similar household disruptions. Throughout the citrus industry, the strain of the hurricane-related issues led to mental fatigue. With the continued loss of fruit and associated harvesting and handling problems, many people were depressed into the winter from the stressful conditions. The Florida citrus industry was able to focus on recovery with the help of storm assistance through the Federal Emergency Management Agency (FEMA), the ability to harvest remaining fruit and market it at higher prices, and the eventual ability to undertake other normal operations.

Fruit Losses

Shortly after the hurricanes, fruit losses were estimated at near 100% in groves nearest the central paths of the hurricanes. Grapefruit was the most affected due to larger fruit size and greatest momentum when pushed by wind gusts. However, oranges and specialty fruit also were blown off of trees. Fruit drop continued for months as damaged twigs and limbs dropped fruit. A later conservative estimate was that 70% of the IR fresh citrus was lost. Fruit loss in DeSoto and Hardee Counties varied from 50 to 70% near the storm center to less than 20% as the distance from the storm center increased to 20 miles.

Grapefruit were hardest hit, with the loss probably being closer to 80% of the 2004 crop. Through Apr. 2005, state-wide fresh grapefruit shipments were 44.6% of the Apr. 2004 levels. Specialty fruit, such as tangerines, lost less, but losses were still significant. Navel oranges were also hit hard. Most of the fruit in the grapefruit and navel trees in the IR were blown off, but lemon trees, particularly, and other varieties didn't lose much fruit. Hamlin fruit removal was usually greater than Valencia perhaps because the Hamlin fruit usually are not held as tightly on the tree as Valencias and they were more mature. Statewide there were 750,000 acres of citrus in Florida, and about 540,000 acres had been damaged in some way by the four hurricanes. Jeanne blew off more oranges and tangerines than Frances, implying that it was more destructive to have higher winds for a short period of time than less wind for a long period of time. In general, fruit were missing from about chest-height and above on the trees, and there was more fruit loss from the outsides of the trees.

In many locations there were actually three sets of dropped fruit on the ground—the fruit that was blown off as the storm went through, the fruit that fell shortly thereafter because the stems were twisted and damaged, and later the fruit that were injured to the point where they could not heal injuries and dropped after decaying. The drop process took several weeks and was part of the reason that the United States Department of Agriculture—Florida Agricultural Statistical Service (USDA-FASS) estimates had to be reduced further after 12 Oct. The industry's large amount of juice in reserves was expected to dampen any juice price rise to consumers, and prices did not rise until later in the season.

Due to continued fruit drop and smaller sizes, the orange and grapefruit forecasts were lowered to 151 and 13 million boxes, respectively, by April of 2005. If we assume that yields were going to be 220 million boxes of oranges and 40 million boxes of grapefruit before the hurricanes, then these yields were reduced by 31 and 68% by the 2004-05 hurricanes. Grapefruit have always been more prone to loss and at least two previous hurricanes had similar impact to the 2004-05 series, but not as much of the industry was impacted. Future USDA-FASS crop estimates will undoubtedly benefit from lessons learned with these experiences.

From the hurricane of 1944, statewide losses included 20% of the orange, 38% of the grapefruit, and 17% of the tangerine crops. Losses were concentrated in Polk, Hardee, DeSoto, and Highlands Counties where 75% of the grapefruit and 25% of the oranges were lost. Hurricane Donna in 1960 was equally devastating, especially to Southwest and Central Florida compared to a 1949 storm. Losses in the most affected counties are shown in Table 3 (Attaway, 1999). These numbers suggest that the proportions of fruit types lost were not unique to the 2004 storms.

Tree Damage

Extensive wind damage occurred in some areas, but tree damage was variable (Syvertsen et al., 2004). Limb and trunk damage from wind was widespread close to the central path of the hurricanes and decreased rapidly, especially for Charley and to a lesser degree for hurricanes Frances and Jeanne, with increased distance from initial landfall and the center of the storm. Tree removal or whole grove replanting may be necessary in some cases. Some lemon tree limbs were broken as the fruit didn't blow off and the limbs were bearing considerable weight. Trees that held their fruit more tightly tended

Table 3. Fruit losses by key affected counties from the 1949 (unnamed) and 1960 hurricanes (Donna).

	Orange (%)		Grapefruit (%)	
County	1949	1960	1949	1960
Lee and Hendry	Y	50	Y	100
Charlotte	Y	40-50	Y	75
DeSoto	Y	40-50	Y	80-90
St. Lucie	52	X	70	X
Indian River	NS	X	40	X
Hardee	NS	40-50	NS	75
Highlands	NS	15-35	52	75-90
Polk	NS	10-20	25	10-95

X = No effect on Indian River District; Y = No effect on West Coast, NS = Not severe.

to not be uprooted but suffered greater limb breakage. The trees with the largest canopies and crops were more severely damaged when compared to smaller or younger trees.

After seeing the devastation in lemons, it appeared as if losing the fruit on grapefruit may have reduced tree injury. Young trees (5-6 years old) which had a large crop, seemed to be damaged a bit more than slightly older trees or trees with a lighter crop. It is possible that the heavy crop on younger trees allowed the limbs to be twisted by the winds more than if the limb had fewer fruit. On the other hand, smaller trees in solid set mature blocks had less damage because they were apparently protected by nearby taller trees. Trees that were recently hedged and topped suffered less damage than tall, overgrown trees, so regular hedging-topping programs may offer some insurance against severe hurricane damage.

Where older trees were damaged by high winds, the location of broken limbs was generally at or near previous freeze or other damage that the trees had sustained. In some cases, one or two large scaffold limbs were broken out. In many of the older trees with five to seven scaffold limbs emerging above the bud union, losses were 16-33% of the canopy volume. Again, this damage varied by block but the damaged limbs occurred on less than 10-15% of the trees in the most affected blocks. Hurricane associated tornados were responsible for some of the block to block variation in damage.

In some areas, entire trees were tipped over or ripped out of the ground. Near the center of Charley, it was interesting to see the low number of trees which had been pushed over with roots exposed. Healthy citrus trees were able to withstand the winds better than the large oak and pine trees. In most groves, the number of trees uprooted was fairly low and in the range of less than 10%, but exceptions with more than 10% uprooted trees occurred. Damage was usually highest along the outer windward sides of the grove, and these outer areas of the grove acted as a wind break for the interior trees. Trees on the south and east ends of blocks in the Gulf area were most damaged, while in the IR District the trees on the north and east sides of the blocks were most damaged. Groves which were solid set with few resets did not receive the damage that a grove with a mixture of tree ages had due to the protection offered by the solid tree rows blocking the wind. Well maintained trees that were healthy before the storm weathered the winds better than weak trees and branches (Syvertsen et al., 2004). Deeply rooted trees suffered less damage than shallow rooted trees. Many previously weakened root systems were exposed.

Experience with re-establishing tipped-over trees after Hurricane Andrew in 1992 indicates it may be worth attempting (Crane et al., 1993). Numerous growers stood trees back up and evaluating this tree rehabilitation process is essential to increase a limited experience base. Unfortunately, no systematic process of evaluation is in place. Second hurricanes or high wind from later storms tipped trees back over if they were not adequately supported.

Tree root system development in relation to wind direction was very important. Trees with asymmetrical root development seemed to blow over more so than those with symmetrical root systems. Tree lifted out of the ground often had few primary roots. Little difference was seen among trees on different rootstocks in several trials, but in one case better root systems did reduce uprooting. In one instance with trees on Benton citrange, there was substantial blow-over, but it appeared due largely to asymmetrical root development. The shallow rooting of trees in the flatwoods did not appear to predispose them to blow over just because of the lack of rooting depth. Many trees of different ages in several trials survived with no apparent structural damage.

Young Tree Damage

Growers had difficulty finding labor to stand up young trees that blew over. Many young trees that Frances blew over were down again after Jeanne. In one case 12,000 young citrus trees blew over and had to be re-planted. The winds from Jeanne were higher than Frances and the ground was totally saturated, so even some newly planted trees blew over in some locations.

Root Flooding

The impact of sustained flooding effects on root survival, tree health and long-term productivity was an area for immediate evaluation and investigation. In the east coast citrus areas, particularly the IR Region, excessive rainfall and rising water tables resulted in standing water in groves for up to a week or longer and roots were re-flooded 3 weeks in a row in September. In the older citrus grove areas, which were planted before modern pumping systems and bedding, water removal was hindered by water pumped from new groves upstream. The storms exceeded the design capabilities of all the drainage system, so everything ran at maximum limits. Backhoes helped clear obstacles in drainage ditches. This process took 3 d for one operation and rigging pumps with tractor PTOs when no other power was available allowed drainage to occur within a week. Water was running over the tops of the flood control structures in the North St. Lucie Water Control District. Groves in the area were completely under water—tree trunk to tree trunk—with water running out of the canals over the top of the roadways. Initial tree recovery under these conditions looks very good, but detrimental long-term effects could develop and growers should carefully monitor the worst flooded blocks, particularly on the heaviest soils.

Roots were undoubtedly damaged in some groves by anaerobic conditions created by these water-logged conditions. It was the opinion of many growers that significant root damage had occurred, and they opted to top and hedge their groves in October-November to balance the tops with the perceived reduction in root system. Soil and root conditions should have been evaluated after the flooding subsided, but often were not before pruning was done. Where root health was evaluated after the storms, it was found that in most cases healthy roots were putting out new growth at least one or two feet down the water furrow side of the trees. A few poorly drained locations did have root loss, but this was not the normal situation. The success of hand labor and tractors on pumps to keep the flood waters moving and most groves drained within a week was sufficient to prevent or minimize serious root loss in most blocks. Cool weather following the hurricanes probably also minimized anaerobic related damage.

Recovery

Re-establishment of Canopy and Whole Tree Balance

A salinity problem may have been created with Frances as the storm picked up an enormous amount of salt from the ocean and deposited it on the trees and soil. Many of the people who witnessed this east coast storm observed that as the storm came through, the sky at night had a green glow. This is a common phenomenon in hurricanes that are coming in from the ocean—the green glow is the phosphorescence, plankton in the seawater that fluoresces green when they are disturbed. If the air was full of plankton, it was also full of seawater. So, the 10-12 inches of precipitation received during the storm probably had a heavy salt load. Fortunately, the heavy rains of Ivan and the fast moving Jeanne should have cleansed the trees and flushed much of the salt out of the soil. Good shoot growth the spring of 2005 confirmed that salt toxicity was apparently not a problem.

One of the most striking phenomena observed was the difference in recovery response between trees on different rootstocks. Sour orange (SO) in particular behaved much differently than Swingle, Carrizo, Cleo, Smooth Flat Seville, or Sun Chu Sha. During the 2004-05 winter, trees on SO were visibly more stressed than trees on other rootstocks. SO trees lost most of their leaves and appeared to be dying back. During the 2005 spring, the trees on the other rootstocks flushed out as soon as warm conditions prevailed while the SO trees did not flush. These declining SO trees suddenly recovered and appeared amazingly healthy. We don't know whether the SO or the other rootstocks behavior was normal nor the reasons for the difference in recovery rate.

As a result of the tremendous wind, many mature citrus leaves were blown off. The percentage of leaf loss appeared to average about 50% in the east coast and less on the west coast where only one storm occurred. Leaf loss was heaviest on the windward side of the trees and in the center of the hurricane paths. Trees may withstand 10-25% defoliation without detrimental effects on next season's yield, however, this may depend upon the seasonal stage of tree development when defoliated (Burns, unpublished). Related to the 2004-2005 crop, defoliation to these levels probably had minimal impact on remaining fruit harvested early, but apparently had a negative impact on soluble solids (SS) accumulation of fruit harvested later. Reportedly, navels and other cultivars had a decrease in SS as fruit volume growth outstripped available SS for accumulation. The tree-fruit behavior will depend on how early a hurricane occurs and how quickly the tree regenerates replacement foliage that will provide photosynthates (Pn) to support fruit development and to produce carbohydrate reserves in shoots for flower bud development. New flush occurred quickly after each hurricane and associated leaf loss, but the last two hurricane stimulated flushes were late in the season and had a short period in which to be strong net Pn producers before cool winter temperatures started. In some cases, a small amount of stress-related bloom developed. The degree to which fall flushes occurred raised several concerns about the impact that this fall flush would have on winter cold-hardiness and ultimately the number of spring flowers to set the 2005-06 crop (Albrigo, 2005). There were no freezes in the winter of 2004-05 to test hardiness and many of the fall flushes were subsequently able to bloom (Salvatore et al., 2005).

Citrus Nutrition after Hurricane Damage

Trees that lost fruit and leaves but had a primarily undamaged root system flushed well and recovered rapidly by the end of spring flush in 2005. Many have set a good crop in the 2005-06 season. Trees without adequate nutrient replacement had very pale leaf color in the spring of 2005. Irrigation and nutrient management is a key. Healthy trees that lost up to half their leaves are recovering rapidly but will need more fertilizer within the next several months as the leaves normally contain a large nutrient reserve (Morgan, 2004; Obreza, 2005). Fertilizer and irrigation water amounts per application should be reduced proportionally to the amount of canopy removed and the expected reduced root system following leaf loss. But overall, trees may require extra N and K for leaf replacement as flushes occur. Frequency of lower rate applications should be increased to supply nutrients slowly as the leaf flushes occur until the trees are again in overall balance. Blocks that did not fruit well for the 2005-06 season should receive less fertilizer.

The N fertilizer rates limited by the Ridge N-BMP rules do not need to be modified for hurricane damaged groves. There is sufficient flexibility in the BMP in the form of the "4-year annual average" N rate, to be utilized in this emergency. This clause in the BMP rule states that "lower or higher rates may be required during a calendar year due to scheduling, horticultural, or climatic factors, but the average annual rate over the four year period may not exceed the maximum rate."

Hurricanes during the wet summer months (15 June to 15 Sept.) should have negligible impact on fertilizer losses by leaching; the soils were likely already depleted by tree uptake and leached by summer rains, and fertilizer application during these months is restricted. Certainly late-season hurricanes (October-November) could have a greater impact on fall fertilizer applications.

With increased tree mortality, using variable rate fertilizer spreaders can best address fertilizer application to only the surviving trees. In groves with heavy tree losses total grove fertilizer requirements per acre should be reduced. Grove middles obstructed by fallen trees can prevent regular granular fertilization. To save time, a useful strategy was to remove debris from every other middle or bed tops and then apply fertilizer on only one side of the trees or the bed top. This permitted quicker grove entry and required only 50% or less of the middles to be cleaned initially.

In summary, growers should modifying the rates per acre according to tree and canopy losses and decrease the rates per application but increase frequency until trees are back to normal canopies and fruit production.

Cropping Potential for Next Season

The spring 2005 bloom was highly dependent on recovery of tree root/shoot balance, proper nutrition, and the balance between lack of late season fruit load this past fall, fall flush development, and reduced leaf area which kept trees from returning to normal physiological patterns (Albrigo, 2005; Buker et al., 2005). Future crops in subsequent years should return to normal to the degree that long-term tree health is restored. Also, while there was a bloom everywhere, it is still too early (June 2005) to tell how much fruit will be retained on the trees. Fruit set is apparently sufficient to prevent a large late bloom.

IR District growers were concerning what long-term economic impacts the hurricane(s) might have on tree productivity. It was proposed to follow the effects of the hurricanes on citrus productivity and recovery over several years. Several mature citrus blocks were identified for which yields and other parameters had been evaluated in previous years. The decline and recovery of yield were to be followed during this and subsequent years. Evaluation parameters included yield, fruit size distribution, internal quality, shelf life, flowering, and canopy development. Some of those flowering recovery results are presented in these 2005 Florida State Horticultural Society Proceedings (Salvatore et al., 2005). The main unanswered question is, how long does it take for a citrus block to become economically profitable and then back to normal production after a hurricane? What are the likely total losses to a citrus grower under the current conditions? As of June 2005, it appears that trees will make considerable recovery this first year.

On the East coast, trees that were severely defoliated and produced a strong post Jeanne flush, had very few if any flowers in 2005 but produced a heavy spring flush. Bloom was heavier on old wood if foliage was damaged or largely missing. Southwest quadrants of trees retained the most foliage, bloomed well and will carry the bulk of the crop in 2005-06. But bloom on spring and summer flush was heavier in tops of trees (areas of fewest leaves) than other parts of the canopy. These flowers may not set well since there are few leaves to support fruit development. Trees sheltered by heavy wind breaks lost few leaves and bloomed heavier than normal. Trees in any given row, however, often did not show a uniform bloom pattern. One tree had ample bloom, the one next to it had some bloom, and the next tree might not have had a single bloom. Much of the variation apparently depended on severity of leaf loss. Very heavy spring flush was observed on all cultivars. If bloom is averaged across a block, and a good fruit set occurs, there should be an average to slightly below average harvest during the 2005-06 season. On the West coast, fall flush matured and flowered along with spring and summer flush resulting in a good initial fruit set. These observations all indicate quick recovery can be expected.

Many growers decided to hedge and top in October-November, shortly after the hurricane stimulated flushes, even though growers were advised to not top and hedge unless they determined that significant root damage had occurred. Observations in March-April of 2005 determined that blocks which were topped and hedged in October-November had significantly less flower formation than blocks hedged and topped in late December or January (Fig. 2). Tremendous vegetative flush was produced on the early hedging and topping surfaces, but apparently at the expense of flower formation. In unpruned or December-January pruned trees, a high percentage of bouquet bloom occurred in mid to late March of 2005. More bloom appeared on the side of the tree (west) where a greater number of mature leaves survived, primarily on the previous spring and summer flush. Flush that had emerged in September and was tattered as a result of the hurricanes did exhibit some flower formation. There was much less flowering observed on the younger flush that emerged after Hurricane Jeanne. Trees which were visually deficient in nutrients did not set a good crop even if they were hedged and topped in late December-January.

As a result of these hurricanes, the entire dynamics of the tree were changed. Removal of a significant portion of mature leaves probably reduced the amount of carbohydrates produced and, therefore, forced the tree to rely on stored carbohydrates. Changing of sink strengths and re-partitioning of carbohydrates probably occurred due to a tremendous amount of young emerging flush, reduced mature crop as well as potentially some root damage. A higher flower formation occurred on the side of the tree where more mature leaves survived, apparently because more leaves provided higher carbohydrate levels to ultimately support flower buds. In the spring of 2005, initial fruit retention generally appeared good, but final fruit set may be reduced because of the reduced leaf area on many of the trees. Appropriate leaf samples were collected and potential reductions in carbohydrate levels will be determined for a future report.

Fig. 2. Profuse flowering when grapefruit tree was hedged in late Dec. 2004 or Jan. 2005 (top) versus flush only from tree hedged in October-November (bottom) after 2 hurricanes in the Fall of 2004.

Pests and Diseases

Wind-blown rain persisted across the state in many episodes. In the spring of 2005, citrus canker was found in many new commercial and residential citrus locations primarily related to spread by hurricane winds. Increased inspection, monitoring and tree removal continue as this is written. Similarly, other citrus diseases that are encouraged by wet weather [Phytophthora root rots, melanose (Phomopsis citri), greasy spot (Mycosphaerella citri)] are likely to have atypical seasons in 2005-06 (Timmer, 2005). Where root damage occurred, potential for fungal invasion should be determined through soil sampling and propagule counts (Graham, 2005). If there is a Phytophthora problem, the use of certain fungicides can improve the situation.

Atypical flushing patterns will likely result in unusual insect pest dynamics, particularly from those that attack new flush [aphids (Toxoptera citricidus), citrus leafminer (Phyllocnistis citrella), psyllids (Diaphorina citri)] (Rogers, 2005). Since some of these insects are disease vectors and systemic disease transmission events might be enhanced, population changes of these insects warrants monitoring.

Following the hurricanes of 2004, the primary arthropod-related pest concerns were to protect new flush needed to aid in tree recovery and to protect the harvestable fruit remaining on the trees. In the areas of the state where large portions of the leaf area was lost, a significant late season flush encouraged Asian citrus psyllid populations which were high from early October into November. Adults of the Asian citrus psyllid are usually present in citrus groves at low levels throughout the year but are typically most abundant during the spring and early summer when new flush is present. New flush is needed by psyllids in order to reproduce and is thus a regulating factor in psyllid population dynamics. As damaged trees began to produce new flush, psyllid populations quickly reached high levels causing damage to a large proportion of the new flush. This damage was most evident on trees in coastal areas that sustained the most leaf loss from the storms; therefore, they produced the most fall flush. In situations where this new flush accounted for more than half of the total leaf area of the tree, foliar applications of insecticides were necessary to control psyllid populations and protect the developing flush.

Immediately following the hurricanes, low levels of rust mites were observed on both fruit and leaves. These low levels of rust mites were likely due to displacement of mites caused by heavy rain and strong wind. However, in a short period of time following the succession of storms, rust mite populations quickly increased on fruit resulting in bronzing of the fruit surface where populations were not closely monitored and controlled.

Populations of both Asian citrus psyllid and rust mite were unusually high in some groves going into the winter months. During the spring flush of 2005, Asian citrus psyllid populations rapidly increased causing damage to new flush in many parts of the state. This rapid buildup of psyllid populations in the spring of 2005 was likely due to higher than normal populations of adult psyllids built up on the fall flush and then having a shorter overwintering period until spring. Rust mite populations were also observed building up on leaves and fruit in May of 2005. However, the resulting higher humidity than normal from high rainfall during the spring of 2005 is likely more of a contributing factor to the early increase in rust mite populations than the lingering effects of the past year's storms.

The Diaprepes root weevil (DRW), *Diaprepes abbreviatus* (L.), in combination with Phytophthora spp. has caused one of the most severe decline syndromes known in Florida citrus. Hurricane survival was evaluated on 4-year-old Hamlin orange trees budded to five rootstocks (C-22, C-32, and C-35 citrange, Cleopatra mandarin, Swingle citrumelo) and treated or not treated for insect suppression in a grove located on a poorly drained clay-loam soil where both DRW and P. nicotianae were present. The trees receiving foliar applied pesticides for adult DRW suppression grew better than the trees receiving only routine horticultural practices. In evaluations conducted during 2003 and 2004, trees receiving chemical protection had a faster growth rate (except those on Cleopatra mandarin), larger tree canopies, fewer adult DRW, and less tree decline than untreated trees. Root injury by DRW larvae appears to facilitate infection by P. nicotianae, and the combination of DRW and P. nicotianae was the primary cause of tree decline. The three 2004 hurricanes caused considerable wind and flooding damage to this experimental grove. Trees receiving chemical treatment for DRW control suffered a disproportionate amount of wind damage (52.4%, i.e., split trunks, broken branches, uprooted) compared to untreated trees (24.7%), probably because they had larger canopies but still had marginal root systems making the trees easy to blow over. These few cases do not justify not treating for Diaprepes.

Weed control was expected to be more critical under trees with heavy leaf loss and increased light penetration (Futch, 2005). Wind disturbance of the ground cover and high rainfall was expected to increase weed seed germination also. Continued rains in the winter and spring favored weed growth. An extra weed control treatment was expected to be necessary for these situations, particularly in the east and west coast groves with high leaf loss. Weed populations did appear heavy in tree rows in groves on the west coast this spring in the central path Hurricane Charley. If root damage has occurred from flooding, disking a grove for weed control will damage the roots most likely to have survived and therefore an extra herbicide application is preferred.

Hurricanes' Impact on Harvesting

The harvesting situation was highly uncertain due to several factors. Reduced crop loads state-wide significantly reduced the fruit supply available for harvest. Partial crop losses within groves required assessment to determine the economics of harvesting the surviving fruit. Higher harvest costs usually occur with lower fruit loads. Availability of harvesting labor, equipment damage, and workers' housing damage affected harvesting. A few groves were not harvested in the 2004-05 crop year due to low yields which would have resulted in very high harvesting costs, but harvest was recommended as long as fruit prices covered harvesting costs (Roka et al., 2004). Scheduling of harvesting in association with packing houses and processing plants was problematic. With reduced crops and damaged facilities, many packing and processing operations scaled back their operations.

Fruit losses were so severe on the east coast that a mechanical harvester in southwest Florida decided not to move his equipment to the east coast this season because insufficient fruit remained on the trees to be economically harvested. Most of these groves were hand harvested. In addition to favorable economic reasons to harvest reduced crops as prices increased, removal of the current crop increases the potential for flowering and fruit set for the following crop.

Growers with lemons ready for harvest could not find packinghouses able to run fruit. Further, most lemons were damaged by the thorns, so they were not satisfactory for fresh use. Use for processing significantly lowered price compared to fresh.

Fruit Quality of Surviving Fruit

With wind damage, standing water, imbedded sand crystals and disease threats, fruit quality was compromised. For example, sand-pitting and wind scar occurred in oranges and grapefruit which were not knocked from the trees. Navels and mandarins were scratched more than other varieties maybe because they are more sensitive to rough handling. A lot of grapefruit had been blown off by Frances, but the grapefruit left on the trees were the fruit that grows inside the canopy of the tree. Inside grapefruit are usually larger in size, flatter in shape, and lower in acidity than the fruit that grows in the periphery of the canopy.

In spite of the high wind scarring and other mechanical peel-related problems in this multiple hurricane year, the demand was so high that buyers accepted more scarred fruit, and therefore pack-outs in several cases were about the same as in previous years.

While the impacts on fruit maturity and quantity were significant (fresh grapefruit shipments reduced by 55% through Mar. 2005), the development of postharvest physiological disorders and decay of fresh citrus was not as severely impacted as originally feared. Peel problems related to excessive water in the groves such as Oleocellosis (Oil Spotting) and Blue Albedo were reported in only a few cases. Concerns of greater fruit dehydration and increased incidence of stem-end rind breakdown did not materialize. Root damage coupled with excessive fall flush might have led to more fruit dehydration. The lack of these fruit problems further supports that less root damage occurred than expected. Packers were encouraged to maintain optimum relative humidity in all degreening and holding environments and to cool fruit quickly after packing to reduce water loss.

There were reports of early season fruit decay problems due to brown rot (Phytophthora), stem-end rot (*Lasiodiplodia theobromae*), and anthracnose (*Colletotrichum gloeosporioides*), in addition to wound-pathogens such as green mold (*Penicillium digitatum*) and sour rot (*Galactomyces citri-aurantii*). However, most packers paid close attention to their decay control and packinghouse practices so that fruit losses after packing and shipping were relatively small.

Overview

Overall, the hurricanes of 2004 caused more but similar results to previous hurricanes. Growers, packers, and processors adjusted to the hardships and managed to salvage a light, but better priced harvest over the 2004-05 season. Tree recovery and prospects for a moderate 2005-06 crop have been good. A major problem that has now surfaced is the serious spread of citrus canker by the winds and rains of the 2004 hurricanes. New finds of infected trees are occurring daily as of June 2005.

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