Preliminary and Regional Reports

Effect of Hurricanes on Commercial Tomato Crop Production in Southern Florida

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ADDITIONAL KEY WORDS. *Solanum lycopersicum*, wind, abiotic stress, risk assessment

SUMMARY. Several experiments were conducted in commercial tomato (*Solanum lycopersicum*) plantings during the 2004–05 and 2005–06 seasons in Immokalee, FL, to understand types of plant damage and potential yield reductions caused by hurricanes. Expt. 1 involved ‘Florida 91’ tomato seedlings damaged during 2004 by hurricane Frances, 15 days after transplanting (DAT). Individual plants were rated and categorized as best, good, or fair, 34 DAT according to plant size and vigor/severity of injury. Ten plants from each category were removed with roots intact, and dry weights were recorded. During 2005, 23 DAT or 8 days after hurricane Wilma, Expt. 2 was conducted to compare rescued and replanted ‘Soraya’ tomato seedlings. Rescued seedlings were left in place after the hurricane and others were removed and replaced with new transplants of the same variety. Expt. 3 (‘Florida 47’) and 4 (‘BHN 586’) involved the contrast of two yield seasons without a hurricane (2004–05) and with hurricane Wilma (2005–06) to estimate the effect of the hurricane damage on tomato 65 and 45 DAT. Fruit was counted, graded by size, and weighed for each experiment from 10 plants/plot. Injury caused by hurricane winds was most evident in Expt. 1 mostly in stem damage below the soil surface showed callous tissue at the site of injury due to plants being whipped around in the planting hole. Plants rated “best” showed greater plant and root dry weight, stem diameter below the injury point, and higher yield of extra large and total marketable fruit at first harvest than plants rated good or fair. Total marketable yields from rescued plants in Expt. 2 were double than that from replanted plants, and fruit matured 20 days earlier for rescued plants indicating that plants injured by Wilma recovered quickly. Hurricane-damaged crops during 2005–06 in Expts. 3 and 4 yielded 60% lower than that of undamaged crops during 2004–05. In the extra large size category, the yields were reduced between 34% and 12% from the previous season. However, hurricane-damaged loss of yield in the extra large category was offset by increased yield in the medium category. It appears that hurricane-damaged plants, when young, were capable of full recovery and normal yields, whereas hurricane-damaged plants, when older at the time injury occurred, were not able to fully recover and eventually produced only half the normal yield.

Southern Florida suffered the effects of four hurricanes during Fall 2004: Charley, Frances, Ivan, and Jeanne (Mitchell and Cantliffe, 2012). Losses in agricultural production occurred during a 7-week period,

beginning with hurricane Charley on 13 Aug. and ending with hurricane Jeanne on 26 Sept. Many Florida vegetable growers replanted damaged crops after the first two hurricanes but decided not to replant after the

third. Even before the fourth hurricane arrived, it was reported that more than \$2 billion were lost by Florida agriculture (Mitchell and Cantliffe, 2012). In Fall 2005, southern Florida suffered another series of three hurricanes: Katrina, Rita, and Wilma. Hurricanes in 2005 were more devastating than those in 2004 with an estimated \$2.2 billion in damage to crops and farms (Mitchell and Cantliffe, 2012). Hurricane Wilma was most damaging to agriculture in southern Florida during the 2004 and 2005 hurricane season. Wilma entered the state on 24 Oct. at Cape Romano near Marco Island in southwestern Florida and exited near West Palm Beach on Florida’s southeastern coast (National Hurricane Center, 2005). Winds did not subside as expected after making landfall and were more intense on the northern side of the storm due to the influence and interaction with a strong cold front moving across the state from north to south. Hurricanes cause direct damage to crops and infrastructure, and displace labor and markets. Although all hurricanes affected vegetable plantings in Florida, Wilma was the most costly in terms of damage to farm structures, power, and communications infrastructures. Continual storm incidences made disease control difficult, leading to reduced yields and fruit quality. Loss of power for coolers and packing houses was a problem, and in the field growers lost plastic mulch, fertilizer, stakes, and power to run irrigation systems. Timing of the hurricane was critical as it happened when vegetable crops were in full production.

Mechanical effects of high winds and hurricanes are well documented on a wide variety of crops (Cleugh et al., 1998), especially those of high value or high acreage that are most susceptible to wind damage: forest products (Everham and Brokaw, 1996), fruit and nut crops (Crane et al., 2001; Reighard et al., 2001; Wood et al., 2001), sugarcane [*Saccharum officinarum* (Moore and Osgood, 1985)], and row crops (Counce et al., 1994; Leihner et al., 1993; Michels et al., 1995). Vegetable crops received less attention and research was often directed toward related issues such as sandblasting or wind erosion, wind-breaks, simulated injury, or opportunistic diseases and insects (Bartolo

and Schweissing, 1998; Greig et al., 1974; Khan et al., 1986; Precheur et al., 1978; Skidmore, 1966). Precheur et al. (1978) exposed young tomato plants grown in pots for 10 or 20 min of wind or wind-with-sand at 30 mph. Wind alone for 20 min caused necrotic lesions to form on leaves but was not sufficiently damaging to remove leaf tissue. Treatments affected plant growth, especially wind-with-sand. Yields were not reported in this study. Greig et al. (1974) also exposed young tomato plants to wind or wind-with-sand at 30 mph, but they were then transplanted after treatment and grown to maturity. Wind alone did not reduce total yield during each of the 2 years of the study but significantly reduced early season yields during 1 year. Wind-with-sand significantly reduced total and early-season yields during each year. Catfacing, defined as a condition involving malformation and scarring of fruit particularly at blossom ends, was also significantly increased by wind and wind-with-sand treatment each year. The objectives of this study were to 1) describe damage to tomato plants and field plantings after exposure to hurricane-force winds, 2) document the extent to which hurricane-damaged tomato plantings were able to recover, and 3) estimate yield losses of rescued plantings in large-scale commercial production conditions in southern Florida.

Materials and methods

Tomato seedlings were transplanted in a commercial farm in southern Florida during the Fall of 2004 and 2005 (Table 1). Hurricane category, dates, duration, wind speed and direction, total rainfall, crop planting, and developmental stages are presented in Table 1.

EXPT. 1. Hurricane Charley occurred after bed preparation (no crop planted), and Frances, Ivan, and Jeanne occurred after crop transplant; however, tomato plants were not staked or supported at the time of these hurricanes (Tables 1 and 2). Tomato plants

that survived Frances (15 DAT) and Ivan (24 DAT) were rated on 24 Sept. and labeled according to plant size and vigor/severity of injury, as best (tallest/leaves damaged), good (medium/leaves and stems damaged, fair (smallest/leaves, stems, shoots, and roots damages), and poor. The sample size consisted of 25 plants per category with four replications. Plants rated poor were not included in this study, because they were not expected to survive or produce marketable fruit. Ten plants per category were removed from beds by hand to maintain an intact root system. Roots were washed to remove soil and potting media remaining in the transplant plug. Injury to plants was most evident on the stem just below the soil surface, and therefore, plant organs were divided into three groups: 1) shoots, stems, and leaves; 2) roots located above stem injury; and 3) roots located below stem injury. All tissues were then oven dried at 130 °F for 7 d and dry weight recorded. Before removing these plants from the field, soil located within 3 inches of the base of each stem was removed and analyzed for soluble salts (bed height was 8 inches).

Three randomly selected plants per category were harvested from the field the same day as those described earlier and examined at the University of Florida's Plant Pathology Laboratory in Immokalee, FL, for presence of potential fungal root or crown pathogens. Ten additional plants of each category were labeled for future sampling for fruit yield and plant dry weight. Fruit from each of these plants were harvested twice, on 8 and 22 Nov. 2004; separated by size into standard market grades of extra large, large, medium, and culls; and counted and weighed (U.S. Department of Agriculture (USDA), 1997). Commercial harvest of tomatoes from

the field prevented a third harvest for the study. Data were subjected to analysis of variance (ANOVA) with mean separation by least significant difference $P \leq 0.05$ (SAS version 9.1; SAS Institute, Cary, NC).

EXPT. 2. Hurricane Wilma occurred on 24 Oct. 2005 (23 DAT); a study was conducted to compare "rescued" and "replanted" seedlings in a randomized complete block design (RCBD) with four replications (Tables 1 and 2). Plants identified as rescued were seedlings transplanted before the hurricane weather but left in place afterward to grow to maturity, however, damaged by the hurricane. Plants identified as replanted were new seedling transplants that took the place of damaged plants. Twelve plants of each type were included in each plot. Ten plants were harvested four times (18 Jan., 10 Feb., 21 Feb., and 7 Mar. 2006) and two times (21 Feb. and 7 Mar. 2006) in the rescued and replanted plants, respectively. Tomato fruit was harvested mature green and separated by size into standard market grades of extra large, large, and medium, and counted and weighed (USDA, 1997). Data were subjected to ANOVA and Student's *t* test $P \leq 0.05$ (SAS version 9.1).

EXPT. 3. Plots were established as part of a larger study involving nitrogen (N) rates and best management practices (BMP) (Table 1 and 2). Treatments consisted of N fertilizer rates of 200, 240, and 270 lb/acre in plots of 0.33 acre during the 2004–05 season and plots of 0.7 acre during the 2005–06 season, both arranged in RCBD with three replications. During the 2005–06 season, an additional 32 lb/acre N was added after the hurricane to compensate for N lost by leaching. Plants planted on 19 Aug. 2005 were exposed to hurricanes Katrina, Rita, and Wilma, but damaged only by hurricane Wilma

Units

To convert U.S. to SI, multiply by	U.S. unit	SI unit	To convert SI to U.S., multiply by
0.4047	acre(s)	ha	2.4711
0.3048	ft	m	3.2808
2.54	inch(es)	cm	0.3937
0.4536	lb	kg	2.2046
1.1209	lb/acre	kg·ha ⁻¹	0.8922
1	mmho/cm	mS·cm ⁻¹	1
1.6093	mph	km·h ⁻¹	0.6214
28.3495	oz	g	0.0353
(°F – 32) ÷ 1.8	°F	°C	(°C × 1.8) + 32

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Table 1. Hurricane name, category, location, dates, wind maximum speed, duration, direction, total rainfall, and tomato age during hurricanes in Immokalee, FL, from August to October of the 2004–05 and 2005–06 seasons. Readings were recorded by the University of Florida/Institute of Food and Agricultural Sciences Florida Automated Weather Network at a height of 33 ft (10.1 m). Maximum wind speeds were then averaged using 1-h intervals and, as a result, may seem low compared with commonly reported “maximum sustained winds.”

Hurricane name	Category ^z /city, state	Date(s)	Wind at Immokalee, FL			Total rainfall (inch) ^y	Tomato age during hurricanes (DAT ^x)
			Category/maximum speed (mph) ^y	Duration (h)	Direction (°)		
Charley	4/Punta Gorda, FL	13 Aug. 2004	1/81.3	8.0	159	0.9	Not crop planted
Frances	2/Hutchinson Island, FL	4–5 Sept. 2004	1/90.6	31.0	272	1.0	15
Ivan	3/Pensacola, FL	14 Sept. 2004	Tropical storm/49.6	8.0	102	0.0	24
Jeanne	3/Hutchinson Island, FL	25–26 Sept. 2004	2/96.0	21.0	253	0.7	46
Katrina	1/Hallandale Beach to North Miami, FL	26 Aug. 2005	Tropical storm/65.4	8.0	91.7	0.0	65
Rita	2/Sabine Pass, TX	20–21 Sept. 2005	Tropical storm/50.8	32.0	77	0.6	40
Wilma	3/Cape Romano, FL	24 Oct. 2005	1/84.8	3.0	239	2.6	23

^zBased on Saffir–Simpson hurricane scale.

^y1 mph = 1.6093 km·h⁻¹, 1 inch = 2.54 cm.

^xDays after transplanting.

Table 2. Summary of tomato production practices and experiment location and hurricane names from Expts. 1 to 4 during Fall 2004–05 and 2005–06 seasons in Immokalee, FL.

Expt. no.	Soil type	Tomato variety	Transplanting date(s)	Distance between plants (inch)/beds (ft) ^z	Mulch type	Irrigation type	Distance from Immokalee, FL (miles) ^z	Hurricanes affect the Expt.
1	Basinger fine sand	Florida 91	21 Aug. 2004	24/6	White-on-black	Drip	20/East	Frances
2	Immokalee, FL, fine sand	Soraya	1 Oct. 2005	24/6	White-on-black	Drip	10/North	Wilma
3 (Farm 1)	Immokalee, FL, fine sand	Florida 47	28 Sept. 2004, 19 Aug. 2005	18/6	White-on-black	Seepage	12/South	Wilma
4 (Farm 2)	Immokalee, FL, fine sand	BHN 586	5 Oct. 2004, 15 Sept. 2005	1.5/5.5	White-on-black	Seepage	18/South	Wilma

^z1 inch = 2.54 cm, 1 ft = 0.3048 m, 1 mile = 1.6093 km.

(Table 1). Ten random plants were harvested each year. Fruit were harvested mature green and separated by size into standard market grades of extra large, large, and medium, and counted and weighed (USDA, 1997). Yields were averaged across all N treatments and used to compare yields between years. Rescued yield was expressed in percentage of replanted plants. Data were subjected to ANOVA and Student's *t* test $P \leq 0.05$ (SAS version 9.1).

EXPT. 4. Similar to Expt. 3 damaged by Wilma, plots were established as part of a larger study involving N rates and BMPs (Tables 1 and 2). Treatments consisted of three N fertilizer rates ranging from 200 to 260 lb/acre in nonreplicated two adjacent blocks of 0.85 acre during 2004–05 and an RCBD with three replications of plots of 5 acres during

2005–06. During the 2005–06 season, an additional 112 lb/acre N was added after the hurricane to compensate for N lost by leaching. Subsample plots were established and marketable yields was recorded as described earlier for Expt. 3. Data were subjected to ANOVA and Student's *t* test $P \leq 0.05$ (SAS version 9.1).

Results

EXPT. 1. Tomato plants were injured by Frances and Ivan with maximum winds in the Immokalee area of ≈ 90 and 50 mph, respectively (Table 1). Winds of Frances were more sustained and longer lasting than any of the other hurricanes during the 2004–05 growing season. Tropical storm Ivan, never closer than 400 miles, was half the intensity and duration of Frances and was not a serious threat to farms in the Immokalee area. Winds from

Jeanne entered the Immokalee area on 25–26 Sept. and were in excess of 90 mph although its duration was shorter than that of Frances.

Plants exposed to hurricane Frances and Ivan showed varying amounts of stem damage. Damage occurred just below the soil line and may be the result of winds whipping the plants. In some areas, plants were not as seriously damaged, but the damage varied from plant to plant without any obvious pattern. For example, plants rated best were located randomly next to plants of all other categories: best, good, fair, and poor.

At the time of examination 34 DAT or 19 d after Frances, plants with damaged stems showed various amounts of callus material at the site of injury. Best-rated roots were thick and fleshy and were located mostly below the section of stem prone to

Table 3. Plant vigor, shoot and root dry weight, stem diameter and soil electrical conductivity (EC) of hurricane-damaged tomato plants harvested from a commercial field 34 d after transplant and 19 d after hurricane Frances.

Apparent plant vigor ^z	Total shoot dry wt	Root dry wt above injury	Root dry wt below injury	Total root dry wt	Stem diam above injury	Stem diam below injury	Soil EC
		(oz/plant) ^y			(inch) ^y		(mmho/cm) ^y
Best	1.29 a ^x	0.009	0.042 a	0.052 a	0.52 a	0.56 a	0.100
Good	0.54 b	0.018	0.016 b	0.035 b	0.43 b	0.38 b	0.112
Fair	0.39 c	0.018	0.008 c	0.026 b	0.43 b	0.28 c	0.107

^zPlants were visually rated at the beginning of the study and divided into three categories according to apparent growth and vigor: best, good, and fair.

^y1 oz = 28.3495 g, 1 inch = 2.54 cm, 1 mmho/cm = 1 mS·cm⁻¹.

^xValues in columns that share at least one letter in common are not significantly different at $P \leq 0.05$. Mean separation by least significant difference. Values are means of 10 single-plant replications.

injury. In contrast, rooting below the damaged area was severely affected in plants rated good and fair, and rooting of these plants was stimulated on stem sections above the injury; however, plants had weaker roots, brown discolorations, lesions, and less dense secondary roots. Only 17% of the total root weight developed above the injury for plants rated best compared with 51% and 69% for plants rated good and fair, respectively. Stem diameter below the injury was greatest for plants rated best compared with those rated good or fair. Nonsignificant differences in soil electrical conductivity (EC) indicated that salt buildup at the base of the plants and around the planting holes may or may not have contributed to this damage (Table 3). Since these measurements were recorded more than 2 weeks after Frances, data may have been different if measured earlier. Plants rated best showed significantly more shoot and root dry weight than plants rated good or fair (Table 3). Plant roots and crowns tested for the presence of potential common soilborne fungi were negative for *Phytophthora* sp. and *Rhizoctonia* sp. (data not shown).

Plants rated best produced significantly higher early yield and larger fruit at first harvest than plants rated good or fair (Table 4). Plants rated good produced 43% less total early yield and 48% less extra large-sized fruit than plants rated best. Plants rated fair produced 46% less total early yield and 67% less extra large-sized fruit than plants rated good. However, at second harvest plants rated good produced 110% higher extra large-sized fruit than plants rated best. Total marketable yields for the second harvest were not significantly different among any of the treatments. First and second harvests occurred during a time when market

Table 4. Plant vigor, marketable and unmarketable yields, and average fruit weight of hurricane-damaged tomato plants from a commercial field. Hurricane Frances occurred 15 d after transplant, and first and second harvests occurred 79 and 93 d, respectively, after transplant.

Apparent plant vigor ^z	Extra large	Large	Medium	Total	Cull	Avg fruit wt (oz) ^y
	(25-lb boxes/acre) ^y					
First harvest						
Best	581 a ^x	64	14 ab	658 a	92	8.4 a
Good	303 b	69	5 b	377 b	60	8.3 a
Fair	100 c	69	35 a	202 b	29	6.4 b
Second harvest						
Best	118 b	125	46	289	21	6.0
Good	248 a	192	72	512	27	6.5
Fair	181 ab	179	75	434	55	6.2
Total harvest						
Best	699 a	191	59	944	113	7.5 a
Good	554 a	263	76	890	87	7.1 b
Fair	281 b	245	110	636	85	6.2 c

^zPlants were visually rated at the beginning of the study and divided into three categories according to apparent growth and vigor: best, good, and fair. Reported yield is based on 3630 plants/acre (8969.9 plants/ha) and 25-lb (11.3 kg) boxes per acre.

^y1 box/acre = 28.0213 kg·ha⁻¹, 1 oz = 28.3495 g.

^xValues in columns and within harvests that are followed by different letters are significantly different at $P \leq 0.05$. Means separation by least significant difference.

prices were high, about \$30 per 25-lb box of green mature extra large fruit for the first harvest and \$40 per box for the second (Fig. 1). These prices would not have been available to growers if the field had been replanted. After the last harvest, there were no significant differences among plants rated best, good, or fair for shoot and root dry weight, stem diameter above the injury, and fresh weight of fruit remaining on each plant (Table 5). By the end of the study, sections of stem below the original injury on some plants rated good or fair appeared to have rotted and decomposed. These plants had lost their original roots and were relying later in the growing season solely on roots and adventitious roots that had developed above the injury point.

EXPT. 2. Although Katrina, Rita, and Wilma affected vegetable plantings in Florida, Wilma occurred later

in the season and had stronger winds (Table 1). Tomato plantings at early stages of growth, from newly planted to almost first harvest, were damaged by Wilma because of the time at which the storm occurred. Strong winds and rain stripped plant beds of plastic mulch and drip irrigation tubing. Damage appeared less severe and plastic mulch more stable where stakes had been installed before the storm. Although plants were damaged at all stages of growth by stripping leaf laminar tissue from petioles and petiolules, small plants were totally stripped of laminar tissue, whereas older plants were moderately to severely stripped. Plant damage was different from that reported during 2004 herein and by Cushman et al. (2005). During Wilma, damaging winds mostly blew north to south, matching the orientation of almost all tomato rows in southern Florida, and caused plants

to stack up against one another within each row. This may have protected plants from the type of stem damage that occurred during the 2004–05 season. Flooding also occurred during

Wilma, but the severity and duration of flooding varied from farm to farm. Most farms prevented further degradation of plants and plant beds by removing water quickly. Short-term

flooding had no obvious effect on plants, but plant beds were often deformed by a loss in structural integrity and probably lost fertilizer salts to leaching.

Young plants injured by Wilma recovered quickly. Two days after the storm, new growth was observed at plant apices and after 8 d plants had produced new leaf growth sufficient to cover almost all evidence of injury. In contrast, replanted seedlings took more than 2 weeks to recover from transplant shock and show new growth. By the time rescued plants grew to the top of the plant stakes, they were ≈ 12 inches taller than replanted plants (data not shown). Harvest of rescued plants started more than 4 weeks before replanted plants (Table 6). Harvests occurred 86 and 109 d after the storm for rescued plants and 120 and 134 d after for replanted plants. Total marketable yields of rescued plants were 33% higher than that of replanted plants. This higher yield was mostly due to four harvests of rescued plants compared with two harvests of replanted plants before the study was ended due to persistently low market prices and abandonment of the field for commercial interests. Average fruit size was unaffected in the extra large size category. However, yields from replanted tomato crops will eventually produce similar or higher yield, but at lower market prices uneconomical for commercial harvesting.

EXPTS. 3 AND 4. Plants at these farms were damaged by Wilma as described earlier in Expt. 2, except these plantings were older. Plants in Expt. 3 and 4 were 65 and 40 DAT when hurricane Wilma occurred, respectively.

Fig. 1. Prices received per 25-lb (11.3 kg) box of US no.1 grade extra large (solid line) and medium-sized (dashed line) tomato grown for the fresh market during the 2004–05 and 2005–06 growing seasons in Florida (U.S. Department of Agriculture, 2006). Timing of commercial harvests in the field in which Expt. 1 was located is indicated by arrows; 1 box/acre = 28.0213 kg·ha⁻¹, \$1/box = \$0.0882/kg.

Table 5. Plant vigor, shoot and root dry weight, stem diameter, and weight of remaining fruit after third harvest, upon termination of study, of hurricane-damaged tomato plants.

Apparent plant vigor ^a	Total shoot dry wt (oz/plant) ^y	Total root dry wt	Stem diam (inch) ^y	Fresh fruit wt (25-lb boxes/acre) ^y
Best	12.0	0.23	0.76	1,500
Good	10.4	0.22	0.74	1,500
Fair	9.6	0.23	0.76	1,510
Significance	NS ^x	NS	NS	NS

^aPlants were visually rated at the beginning of the study and divided into three categories according to apparent growth and vigor: best, good, and fair. Stem diameter was measured at soil line. Yield based 3630 plants/acre (8969.9 plants/ha) and 25-lb (11.3 kg) boxes per acre.

^y1 oz = 28.3495 g, 1 inch = 2.54 cm, 1 box/acre = 28.0213 kg·ha⁻¹.

^xNS = not significantly different at $P \leq 0.05$; mean separation by least significant difference.

Table 6. Marketable yields and average fruit weight comparison of hurricane-damaged tomato plants after being rescued or replanted after hurricane Wilma during the 2005–06 growing season in Immokalee, FL.

Harvest (2006)	Rescued plants, marketable yield ^a					Replanted plants, marketable yield				
	Extra large	Large	Medium	Total	Avg fruit wt (oz) ^x	Extra large	Large	Medium	Total	Avg fruit wt (oz)
	(25-lb boxes/acre) ^y					(25-lb boxes/acre)				
18 Jan.	826	178	94	1,098	8.6	0	0	0	0	-
10 Feb.	475	263	73	811	7.3	0	0	0	0	-
21 Feb.	225	411	177*	813	7.3	799*	389	92	1,281*	7.9
7 Mar.	134	134	231	499	6.7	217*	263*	392*	872*	7.3
Total	1,660*	986*	575*	3,221*	7.8	1,016	652	484	2,153	7.6
Total yield relative to rescued plants ^w	100	100	100	100		61	66	84	67	

^aMarketable yield is mature green fruit plus colored fruit (breaker, turning, pink, and red) minus culls (unmarketable). Values are means of 10-plant subsample areas.

^y1 25-lb (11.3 kg) box/acre = 28.0213 kg·ha⁻¹.

^xExtra large-sized fruit only; 1 oz = 28.3495 g.

^wPercent of rescued yield = (total yield of replanted plants/total yield of rescued plants) $\times 100$.

*Mean separation by Student's *t* test ($P \leq 0.05$) to compare rescued vs. replanted plants by harvest date and tomato size categories.

These plants had not yet reached final height, they were at third or fourth string, and the largest fruit were 1 inch or greater in size. Although plants were also exposed to Katrina and Rita, the plants were not damaged (Table 1). Tomato plants maintained adequate levels of N and potassium (K) even after severe damage (data not shown). Water table depth and soil water tension were not greatly affected by short-duration flooding at these farms, indicating that plant growth was probably affected more by wind than by flooding (data not shown).

Hurricane-damaged tomato plantings during 2005–06 on farms in Expts. 3 and 4 appeared to be less productive than undamaged plantings during 2004–05 on the same farms. Similar to plants in Expt. 2, plants on these farms were pushed against each other

in a direction parallel with the plant beds and may have benefited from this arrangement. Leaf laminar tissue was also moderately to severely stripped from plants similar to plants in Expt. 2. Managers at these farms chose to rescue rather than abandon these plantings, and plants appeared to recover by the time of first harvest. Plants continued to grow to the top of the stakes and normal harvest operations were conducted at the appropriate time.

Total marketable yields of these plantings appeared to be reduced to 57%–52% of that of the previous season for Expt. 3 and Expt. 4, respectively (Tables 7 and 8). In the extra large size category, the yields were reduced between 34% and 12% from the previous season in Expts. 3 and 4, respectively. However, hurricane-damaged plantings' loss of yield in the

extra large category was offset by increased yield in the medium category. Yield of this size category increased by 20%–53% compared with the previous season. Despite yield losses in the extra large size category, average fruit size was unaffected. These observations are in contrast to those from the replant study described earlier. It appears that hurricane-damaged plants, when young, were capable of full recovery and normal yields, whereas hurricane-damaged plants, when older at the time injury occurred, were not able to fully recover and eventually produced only half the normal yield.

Discussion

Plants exposed to hurricane winds showed varying amounts of damage depending on plant age and location on each farm and within each

Table 7. Marketable yields and average weight of extra large fruit from a commercial tomato farm, “Farm 1,” during the 2004–05 and 2005–06 growing seasons in southwestern Florida. The 2004–05 season was not greatly affected by hurricanes but plants during the 2005–06 season were severely damaged by hurricane Wilma. This farm was part of a larger study related to nitrogen rates and best management practices for seepage-irrigated tomato.

Season 2004–05 ^z						Season 2005–06					
Harvest date(s)	Extra large	Large	Medium	Total	Avg fruit wt (oz) ^x	Harvest date(s)	Extra large	Large	Medium	Total	Avg fruit wt (oz)
	(25-lb boxes/acre) ^y						(25-lb boxes/acre)				
27 Dec. 2004	630	87	0	717	7.2	10 Jan. 2006	376	354	159	889	7.2
19 Jan. 2005	988	644	179	1,811	6.8	26 Jan. 2006	199	229	232	661	7.0
8 Feb. 2005	137	125	227	489	5.4	7 Feb. 2006	19	57	99	175	5.0
Total	1,755	856	406	3,017	7.6	Total	594	641	490	1,725	7.2
Total yield relative to 2004–05 season ^w	100	100	100	100			34	75	120	57	

^zMarketable yield is mature green fruit plus red fruit minus culls (unmarketable). Values are means of at least six replications of 10-plant subsample areas.

^y1 25-lb (11.3 kg) box/acre = 28.0213 kg·ha⁻¹.

^xExtra large-sized fruit only; 1 oz = 28.3495 g.

^wPercent of 2004–05 yields = (total yield 2005–06/total yield 2004–05) × 100.

Table 8. Marketable yields and average weight of extra large fruit from a commercial tomato farm, “Farm 2,” during the 2004–05 and 2005–06 growing seasons in southwestern Florida. The 2004–05 season was not greatly affected by hurricanes, but plants during the 2005–06 season were severely damaged by hurricane Wilma. This farm was part of a larger study related to nitrogen rates and best management practices for seepage-irrigated tomato.

Season 2004–05 ^z						Season 2005–06						
	Extra large	Large	Medium	Total	Avg fruit wt (oz) ^x	Harvest date(s)	Extra large	Large	Medium	Total	Avg fruit wt (oz)	
Harvest date(s)	(25-lb boxes/acre) ^y						(25-lb boxes/acre)					
10 Jan. 2005	1520	207	0	1730	8.3	5 Jan. 2006	181	340	223	744	6.4	
28 Jan. 2005	498	352	210	1060	6.1	19 Jan. 2006	30	198	185	413	6.0	
10 Feb. 2005	99	128	255	482	5.1	2 Feb. 2006	44	188	304	536	5.8	
Total	2120	687	465	3270	6.5	Total	255	726	712	1690	6.2	
Total yield relative to 2004–05 season ^w	100	100	100	100			12	106	153	52		

^zMarketable yield is mature green fruit plus red fruit minus culls (unmarketable). Values are means of at least six replications of 10-plant subsample areas.

^y1 25-lb (11.3 kg) box/acre = 28.0213 kg·ha⁻¹.

^xExtra large-sized fruit only; 1 oz = 28.3495 g.

^wPercent of 2004–05 yields = (total yield 2005–06/total yield 2004–05) × 100.

field. Expt. 1 showed that strong, but erratic winds caused injury that was highly localized in stem tissue just below the soil surface. In contrast, Expts. 2, 3, and 4 showed that strong, but straight-line winds caused leaf laminar tissue to be moderately or completely stripped from plants. Other types of damage were observed that were severe enough for producers to consider replanting but were not included in these experiments. Greig et al. (1974) recommended protecting plants from wind erosion until plants were at least 6 weeks old to prevent yield losses. Plants older than 6 weeks were considered established and strong enough to withstand wind damage and capable of producing normal yields (Greig et al., 1974).

Our results show that tomato plants can recover quickly from these injuries and continue normal growth, and these results are consistent with studies of simulated wind damage (Cleugh et al., 1998; Greig et al., 1974; Precheur et al., 1978). Total marketable yields of rescued plants were 33% higher than that of replanted plants; however, replanted plants were harvested two times. As the amount of injury and age of plants increased (in Expt. 3 and 4) our results showed that early yields in the extra large size category appeared to decrease.

In conclusion, tomato plants can sustain considerable wind injury and still recover to produce commercially acceptable yields. Though yields may be reduced compared with undamaged plantings, the potential to capture high prices at a time of limited supply provides a strong incentive to

rescue hurricane-damaged plantings rather than abandon or replant.

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