Irrigation cutback effects on drip-irrigated tomato yields

Allen G. Smajstrla
Agricultural Engineering Dept.
Salvadore J. Locascio
Horticultural Sciences Dept.
IFAS, University of Florida
Gainesville, FL 32611

Abstract. Staked tomatoes (Lycopersicon esculentum Mill.) were grown on a fine sand soil using drip irrigation and polyethylene mulch in 1992. The research objective was to evaluate the effect of drought stress on fruit yield and size grade. Drought stress was caused by the cutback in irrigation amounts of 15%, 30%, and 45% compared to a well-irrigated (0% cutback) reference treatment in which irrigations were automatically scheduled with magnetic switching tensiometers set at 10 cb. The amount of water applied per reference irrigation was equal to 0.5 times pan evaporation. The N and K fertilizer was applied 40% pre-plant and 60% weekly by fertigation. In a non-irrigated control treatment, all fertilizer was applied pre-plant. Marketable yields were significantly greater with irrigation as compared to the non-irrigated control. Yields were also significantly reduced by irrigation cutback. Extra-large and total marketable fruit yields were reduced by up to 31% and 13%, respectively, by cutbacks up to 45%.

The use of drip irrigation for commercial tomato production in Florida has increased in recent years as competition for water resources has increased, and as management practices have been developed to produce yields that equal or exceed yields obtained with other irrigation systems. Freie and Pugh (1994) reported that 48,400 acres of tomatoes with a market value of $626 million were produced in Florida in 1992-93. Smajstrla et al. (1993) estimated that over 20% of this acreage is drip-irrigated.

Locascio and Myers (1974), Csizinsky et al. (1987) and Pitts et al. (1988) demonstrated reduced water requirements for drip-irrigated tomatoes as compared to tomatoes irrigated by other methods for Florida conditions. In each of these cases, drip-irrigated crops used less than 1/2 and 1/3 of the water applied by sprinkler and seepage irrigation systems, respectively.

Many research studies have been conducted to optimize irrigation scheduling and minimize tomato irrigation requirements with drip irrigation. Locascio et al. (1989) reported maximum yields when irrigations were scheduled at rates of 0.5 to 1.0 times pan evaporation. Locascio and Smajstrla (1989, 1993) also scheduled irrigations based on pan evaporation. They found that fruit yields were highest with irrigation quantities of 0.75 and 1.0 times pan evaporation.

Smajstrla and Locascio (1990) used automatic switching tensiometers to schedule tomato drip irrigation based on continuously measured soil water tensions. They found that irrigation requirements were reduced 40% to 50% with tensiometers placed at 6-inch depths and set at 10 and 15 cb tensions, respectively, without reducing yields. Locascio and Smajstrla (1993) reported similar water savings and yield responses with 10 cb tensiometers as compared to schedules based on pan evaporation.

In recent years, water management districts have implemented water shortage management plans designed to reduce water usage from a source when insufficient water is available to meet user demands from that source. As an example, the South Florida Water Management District (South Fla. Water Mgt. Dist., 1985), defined four water shortage phases.
each requiring an incremental reduction or "cutback" in water use of 15% as compared to permitted amounts. The effects of these cutbacks on crop yield are unknown, especially the effects on very intensively managed production systems such as drip-irrigated tomatoes. Therefore, the objective of this research was to evaluate the effects of cutback (deficit) irrigation on drip-irrigated tomato yields under typical Florida production conditions.

Materials and Methods

'Sunny' tomatoes were grown during the spring, 1992 season on Arredondo fine sand (Grossarenic Paleudult) at the University of Florida Institute of Food and Agricultural Sciences (IFAS) Horticultural Unit near Gainesville. The effect of "cutback" or deficit irrigation on tomato yield was studied. Four irrigation schedules were implemented: optimum or reference (0% cutback) irrigation at 0.5 times pan evaporation whenever the soil water tension as measured with tensiometers placed at 6-inch depths exceeded 10 cb, and simultaneous irrigations of the deficit treatment plots with applications of 85%, 70% or 55% (cutbacks of 15%, 30%, or 45%) of the amount of water applied to the 10-cb reference irrigation plot. A no-irrigation control treatment was also included in the study. Each treatment was replicated four times in a randomized complete block design.

Plant beds were 3 ft wide, bed centers were spaced 6 ft apart, and plots were 30 ft long. Beds were fumigated with 240 lb/acre of 67% methylbromide - 33% chloropicrin mix and were covered with 1.5-mil thick black polyethylene mulch.

Irrigation was applied using double-wall drip tubing (Twinwall, Chapin Watermatics, Watertown, NY) with emitters spaced 9 inches apart and a delivery rate of 0.5 gpm/100 ft at 10 psi. Drip tubes were placed on the soil surface, one per bed, 4 inches from the center of the beds.

Fertilizer was applied at 200-40-240-40 lb/acre N-P-K-micronutrient mix. For the no-irrigation control treatment, all of the fertilizer was applied pre-plant by broadcasting and roto-tilling it into the top 6 inches of the bed. For the irrigation treatments, 40% of the N and K and all of the P and micronutrients were applied pre-plant. The remaining 60% of the N and K was applied at 12 and 14 lb/acre/week, respectively, in one application per week for 10 weeks. Nutrient sources were ammonium nitrate, triple superphosphate, potassium chloride, and FN 503 micronutrient mix (Frit Industries, Ozark, AL).

Tomatoes were transplanted on 26 Mar. 1992. Plants were spaced 1.5 ft apart along the center of the beds. For establishment, all treatments were irrigated daily for one hour. Irrigation treatments were initiated on 6 Apr., after which the control treatment received no more irrigation.

Vacuum gauge magnetic switching tensiometers installed in the 0% cutback reference treatment plots were used to automatically schedule irrigation of all treatments when the 10 cb soil water tension was reached. Two tensiometers were installed per plot. The ceramic tips of the tensiometers were placed at 6-inch depths, midway between plants, and midway between the drip tube and plant row. An irrigation timer-controller was set to permit automatic irrigation as often as three times per day, depending on soil water tension.
Irrigation amounts were controlled by regulating flow rates and irrigation times. Flow rates were set with a 0.75 gpm flow control valve for each plot, and times were set on the irrigation controller. For the 0% cutback reference treatment, the amount of water applied at each irrigation was set equal to 0.5 times the depth of water evaporated from a National Weather Service Class A evaporation pan based on the 6 ft x 30 ft plot size. For the deficit irrigation treatments, irrigations were applied whenever the 0% cutback reference treatment was irrigated, however, the controller time was reduced to apply 85%, 70%, and 55% of that applied to the 0% cutback treatment. Totalizing flow meters were used to measure the volumes of water applied to each treatment plot.

Tomatoes were pruned and staked, and insecticides and fungicides were applied as needed during the growing season. Mature green to red-ripe fruits were manually harvested on 15, 19, and 26 Jun. Fruit were graded by size into extra-large, large, and medium marketable fruit by U.S. grade standards. Mean fruit weights were 7.3, 5.3, and 4.1 oz, respectively, for extra-large, large, and medium size categories. Small fruits were classified as culls and not included in marketable yield. Data were analyzed by analysis of variance and mean separation was by orthogonal contrasts.

Results and Discussion

The seasonal distributions and total irrigation amounts applied to all irrigation treatment plots are shown in Figure 1. The largest amount of irrigation, 7.24 inches, was applied to the 0% cutback reference treatment plot. Approximately 15%, 30%, and 45% smaller amounts (6.29, 5.34, and 4.46 inches, respectively) were applied to the deficit irrigation plots. The no-irrigation control treatment received only 1.30 inches for transplant establishment and no additional irrigation after establishment.

All plots were irrigated at the same rate for establishment from transplanting on 26 Mar., day-of-year (DOY) 85, through 6 Apr. (DOY 96), when irrigation treatments were begun. Little irrigation occurred from DOY 96 through DOY 107 because of small plant size, adequate soil moisture resulting from the daily irrigations during the plant establishment period, and a 1.1-inch rain that occurred on DOY 103.

Significant tensiometer-controlled irrigation applications began on DOY 108. After that date, irrigation amounts generally increased throughout the season as plants grew and climate demand increased. Bi-weekly average pan evaporation is shown as an index of climate demand in Figure 2. Climate demand steadily increased with increasing temperatures and levels of solar radiation from Mar. through May, but then de-
Figure 3. Daily rainfall amounts and distributions during the spring, 1992 growing season.

Table 1. Main effects of irrigation scheduling on marketable tomato yield.

<table>
<thead>
<tr>
<th>Irrigation treatment</th>
<th>Ext-Large</th>
<th>Large</th>
<th>Medium</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>0% cutback (reference)</td>
<td>1274</td>
<td>435</td>
<td>910</td>
<td>2619</td>
</tr>
<tr>
<td>15% cutback</td>
<td>1235</td>
<td>507</td>
<td>817</td>
<td>2559</td>
</tr>
<tr>
<td>30% cutback</td>
<td>1046</td>
<td>475</td>
<td>935</td>
<td>2455</td>
</tr>
<tr>
<td>45% cutback</td>
<td>874</td>
<td>482</td>
<td>903</td>
<td>2291</td>
</tr>
<tr>
<td>No-Irr.</td>
<td>414</td>
<td>246</td>
<td>510</td>
<td>1171</td>
</tr>
</tbody>
</table>

Significance: Ext-Large: L**: NS NS L*

No-Irr. vs Irr.: ** ** ** **

<table>
<thead>
<tr>
<th>Irrigation treatment</th>
<th>Ext-Large</th>
<th>Large</th>
<th>Medium</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>0% cutback (reference)</td>
<td>73.9</td>
<td>32.5</td>
<td>88.3</td>
<td>194.7</td>
</tr>
<tr>
<td>15% cutback</td>
<td>70.9</td>
<td>38.5</td>
<td>78.0</td>
<td>187.4</td>
</tr>
<tr>
<td>30% cutback</td>
<td>62.1</td>
<td>35.5</td>
<td>91.1</td>
<td>188.6</td>
</tr>
<tr>
<td>45% cutback</td>
<td>53.1</td>
<td>36.3</td>
<td>86.7</td>
<td>176.0</td>
</tr>
<tr>
<td>No-Irr.</td>
<td>24.4</td>
<td>18.5</td>
<td>47.6</td>
<td>90.7</td>
</tr>
</tbody>
</table>

Significance: Ext-Large: L**: NS NS L*

No-Irr. vs Irr.: ** ** ** **

*Mean fruit weight for fruit categories were 7.3, 5.3, and 4.1 oz, for extra-large, large, and medium size categories, respectively.

**Values for comparisons were significant at the 1% (**) level, 5% (*) level, or not significant (NS), and irrigation cutback effects were linear (L) or quadratic (Q).

Increased in Jun. The decrease was due to the extensive cloud cover associated with the frequent rainfall in Jun. Daily rainfall amounts and distributions are shown in Figure 3.

Irrigation application patterns were strongly influenced by rainfall amounts and distributions. For example, only one irrigation occurred from DOY 111 through DOY 114 because of the 0.6 and 3.4-inch rains that occurred on DOY 109 and 110. Likewise, irrigations did not occur for one day following the 0.84-inch rain on DOY 134 and the 0.90-inch rain on DOY 154. Irrigations were also delayed by the combined effect of three small rains from DOY 160-165. Finally, no irrigations occurred during the final four days of the season because of the 0.65 and 0.90-inch rains on DOY 174 and 175.

Smaller rains did not delay irrigations. Irrigations were not delayed by the 0.33 and 0.35-inch rains on DOY 128 and 148, respectively, nor by smaller rains that occurred on several other occasions. Clearly, the polyethylene mulch and the plant canopies shed rainwater from the plant beds so that small rains were not very effective in reducing irrigation requirements.

The 1992 rainfall pattern was not typical of long-term average rainfall in the Gainesville area. Both 1992 and long-term (1961-1990) average monthly rain amounts are shown in Fig. 4. Mar. and Apr. 1992 rains were 25% and 77% above normal, although most of the Apr. rain occurred in one large event which was not very effective because of the small plant
Marketable tomato yields are shown in Table 1 as number of 25-lb cartons and number of fruit per acre. Data shown are the totals for all three harvests. Fruit weight and number were significantly greater in all size categories with all irrigated treatments as compared to the non-irrigated control treatment. Irrigation was clearly demonstrated to be a necessary production practice as total marketable yields were doubled by irrigation, while yields of high-value extra-large fruit were tripled by irrigation.

Both extra-large and total fruit weight were linearly reduced as irrigation amount was reduced from the 0% cutback reference amount to the 45% cutback amount, while yields of large and medium fruit were not significantly affected (Table 1). This demonstrates that the effect of water stress caused by deficit irrigation, even for the relatively small 15% cutback, is a reduction in the yield of the highest-value extra-large fruit. Extra-large and total marketable fruit yields were reduced up to 31% and 15%, respectively, by irrigation cutbacks up to 45%.

Although the total number of fruit per acre tended to decrease with larger irrigation deficits, only the number of extra-large fruit was significantly reduced by cutback irrigation. The number of extra-large fruit was reduced up to 28% by irrigation cutbacks up to 45%. This again demonstrates that the main effect of deficit irrigation was a reduction in the amount of the highest-quality extra-large fruit.

**Literature Cited**


MUNICIPAL SOLID WASTE MATERIALS AS SOILLESS MEDIA FOR TOMATO TRANSPLANT PRODUCTION

CHARLES S. VAVRINA
IFAS, University of Florida
Southwest Florida Research & Education Center
P.O. Drawer 5127
Immokalee, FL 33934

Additional index words: germination, seed, seedling growth, stand establishment.

Abstract. Seed of ‘Allstar’ tomato was planted in three commercially available municipal solid waste (MSW) products to evaluate MSW as a soilless potting medium for transplant production. Ratios of MSWs to Metro Mix 220 of 0:1, 1:3, 1:1, 3:1 and 1:0 were made to determine if MSW mixtures with a standard vegetable soilless mix would be more appropriate. Florida Organix MSW, at all mix ratios, suppressed seed germination after five and 14 days. Most mix ratios resulted in reduced stem length, leaf area, root and shoot dry weight, and root to shoot ratio in six-week-old tomato transplants. Reuter MSW did not affect germination, but did suppress plant growth in one of two trials. Eweson MSW did not affect germination or plant growth at any mix ratio compared to soilless medium. Data indicated that a properly matured, composted commercial MSW product can safely be used as soilless medium for tomato transplant production.

There are few scientific reports on use of municipal solid wastes (MSW) as soilless medium for the production of vegetable transplants. Sterrett et al. (1989) utilized raw and digested, composted, and leached sewage sludge at 33% and 50% of a total transplant mix including peat and vermiculite to determine use as an effective, low-risk component of a transplant media. Falahi-Ardakani et al. (1987) also studied sewage sludge as a component of a transplant mix, concentrating on ion accumulation in the transplant media. Other studies have used composted broiler or mushroom production litter as a component of a transplant mix (Behe et al., 1993; Lohr et al., 1984). Recent advances in MSW technology have resulted in new commercial products derived from household garbage, horticultural waste, and other sources. Data from direct-seeded, field application studies with these materials indicates vegetable seed germination may be jeopardized by composted materials. Effects on germination appears to depend on product maturity and the N source used to produce the compost (Ozores-Hampton and Bryan, 1993; Roe and Kostewicz, 1992). To date, no data exists on the use of these new MSW materials, in whole or in part, as a soilless mix for vegetable transplant production.

The objective of this study was to evaluate three commercial MSWs used as soilless medium in tomato transplant production.

Materials and Methods

Three commercially available MSW materials, Florida Organix (FL-O, South Dade Soil and Water Conservation District, Miami, Fla.), Reuter (RU, Reuter Recycling, Inc., Pembroke Pines, Fla.), and Eweson (EW, Bedminster Bioconversion, Inc., Cherry Hill, NJ) were tested for use as a soilless medium for tomato transplant production in the fall of 1993 in two separate trials, 21 Sept. 1993 and 10 Oct. 1993. FL-O is a composted, dried sewage sludge. Reuter is an aerobically-composted household garbage. Eweson is a composted household garbage/sewage sludge combination at a 2:1 ratio. All MSWs were used alone and in combination with Metro Mix 220 (MM, Grace Sierra Horticultural Co., Milpitas, CA), a peat based vegetable transplant mix, to determine if mixtures might provide a more appropriate medium compared to MSW or peat mix alone. The MSW to Metro Mix 220 ratios were: 0:1, 1:5, 1:1, 3:1, and 1:0.

A 200-cell styrofoam flat was divided into five 40-cell sections. Each 40-cell section of the flat received one MSW portioned into the five media prepared according to the ratios defined above. Four replications were implemented for each MSW. Individual cells contained 18.8 cm$^3$ of media when filled. After filling, the flat was dibbled, seeded with ‘Allstar’ (Petoseed, Saticoy, CA) tomato seed, and covered with additional material appropriate to the treatment. Plants were grown under southwest Florida commercial vegetable transplant production conditions, and received 50 mg N liter$^{-1}$ from Miller’s Nutri-Leaf (Miller Chem. & Fert. Corp., Hanoever, PA) 20N-4P-17K daily via overhead irrigation.

Germination was recorded at five and 14 days. After six weeks, 10 plants in each treatment were harvested, and plant height, leaf area, shoot (with leaves) and root dry weight, and root-to-shoot ratio were measured. Data were analyzed by analysis of variance with linear and quadratic contrasts (SAS Institute, 1988).

Results and Discussion

Germination. Florida Organix, alone or in combination with MM inhibited tomato seed germination at 5 days, and significantly reduced germination 14 days after planting (Table 1). This was perhaps the result of high soluble salts or high N in an unleached sewage sludge (Sterrett et al., 1983; Roe et al., 1983)