YIELDS OF HURRICANE-DAMAGED TOMATO CROPS IN SOUTHERN FLORIDA

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Additional index words. Lycopersicon esculentum, fruit yield, wind damage

Abstract. In 2005, Florida agriculture experienced a second year of devastating hurricanes with $2.2 billion in damage to crops and farms. Hurricane Wilma occurred on 24 October 2005 and stripped tomato (Lycopersicon esculentum L) plants of leaf tissue. A study was installed 8 days after Wilma to compare tomato seedlings that were either rescued or replanted. In addition, data from two seepage-irrigated tomato farms during two seasons (2004-2005 and 2005-2006) were used to estimate the effect of severe wind damage on commercial tomato yields. Fruits were counted, graded by size, and weighed in each experiment. Total marketable yields from rescued plants were almost twice that of replanted plants, indicating rescued plants recovered quickly. Replanted plants delayed harvest compared to rescued plants. Hurricane-damaged crops during 2005-2006 consistently yielded 60% lower than undamaged crops during 2004-2005. Reduced yield was mostly in the extra-large size category; though yield of large- and medium-sized fruit increased by 20% to 53% over that of the 2004-2005 season. Petiole sap data indicated that plants received adequate nutrition after the hurricane and plant nutrition did not limit yield. Results indicate seepage-irrigated tomato plantings can be rescued after hurricanes though yield may suffer in the extra-large size category.

In 2005, Florida agriculture experienced a second year of hurricanes, causing an estimated $2.2 billion in damage to crops and farms. Hurricane Wilma was the most devastating storm of the season, entering the state 24 Oct. 2005 at a location near Marco Island and exiting near West Palm Beach. Winds did not subside after making landfall and were more intense on the northern side of the storm due to the influence of, and interaction with, a strong cold front moving across the state from north to south. Timing of the hurricane made it especially damaging to vegetable producers because it came when tomato crops were in full production. Wind gusts of 100 miles/hr and rainfall of about 8.1 inches were recorded at the Southwestern Research and Education Center in Immokalee. Tomato fruit and leaf tissue were stripped from plants and some fields were flooded for more than 8 h. Retail tomato prices after the storm increased from $1.36 to $3.64 per lb.

Past research under laboratory conditions have limited application to hurricane-force winds and field plantings. Prechur et al. (1978) exposed young tomato plants grown in pots to 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, but dry weight of plants was not significantly reduced 5 d after treatment. 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 two years of the study but significantly reduced early season yields during one year. Wind-with-sand significantly reduced total and early season yields during each year. Fruit deformation (catfacing) was also significantly increased by wind and wind-with-sand each year. The objective of this study was to examine yields of hurricane-damaged tomatoes with that of tomatoes planted after the hurricane under large-scale commercial conditions in southern Florida.

Materials and Methods

Replant Study

Tomato seedlings of cv Soraya were transplanted 1 Oct. 2005 on a large-scale commercial farm located about 10 miles north of Immokalee, Fla. The crop was grown using typical raised-bed and white-on-black, white side up, polyethylene mulch cultural practices and drip irrigation. Plants were spaced 2 ft apart in rows spaced 6 ft apart. Eight days after Wilma, on 2 Nov. 2005, a study was installed to compare rescued and replanted seedlings in a randomized complete block design with four replications. Plants identified as ‘rescued’ were original transplants damaged by wind and left in place to grow to maturity after the storm. Plants identified as ‘replanted’ were undamaged transplants of the same cultivar. Hurricane-damaged plants were removed and these undamaged transplants were planted in their place and then grown under the same care and conditions as rescued plants. Plant beds at this farm were arranged in groups of three with drive rows between each group. Plots were 24 ft long, established in the center row of a three-row set, and contained 12 rescued or replanted plants. Percent of rescued yield was calculated as total yield of replanted plants divided by total yield of rescued plants and expressed as a percent.

Farms 1: Yield Comparison 2004-05 and 2005-06 Seasons

Tomato seedlings of cv Florida 47 were transplanted 28 Sept. 2004 and 19 Aug. 2005 on a large-scale commercial farm located about 12 miles south of Immokalee, Fla. The crop was grown using typical raised-bed and white-on-black, white side up, polyethylene mulch cultural practices with seepage irrigation. Plants were spaced 1.5 ft apart in rows spaced 6 ft apart.
Plots were established as part of a larger study involving N rates and best management practices (BMP). Treatments consisted of N fertilizer rates of 200, 240, and 270 lb/acre in two adjacent blocks of 0.33 acre for the 2004-2005 season and a completely randomized experimental design in blocks of 0.7 acre with three replications for the 2005-2006 season. During the 2005-2006 season an additional 32 lb/acre was added after the hurricane to compensate for the loss of N. Two 10-plant subsample plots were harvested within each treatment, and fruit were graded, counted, and weighed at time of harvest. Plots were 16 ft long and marked to prevent unscheduled harvests by commercial crews. Marketable tomatoes were graded in the field according to USDA specifications of number and weight of extra-large (5 x 6), large (6 x 6), and medium (6 x 7) fruit (USDA, 1997). Data from these BMP trials were averaged across all N treatments and presented by year. Statistical analyses were not performed due to lack of replication across year. Fresh petiole sap concentrations for NO$_3$-N and K of the crops beginning at first flower buds and continuing until first harvest were assessed bi-weekly using specific ion meters (Cardymeter, Spectrum Technologies, Inc., Plainfield, Ill.). Percent of undamaged yield was calculated as total yield of hurricane-damaged plants divided by total yield of undamaged plants and expressed as a percent.

Farm 2; Yield Comparison 2004-05 and 2005-06 Seasons

Tomato seedlings of cv BHN 586 were transplanted 5 Oct. 2004 and 15 Sept. 2005 on a large-scale commercial farm located about 18 miles south of Immokalee. The crop was grown using typical raised-bed and white-on-black polyethylene mulch, white side up, cultural practices with seepage irrigation. Plants were spaced 1.6 ft apart in rows spaced 5.5 ft apart. As described above, plots were established as part of a larger study involving N rates and BMP. Treatments consisted of N fertilizer rates ranging from 200 to 260 lb/acre in two adjacent blocks of 0.85 acre for the 2004-2005 season and a completely randomized experimental design of 5 acres with three replications for the 2005-2006 season. During the 2005-06 season, an additional 112 lb/acre N was added after the hurricane to compensate for the loss of N. Tomatoes were harvested from six plots in each treatment. Values were averaged across all N treatments and used to calculate yields of each size category and to calculate total yield.

Fresh petiole sap concentrations for NO$_3$-N and K of the crops at first flower buds and continuing until first harvest were assessed weekly using specific ion meters (Cardymeter, Spectrum Technologies, Inc., Plainfield, Ill.). Tomatoes were harvested from 10-plant plots. Plots were 16 ft long and marked to prevent unscheduled harvests by commercial crews. Marketable tomatoes were graded in the field according to USDA specifications of number and weight of extra-large (5 x 6), large (6 x 6), and medium (6 x 7) fruit (USDA, 1997). As with Farm 1, percent of undamaged yield was calculated as total yield of hurricane-damaged plants divided by total yield of undamaged plants and expressed as a percent.

Results and Discussion

Hurricane Damage

Hurricane Wilma occurred later in the growing season and was more severe in the Immokalee area than hurricanes Katrina during 2005 or Charley, Frances, or Jeanne during 2004 (Fig. 1). Each of these storms greatly affected vegetables grown in south Florida, though Wilma was the most costly in terms of damage to farm structures, power and communications infrastructures, and established vegetable plantings (FFVA, 2005). Tomato plantings at almost every stage of growth, from newly planted to first harvest, were damaged by Wilma because of the time at which the storm occurred.

Strong winds and rain stripped plant beds of polyethylene mulch and drip irrigation tubing (Fig. 2a). Damage appeared less severe and polyethylene mulch more stable where stakes had been installed before the storm (Fig. 2b). Plants were damaged at all stages of growth by stripping leaf laminar tissue from petioles and petiolules, though the amount of leaf tissue stripped from plants varied. Small plants were totally stripped of laminar tissue whereas older plants were moderately to severely stripped (Fig. 2c, d). Plant damage was different than that reported during last year’s storms where plants were whipped around in the planting hole and stems were injured at and below the soil line (Cushman et al., 2005). During Wilma, damaging winds occurred mostly in the direction north to south, matching the north/south orientation of almost all tomato rows in southern Florida, and caused plants to stack up against one another within each row (Fig. 2e-g). This may have protected plants from the type of stem damage that occurred during the 2004-2005 season. Flooding also occurred during Wilma but the severity and duration of...
Fig. 2. Wind- and flood-damaged tomato plant beds with (a) and without (b) stakes installed before hurricane Wilma. Tomato leaves from young (c) and older (d) plants stripped of laminar tissue. Pictures of leaves were taken 2 days after the storm. Examples of older plants from first to fourth string on commercial farms in southwestern Florida with varying severity of damage (e, f, and g). Note loss of integrity of plant bed shoulders due to flooding in e and f. Strong winds occurred north to south, in the same direction as row orientation. An unplanted transplant, on left, compared to two established but hurricane-damaged transplants that had been left in place since the storm, on right, and then removed eight days after storm (h).
flooding varied from farm to farm. It appeared that many production managers were able to remove water quickly from tomato fields and prevent further degradation of plants and planting beds. Short-term flooding had no obvious effect on plants but plant beds were often deformed by a loss of integrity at the outer edges or “shoulders” (Fig. 2e, f).

Replant Study

Young plants injured by Wilma recovered quickly even though leaves had been mostly stripped of laminar tissue leaving intact only petioles and petiolules. Two days after the storm new growth was observed at plant apexes and after eight days plants had produced enough new leaf growth to cover almost all evidence of injury (Fig. 2h). In contrast, replanted seedlings took more than two weeks to recover from transplant shock and begin to exhibit new growth. By the time rescued plants grew to the top of the plant stakes, before first harvest, replanted plants were about 12 inches shorter. Fruit yield of first and second harvests followed a similar trend as plant growth, with harvest of rescued plants occurring more than three weeks before replanted plants (Table 1). The first two harvests occurred 86 and 109 d after the storm for rescued plants and 120 and 134 d after for replanted plants. Accounting for the 8 d from when the storm occurred to when the replanted plants were transplanted to the field, this is a difference of about 20 d between rescued and replanted treatments for each harvest.

In addition, total marketable yields from rescued plants were almost twice that of replanted plants, but this was a result of rescued plants being harvested four times and replanted plants being harvested just two times before the study was ended due to persistently low market prices (Table 1). Total marketable yields of the replanted plants would have been higher if they had been harvested a third or fourth time. Average fruit size was not affected in the extra-large size category.

Farms 1 and 2: Yield Comparison 2004-05 and 2005-06 Seasons

Petiole sap NO$_3$-N and K concentrations tended to be above UF-IFAS sufficiency threshold levels during the 2005-2006 seasons at Farms 1 and 2 (Fig. 3a, b). Hurricane damage to plants and wet soil conditions after the hurricane did not cause petiole sap nutrient concentrations to fall below the sufficiency range. These plant-based data suggest that tomato plants maintained adequate levels of N and K even after severe plant damage due to the storm. In addition, water table levels and soil water tension were not greatly affected by short-duration flooding at these farms (Fig. 3c, d), indicating that plant growth may have been affected more by wind than by flooding.

Hurricane-damaged tomato plantings during 2006 on farms 1 and 2 appeared to be far less productive than undamaged plantings during 2005 on the same farms. Total marketable yields of plants with fruit about 1 inch or greater in size when the storm occurred were reduced to 52% to 57% of that of the previous season (Tables 2 and 3). Reduced yield was

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**Table 1. Yield comparison of hurricane-damaged plants after being rescued or replanted during the 2005-2006 season in Immokalee.**

<table>
<thead>
<tr>
<th>Harvest (2006)</th>
<th>Extra-large</th>
<th>Large</th>
<th>Medium</th>
<th>Total</th>
<th>Avg fruit wt (oz) $^y$</th>
<th>Extra-large</th>
<th>Large</th>
<th>Medium</th>
<th>Total</th>
<th>Avg fruit wt (oz) $^y$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan. 18</td>
<td>826</td>
<td>178</td>
<td>94</td>
<td>1098</td>
<td>8.6</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>—</td>
</tr>
<tr>
<td>Feb. 10</td>
<td>475</td>
<td>263</td>
<td>73</td>
<td>811</td>
<td>7.3</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>—</td>
</tr>
<tr>
<td>Feb. 21</td>
<td>225</td>
<td>411</td>
<td>177</td>
<td>813</td>
<td>7.3</td>
<td>799</td>
<td>389</td>
<td>92</td>
<td>1281</td>
<td>7.9</td>
</tr>
<tr>
<td>Mar. 7</td>
<td>134</td>
<td>134</td>
<td>231</td>
<td>499</td>
<td>6.7</td>
<td>217</td>
<td>263</td>
<td>392</td>
<td>872</td>
<td>7.3</td>
</tr>
<tr>
<td>Total</td>
<td>1660</td>
<td>986</td>
<td>575</td>
<td>3221</td>
<td>7.8</td>
<td>1016</td>
<td>652</td>
<td>484</td>
<td>2153</td>
<td>7.6</td>
</tr>
</tbody>
</table>

Yield as %$^x$ $^z$

$^x$Marketable yield is mature green fruit plus colored fruit (breaker, turning, pink, red) minus culls (unmarketable). Values are means of 1 to 4 replications of 10-plant subsample areas.

$^y$Extra-large sized fruit only.

$^z$Percent of rescued yield = (total yield of replanted plants/total yield of rescued plants)*100.

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**Fig. 3. NO$_3$-N and K petiole sap concentrations, water table depths, and soil tension for Farms 1 (solid line) and 2 (dashed line) during winter 2005-2006. Grayed areas represent approximate nutrient sufficiency ranges for Florida tomatoes (Hochmuth et al., 2004). Soil water tension was not available for Farm 1.**
mostly in the extra-large size category, which was reduced to 12% to 34% of that of the previous season. Hurricane-damaged plantings appeared to compensate for loss of yield in the extra-large category by increased yield in the medium category. Yield of this size category increased by 20% to 53% over that of the previous season. Despite yield losses in the extra-large size category, average fruit size was not affected. These observations are in contrast to those from the replant study described above. 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.

In conclusion, young tomato plants can not only survive the effects of severe wind injury but also recover fully and produce high yields of high quality fruit. Older plants can also recover, but yields appeared to be reduced by about half, especially in the extra-large size category. This is opposite of that reported by Greig et al. (1974) where it was recommended to protect plants from wind erosion until they 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. Winter weather after hurricane Wilma was almost ideal, with relatively warm and sunny days and few rain or freeze events. The weather appeared to help growers rescue their hurricane-damaged crops. Businesses that harvested tomatoes before mid January were rewarded with high prices, but afterwards prices fell quickly to a low level (Fig. 4). The potential to capture high prices provides a strong incentive to rescue hurricane-damaged plantings, even when yields are reduced, so as not to jeopardize returns from early harvests.

Table 2. Marketable yields and average fruit weight from a commercial tomato farm, “Farm 1”, during the 2004-2005 and 2005-2006 growing seasons in southwestern Florida. The 2004-2005 season was not greatly affected by hurricanes but plants during the 2005-2006 season were severely damaged by hurricane Wilma. This farm was part of a larger study related to nitrogen rates and BMPs for seepage-irrigated tomato.

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<thead>
<tr>
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<tbody>
<tr>
<td></td>
<td>Extra-large</td>
<td>Large</td>
</tr>
<tr>
<td>27 Dec. 2004</td>
<td>630</td>
<td>87</td>
</tr>
<tr>
<td>19 Jan. 2005</td>
<td>988</td>
<td>644</td>
</tr>
<tr>
<td>8 Feb. 2005</td>
<td>137</td>
<td>125</td>
</tr>
<tr>
<td>Total</td>
<td>1755</td>
<td>856</td>
</tr>
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</table>

Yield as %

1Marketable yield is mature green fruit plus red fruit minus culls (unmarketable). Values are means of at least 6 replications of 10-plant subsample areas.
2Extra-large sized fruit only.

Table 3. Marketable yields and average fruit weight from a commercial tomato farm, “Farm 2”, during the 2004-2005 and 2005-2006 growing seasons in southwestern Florida. The 2004-2005 season was not greatly affected by hurricanes but plants during the 2005-2006 season were severely damaged by hurricane Wilma. This farm was part of a larger study related to nitrogen rates and BMPs for seepage-irrigated tomato.

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<tbody>
<tr>
<td></td>
<td>Extra-large</td>
<td>Large</td>
</tr>
<tr>
<td>10 Jan. 2005</td>
<td>1520</td>
<td>207</td>
</tr>
<tr>
<td>28 Jan. 2005</td>
<td>498</td>
<td>352</td>
</tr>
<tr>
<td>10 Feb. 2005</td>
<td>99</td>
<td>128</td>
</tr>
<tr>
<td>Total</td>
<td>2120</td>
<td>687</td>
</tr>
</tbody>
</table>

Yield as %

1Marketable yield is mature green fruit plus red fruit minus culls (unmarketable). Values are means of at least 6 replications of 10-plant subsample areas.
2Extra-large sized fruit only.

Fig. 4. Prices received per 25-lb box of extra-large (solid line) and medium-sized (dashed line) tomato grown for the fresh market during 2004-2005 and 2005-2006 seasons in Florida (USDA, 2006).
Literature Cited


