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# GROWTH AND YIELD OF HURRICANE-DAMAGED TOMATO PLANTS

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*Abstract.* **'Florida 91' tomato seedlings (*Lycopersicon esculentum* L) grown on a commercial farm in south Florida were damaged by hurricane Frances 15 days after transplant (DAT). Plants were observed 34 DAT and placed in one of three categories according to size and apparent injury (best, good, or fair) to assess the ability of these plants to recover. Ten plants of each category were removed with roots intact and dry weights recorded. Fruit from ten other plants of each category were harvested 78 and 92 DAT. At the end of the season, five plants of each category were harvested and dry weights of shoots and roots recorded. Injury caused by hurricane winds was most evident on sections of stem just below the soil surface. Plants rated best exhibited greater plant mass, greater root mass and stem diameter below the injury, and higher yield of extra large and total marketable fruit at first harvest, a time when prices were high, then plants rated good or fair. Plants rated good had greater plant mass, root mass and stem diameter below the injury, and extra large fruit than plants rated fair. At the end of the season, total yield and plant and root dry mass were similar among plants regardless of rating. Investigations of soil-borne diseases were informative but inconclusive. Overall, these results indicate that tomato plants can sustain a surprising amount of wind injury and still produce acceptable yields, though early yields of extra large fruit may be reduced depending on the severity of injury.**

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 (Crane et al., 2001; Reighard et al., 2001; Wood et al., 2001), sugarcane (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), windbreaks, simulated injury, or opportunistic diseases and insects (Bartolo and Schweissing, 1998; Greig et al., 1974; Khan et al., 1986; Precheur et al., 1978; Skidmore, 1996).

Florida suffered the effects of four hurricanes during Fall 2004. Losses to agriculture occurred during a 7-week period, beginning with hurricane Charley on 13 Aug. and ending with Jeanne on 27 Sept. Many vegetable growers along Florida's eastern coast 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 two billion dollars were lost to Florida agriculture (McElroy, 2004). Not all growers chose to replant or abandon their fields and instead some chose to nurse their plantings back to health. This report describes injury, growth, and yield of hurricane-damaged tomato plants under large-scale commercial conditions in southwest Florida.

## Materials and Methods

Tomato seedlings of 'Florida 91' were grown 5 weeks in a commercial transplant production facility and then transplanted to raised beds at a commercial farm near Immokalee, Fla. on 21 Aug. 2004. Beds were 6 inches high, 34 inches wide, and covered with white-on-black plastic mulch. The soil was a Basinger fine sand (sandy, siliceous, hyperthermic, Spodic Psammaquents). Hurricane Charley arrived on 13 Aug. and occurred before the seedlings were transplanted to the field. Hurricanes Frances and Ivan occurred on 5 Sept. and 14 Sept., respectively, some 15 and 24 d after transplant, though hurricane Frances caused by far the greatest damage to plants discussed in this report. Plants were not staked or supported at the time of these hurricanes.

Plants that survived these hurricanes were rated 24 Sept. and labeled according to categories of size and apparent vigor: best, good, fair, and poor (Fig. 1). Plants rated poor, which were small and stunted, were not included in this study because they were not expected to survive or produce marketable fruit. Ten plants of each category were then removed from beds by hand with roots intact. In the lab, roots were washed to remove soil and any potting media still remaining in the original transplant plug. Injury to plants was most evident on the stem just below the soil surface. Plants were divided into three parts: (1) shoots, stems, and leaves, (2) roots

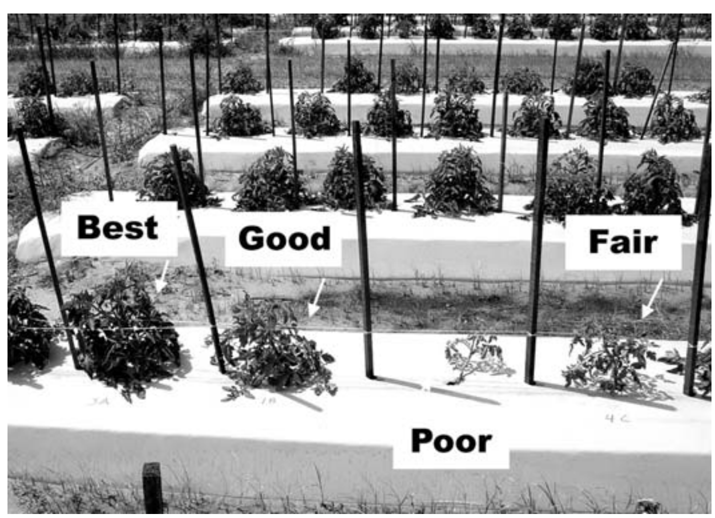


Fig. 1. Rating of hurricane-damaged tomato plants according to plant size and apparent severity of injury at the beginning of the study.

*Corresponding author; e-mail: kecushman@ifas.ufl.edu located above stem injury, and (3) roots located below stem injury. All tissue were then dried in a forced-air, constant-temperature room at 130°F for 7 d and dry mass 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.

Three plants of each category were harvested from the field the same day as those described above and examined by staff of the SWFREC Plant Pathology Lab for presence of potential root or soil borne pathogens. Ten additional plants of each category, located in the same area of the field as those described above, were not removed from the field but were labeled for future sampling for fruit yield and plant dry mass. Fruits from each of these plants were harvested on 8 and 22 Nov., separated by size into standard market grades, and weighed individually. Commercial harvest of tomatoes from the field precluded a third harvest. The ANOVA procedure of SAS v. 8.01 was used for all analyses (SAS Institute, Inc., Cary, N.C.).

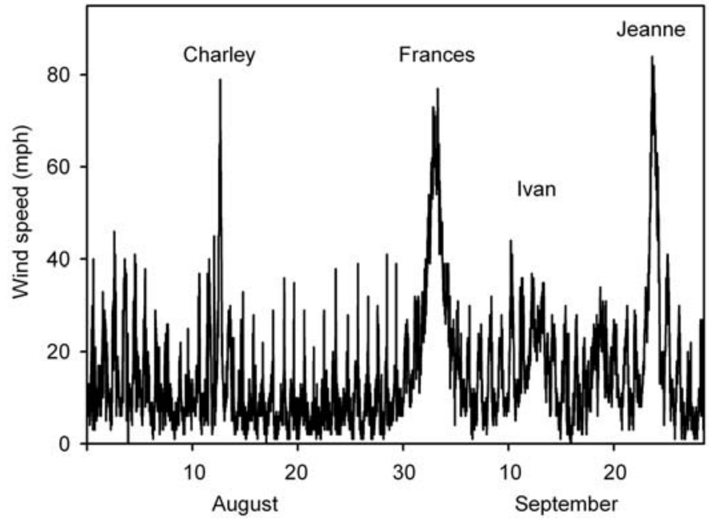


Fig. 2. Wind speed at Immokalee, Fla. during Aug. and Sept. 2004. Readings were recorded by an automated weather system (FAWN) every 15 min. at a height of 33 ft (10 m). There were four named hurricanes during this period.

## Results and Discussion

Winds from hurricanes Charley, Frances, Jeanne and, to some extent, Ivan greatly affected vegetable plantings in southwest Florida, though the intensity and duration of each varied in the Immokalee area (Fig. 2). The path of Charley tracked within 40 to 50 miles of Immokalee, but winds from Charley were not as intense or long lasting as winds from Frances or Jeanne, each of which tracked about 75 or 80 miles from the area.

Tomato plants described in this report were injured by Frances with maximum winds in the Immokalee area of approximately 80 mph. Winds of Frances were more sustained and long lasting than any of the other hurricanes. Winds from Frances originated from the north and slowly rotated to the west, south, and then southeast (data not shown). Hurricane 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 27 Sept. and were in excess of 80 mph. Its duration was half that of Frances.

Plants exposed to these winds exhibited varying amounts of stem damage. Damage occurred just below the soil line and appeared to be the result of plants being whipped around in the planting hole by strong winds. Plants rated best and sampled 34 d after transplant (19 d after Frances) exhibited significantly more shoot and root dry mass than plants rated good or fair (Table 1). Roots of plants rated best were thick and fleshy and were located mostly below the area of the stem that was damaged (Fig. 3). 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. Stem diameter below the injury also varied according the amount of damage incurred. Stem diameter below the injury was greatest for plants rated best compared to those rated good or fair. Measurements of soil EC indicated that salt buildup at the base of the plants and around the planting holes may not have contributed to this damage, though these measurements were recorded more than two weeks after Frances (Table 1).

Plants tested for the presence of common soil-borne pathogens had no evidence of *Phytophthora* spp. (Table 2). Recovery of *Pythium* spp. and *Fusarium* spp. was greater among plants rated fair compared with those rated best. Plants rated good were intermediate. *Pythium* and *Fusarium* spp. are opportunistic organisms that frequently colonize wounded plant tissue, and it is not unusual to identify these pathogens under these circumstances. Slightly greater recovery of bacteria occurred in plants rated best and good than in plants rated fair. The number of plants sampled for disease ratings was too small to draw firm conclusions.

Plants injured by Frances and rated best produced significantly more early yield and larger fruit at first harvest than

Table 1. Shoot and root dry mass and soil 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] | Shoot dry mass (oz/plant) | Root dry mass above injury (oz/plant) | Root dry mass below injury (oz/plant) | Root dry mass Total (oz/plant) | Stem diameter above injury (in) | Stem diameter below injury (in) | Soil EC ($dS \cdot g^{-1}$) |
|---|---|---|---|---|---|---|---|
| Best | 1.29 a[y] | 0.009 a | 0.042 a | 0.052 a | 0.52 a | 0.56 a | 0.100 a |
| Good | 0.54 b | 0.018 a | 0.016 b | 0.035 b | 0.43 b | 0.38 b | 0.112 a |
| Fair | 0.39 c | 0.018 a | 0.008 c | 0.026 b | 0.43 b | 0.28 c | 0.107 a |

[z]Plants were visually rated at the beginning of the study and divided into three categories according to apparent growth and vigor: best, good, and fair.
[y]Values in columns followed by different letters are significantly different at $P \leq 0.05$. Means separation by Least Significant Difference. Values are means of ten replications.

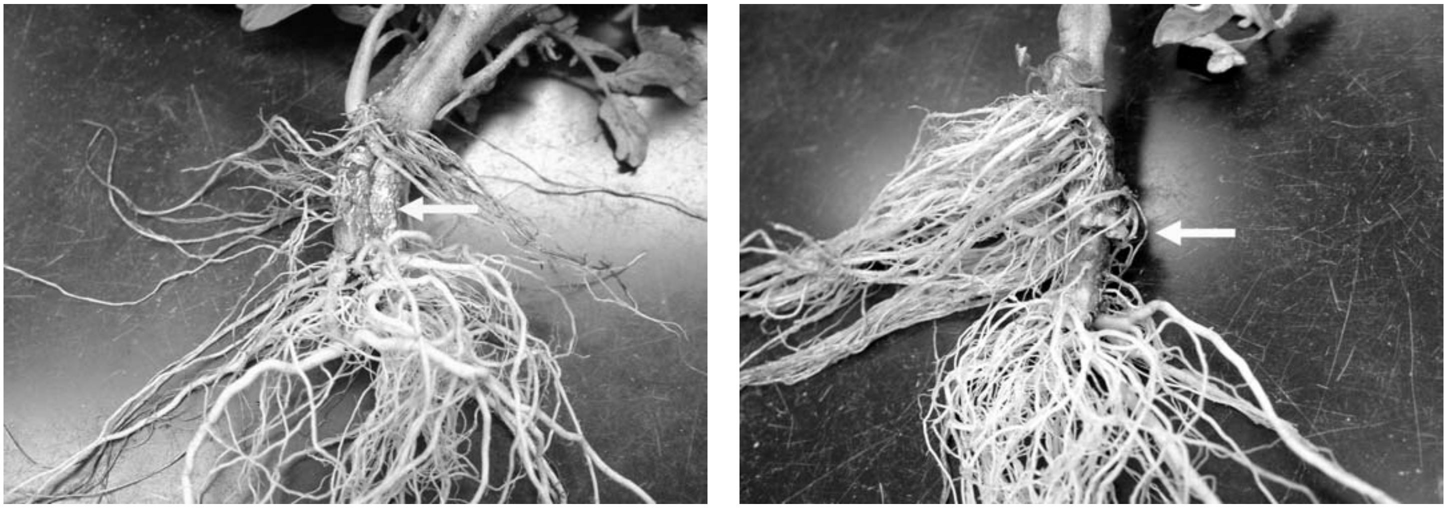

Fig. 3. rooting of tomato plants rated best (left) and fair (right) 34 d after transplant and 19 d after hurricane Frances. Note small calloused area on stem section located just below soil line on the plant rated good compared to large calloused area on plant rated fair (arrows). Note also differences in stem diameter above and below injury on plants rated fair. Plants rated good (not shown) were intermediate to those rated best and fair.

plants rated good or fair (Table 3). 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. At second harvest, however, plants rated good produced 110% higher extra-large sized fruit than plants rated best. Total yields for the second harvest were not significantly different among any of the treatments.

Upon reflection, it was a wise decision by the production manager of this farm to nurse hurricane-damaged plants back

Table 2. Recovery of microorganisms from hurricane-damaged tomato plants harvested from a commercial field 34 d after transplant and 19 d after Hurricane Frances. Three plants of each category were tested for the presence of potential pathogens.

| | Phytophthora | | Pythium | | Fusarium | | Bacteria | |
|---|---|---|---|---|---|---|---|---|
| Apparent plant vigor[z] | +[y] | - | + | - | + | - | + | - |
| Best | 0 | 3 | 0 | 3 | 1 | 2 | 1 | 2 |
| Good | 0 | 3 | 1 | 2 | 2 | 1 | 1 | 2 |
| Fair | 0 | 3 | 2 | 1 | 3 | 0 | 0 | 3 |

[z]Plants were visually rated at the beginning of the study and divided into three categories according to apparent growth and vigor: best, good, and fair.
[y]Presence or absence of fungi or bacteria recovered from plant tissue plated on selective media.

Table 3. First, second, and total harvest yields 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] | Medium (boxes/acre) | Large (boxes/acre) | X-large (boxes/acre) | Total (boxes/acre) | Cull (boxes/acre) | Avg. fruit wt. (oz) |
|---|---|---|---|---|---|---|
| | | | First harvest | | | |
| Best | 14 ab[y] | 64 a | 581 a | 658 a | 92 a | 8.4 a |
| Good | 5 b | 69 a | 303 b | 377 b | 60 a | 8.3 a |
| Fair | 35 a | 69 a | 100 c | 202 b | 29 a | 6.4 b |
| | | | Second harvest | | | |
| Best | 46 a | 125 a | 118 b | 289 a | 21 a | 6.0 a |
| Good | 72 a | 192 a | 248 a | 512 a | 27 a | 6.5 a |
| Fair | 75 a | 179 a | 181 ab | 434 a | 55 a | 6.2 a |
| | | | Total | | | |
| Best | 59 a | 191 a | 699 a | 944 a | 113 a | 7.5 a |
| Good | 76 a | 263 a | 554 a | 890 a | 87 a | 7.1 b |
| Fair | 110 a | 245 a | 281 b | 636 a | 85 a | 6.2 c |

[z]Plants were visually rated at the beginning of the study and divided into three categories according to apparent growth and vigor: best, good, and fair. Yield based on 3630 plants/acre and 25-lb boxes.
[y]Values in columns followed by different letters are significantly different at $P \leq 0.05$. Means separation by Least Significant Difference. Values are means of ten replications.

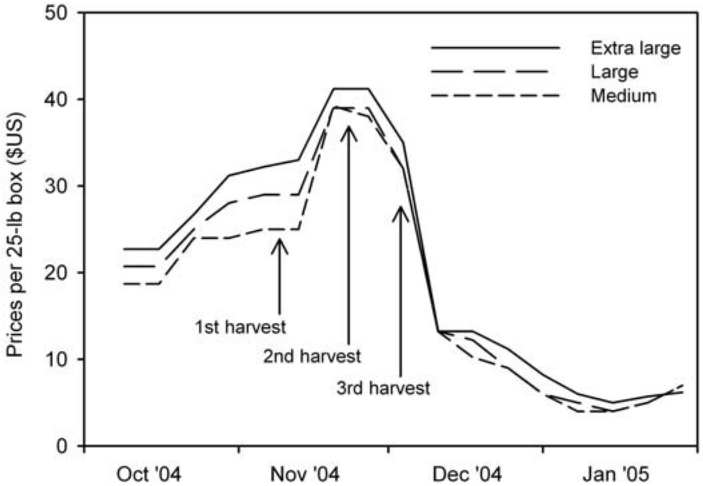


Fig. 4. Prices for mature green tomatoes per 25-lb box, US #1 grade, during the period when plants in this study were evaluated and harvested, 2004 to 2005 (Source: F. Roka, pers. comm., compiled from USDA/AMS Market News Reports).

Fig. 5. Tomato plants on the same farm that escaped injury by hurricane Frances but were damaged later by hurricane Jeanne. It was decided to replace plants in the foreground, but those in the background were salvaged and remained in place for the duration of the season.

to health rather than replant the field. Early yield from these plants occurred during a time when market 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. 4). These prices would not have been captured if the field had been replanted. Prices at the time of the third harvest were still high but declined rapidly.

It was observed that the production manager was quick to adjust the farm's normal water, fertilizer, and pest control programs in response to the needs of the damaged crop. First, moisture content of plant beds was increased to ensure that roots arising from above the damaged areas of plant stems, located at or near the surface of the plant bed, would not dry out. Second, a complete nutrient mix was applied via drip irrigation because it was not assumed plants could easily access nutrients already present in the plant bed. Third, the farm's pest control program was adjusted to minimize further damage caused by opportunistic pathogens invading fresh wounds and weakened plants.

The rating system used in this research—best, good, and fair—was an arbitrary rating system based on obvious differences among individual plants at the beginning of the study. In addition, it cannot be known how damaged plants would perform compared to those not damaged by hurricane-force winds. Despite these limitations, it is clear that the amount of damage sustained by plants varied greatly. Plants rated best produced greater early yields than plants rated fair and these plants may have produced greater total yields if yield from the third harvest had been recorded. Yields of plants rated good and fair appeared to recover, but yields appeared delayed compared to that of plants rated best. In conclusion, tomato plants can sustain a surprising amount of wind injury and still recover, producing high yields when growing conditions are carefully managed. Damage to plants was highly localized in an area of stem tissue just below the soil surface. As injury increased, early yields decreased. Early yield of extra-large sized fruit was especially sensitive to amount of injury sustained. After the third harvest, all plants had recovered and significant differences in shoot or root growth were not detected among plants rated best, good, or fair (Table 4). Finally, plants described in this report were mostly affected by Frances. Plants on the same farm and located less than a mile away were affected to a greater extent by Jeanne (Fig. 5).

Table 4. Shoot and root dry mass, stem diameter, and weight of remaining fruit after third harvest, upon termination of study, of hurricane-damaged tomato plants.

| Apparent plant vigor[z] | Shoot dry mass (oz/plant) | Root dry mass Total (oz/plant) | Stem diameter (in) | Fresh fruit wt. (boxes/ac) |
|---|---|---|---|---|
| Best | 12.0 a[y] | 0.23 a | 0.76 a | 1500 a |
| Good | 10.4 a | 0.22 a | 0.74 a | 1500 a |
| Fair | 9.6 a | 0.23 a | 0.76 a | 1510 a |

[z]Plants 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 on 3630 plants/acre and 25-lb boxes.
[y]Values in columns followed by different letters are significantly different at $P \leq 0.05$. Means separation by Least Significant Difference. Values are means of five replications.

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