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IRRIGATION SCHEDULING OF DRIP-IRRIGATED TOMATO USING TENSIOMETERS AND PAN EVAPORATION

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Abstract. **Tomatoes (*Lycopersicon esculentum* Mill.) were grown on an Arredondo fine sand soil using drip irrigation and polyethylene mulch in a two-year study. Irrigations were scheduled with tensiometers and pan evaporation to determine the effects of these irrigation scheduling practices on irrigation water requirements and fruit yield. Vacuum gauge tensiometers were used to automatically schedule irrigations at 10 and 15 cb soil water tensions measured 6 inches below the drip tubing. The pan evaporation treatment was scheduled daily at a rate of 0.5 times pan evaporation except during rains. The N + K fertilizer was applied 40 percent preplant and 60 percent through the irrigation system on a weekly basis. Water applications were reduced when irrigations were based on soil tensions as compared to pan evaporation. Irrigation applications were greater with the 10 cb versus the 15 cb treatment. Yields were compared to a non-irrigated control in which all fertilizer was applied pre-plant. Yields of extra-large and total fruit were significantly greater with all treatments than with the control. Marketable yields with the tensiometer-based treatments were not significantly different than with the pan evaporation treatment either year.**

Tomatoes grown on Florida sandy soils require irrigation to avoid yield and quality reductions due to drought stress. The use of drip irrigation for commercial tomato production has increased in recent years as competition for water resources has increased. Many researchers have demonstrated reduced water requirements with drip as compared to other irrigation methods (3, 4, 9). Tomato yields equal to or greater than commercial yields produced using other irrigation systems have been reported with drip irrigation by many researchers (2, 4, 5, 8, 9, 10).

Yields were greater when some nutrients were injected with the irrigation water as compared to pre-plant applications on sandy soils (4, 5, 7). Split applications, with 40 percent N and K applied pre-plant by incorporation into the plant bed and the remaining 60 percent in uniform weekly applications produced greater yields than when all of the nutrients were applied preplant (5, 7).

Precise irrigation schedules are required because of the low water- and nutrient-holding characteristics of sandy soils. Under-irrigation can result in reduced yields due to drought stress (7), while over-irrigation has been demonstrated to leach nutrients (1, 2, 5, 6). Several earlier studies have demonstrated that pan evaporation can be effectively used to schedule drip irrigation of tomatoes (5, 6, 7). Locascio et al. (5) and Locascio and Smajstrla (7) found that yields of tomatoes grown on sandy soil at Gainesville, FL were greatest when irrigations were scheduled on a daily basis at 0.5 times the evaporation rate from a Class A evaporation pan.

This research was conducted to evaluate the effects of both climate (pan evaporation) and soil moisture status (tensiometer) based irrigation scheduling methods on irrigation requirements and yield of drip-irrigated tomatoes.

Materials and Methods

'Sunny' tomatoes were grown 2 seasons, Spring 1989 and Spring 1990, on an Arredondo fine sand (Grossarenic Paleudult) at the University of Florida Institute of Food and Agricultural Sciences (IFAS) Horticultural Farm near Gainesville. Three irrigation schedules were studied: irrigation at 0.5 times pan evaporation and irrigation at 2 soil water tensions, 10 cb and 15 cb. In addition, a no-irrigation control treatment was included in the study. Each treatment was replicated 4 times.

Plant bed tops were 3 feet wide spaced 6 feet apart. Plants were spaced 1.5 feet apart in the center of the beds. Beds were covered with 1.5-mil thick black polyethylene mulch. In 1989, plots were 40 feet long, and in 1990 plots were 34 feet long.

Fertilizer was applied at 200-50-240-40 lb/acre N-P-K-micronutrient mix. For the no-irrigation treatment, all of the fertilizer was applied pre-plant by broadcasting and mixing it into the bed. For the drip irrigation treatments, 40 percent of the N and K and all of the P and micronutrients were applied pre-plant by broadcasting and mixing it into the bed. The remaining 60 percent of the N and K was applied at 12-0-14 lb/acre/week in one application per week for 10 weeks. Nutrient sources were ammonium nitrate, potassium nitrate, potassium sulfate, triple superphosphate, and FN 503 (Frit Industries, Ozark, AL).

Double-wall drip tubing (Chapin Twinwall, Watertown, NY) was installed under the polyethylene mulch when the mulch was installed, one tube per bed. Tubes were placed on the soil surface, 4 inches from the center of the beds. In 1989, tubing with a 9-inch emitter spacing with a flow rate of 0.5 gpm/100 feet was used. In 1990, tubing with a 12-inch emitter spacing with a flow rate of 0.3 gpm/100 feet was used.

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Beds were fumigated with 240 lb/acre of 67 percent methylbromide-33 percent chloropicrin mix when the polyethylene mulch was installed. In 1989, tomatoes were transplanted on 15 Mar. For establishment, transplants were irrigated daily at a rate of 0.5 times pan evaporation for several days. Irrigation treatments were initiated on 3 Apr. 1989 and 2 Apr. 1990. After these dates, the no-irrigation control treatment received no further irrigation for the remainder of the growing season.

With pan evaporation, irrigation was applied daily at 0.5 times the daily evaporation from a National Weather Service Class A Evaporation Pan. To set the irrigation controller, the mean value of pan evaporation was used each week from the previous week's evaporation.

Vacuum gauge switching tensiometers were used to schedule irrigations of the 10-cb and 15-cb treatments when the critical soil water tension was reached. Soil water tensions were measured 6 inches below the drip tubing, midway between plants. The amount of water applied at each irrigation was set to equal the 0.5-pan daily application during that week. Tensiometer controlled treatments were set to permit automatic irrigation as often as 3 times per day, depending on the soil water tension.

Tomatoes were pruned and staked as required during the growing season. Mature green to red-ripe fruits were harvested on 19 and 29 Jun. 1989 and 13 and 21 Jun. 1990.

Results and Discussion

Irrigation applications: Rainfall and irrigation amounts applied with each of the irrigation treatments are shown in Table 1 for the 1989 and 1990 crop seasons. In both years, more irrigation was applied with the 0.5-pan treatment as compared to the tensiometer-controlled treatments, and more water was applied with the 10-cb as compared to the 15-cb tensiometer treatment.

Pan evaporation was approximately 23 inches both years. The actual amount of irrigation applied with the 0.5-pan treatment resulted from both the season distribution of pan evaporation and interruptions in irrigation due to rain. In 1989, the rainfall total was only 7.84 inches, while in 1990 it was 12.05 inches. During both years, irrigations were manually interrupted only when large rainfall events (greater than 1 inch) occurred. The polyethylene mulch shed most of the rain from the production beds, thus small rainfall events were assumed to be ineffective.

With tensiometer-based irrigation shedules, irrigation only occurred after soil water tensions reached the 10 and 15 cb levels set on the tensiometers. Smaller total irrigation amounts were applied with the tensiometer-controller treatments as compared to the 0.5-pan treatment because irrigation was not applied when the soil was sufficiently moist, thus excessive water applications were avoided. Smaller irrigation amounts were applied with the 15-cb as compared to the 10-cb treatment because the 15-cb treatment required greater soil water depletion before an irrigation was scheduled. Thus, the 15-cb treatment reduced the frequency of irrigations as compared to the 10-cb treatment.

The irrigation patterns that occurred in 1989 and 1990 are shown in Figs. 1 and 2, respectively. In both figures, the cumulative depths of irrigation applied are shown as a function of day of year for all 3 treatments. For the 0.5-pan treatment, the steeper slopes of these curves show time periods of high pan evaporation rates (high climatic demand) and low rainfall. For the tensiometer-based treatments, the steeper slopes show time periods of high soil water extraction rates.

In both years, the greatest difference in irrigation applications occurred during the early crop growth stages. The young tomato plants were irrigated daily for establishment for several days after transplanting. During these establishment periods, cumulative irrigation applications were identical with all treatments. After establishment, from Day 94 to 111 in 1989 (Fig. 1) and from Day 93 to 120 in 1990 (Fig. 2) very little irrigation was applied with the tensiometer-based controllers because the plants were small and only slowly depleted the soil water.

Table 1. Rainfall and drip irrigation amounts applied to the 0.5-pan, 10-cb, and 15-cb irrigation treatments during the 1989 and 1990 tomato seasons.

Time period	Rain (inches)	Irrigation amount (inches)		
		0.5-pan	10-cb	15-cb
		1989		
30/3-13/4	0.66	1.46	0.36	0.36
14/4-28/4	0.08	2.38	1.29	0.43
29/4-10/5	0.70	2.16	2.08	1.90
11/5-26/5	1.90	1.34	1.10	0.87
27/5-8/6	1.30	1.34	1.20	1.29
9/6-19/6	1.20	2.36	0.87	0.90
20/6-29/6	2.00	0.76	0.48	0.41
Totals	7.84	11.81	7.37	6.16
		1990		
15/3-28/3	0.25	0.66	0.69	0.63
29/3-12/4	3.10	0.93	0.47	0.43
13/4-26/4	2.10	0.74	0.22	0.21
27/4-11/5	1.80	1.35	0.81	0.61
12/5-23/5	0.30	2.52	1.39	1.40
24/5-7/6	3.90	1.51	1.87	1.45
8/6-21/6	0.60	1.44	1.85	1.15
Totals	12.05	9.16	7.31	5.88

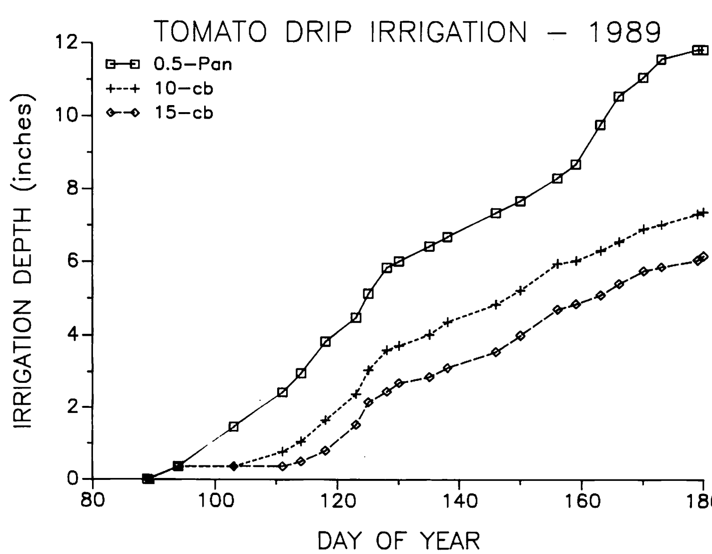

Fig. 1. Cumulative depths of irrigation applied with the pan evaporation and tensiometer based irrigation scheduling treatments during the 1989 tomato growing season.

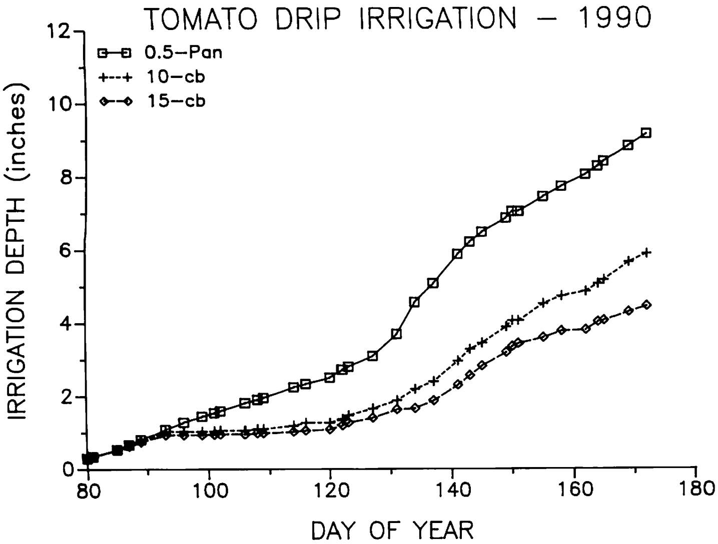

Fig. 2. Cumulative depths of irrigation applied with the pan evaporation and tensiometer based irrigation scheduling treatments during the 1990 tomato growing season.

After Day 103 in 1989 irrigation application rates increased rapidly to approximately the same rate as the 0.5-pan treatment, as demonstrated by the slopes of the curves in Fig. 1. In 1990, the tensiometer-controlled application rates did not reach the 0.5 pan rates until after Day 136 (Fig. 2). Thus, the tensiometer-controlled treatments reduced irrigation applications as compared to the 0.5-pan treatment by matching irrigation applications to soil water extraction rates during early plant growth stages.

Irrigation application rates were approximately the same with all treatments during the mid-season peak crop growth stages from Day 128 to 159 in 1989 and Day 136 to 160 in 1990. This is shown by the nearly identical slopes of all 3 curves during mid-season in Figs. 1 and 2. This demonstrates that the irrigation application rate of one-half of pan evaporation very nearly approximated the soil water extraction rate during these growth stages. This also demonstrates that there was very little difference in the irrigation frequency between the 10-cb and 15-cb soil water tensions during peak growth stages. Apparently, the soil water tension changed very rapidly in this sandy soil under these water extraction conditions, thus the 15 cb soil water tension was reached soon after the 10 cb tension and irrigation frequencies were almost identical with both soil water tensions.

During the latter part of the season, the slopes of the irrigation depth curves shown in Figs. 1 and 2 demonstrate that the 0.5 pan application rate exceeded the tensiometer-based rate in 1989, while all 3 treatment rates were about the same in 1990. The reason for the difference in irrigation applications in 1989 is thought to have occurred because the 0.5-pan treatment was not sufficiently interrupted for rainfall, and some of the large rainfall events were effectively used by the crop. In 1990, irrigation applications continued at approximately the same rates with all 3 treatments until the end of the season, indicating that the 0.5-pan application rate matched soil water extraction rates up until crop harvest. In this case, little rain occurred during this period, and rainfall effectiveness was thought to be very low. Further evidence of the effectiveness of rainfall is seen in the reduced slope of the tensiometer treatment curves between Days 155 and 162 (Fig. 2). This period corresponds to the high (3.90-inch) rainfall period shown in Table 1.

Table 2. Main effects of irrigation scheduling on marketable tomato yield, 1989 and 1990.

Irrigation treatment	Marketable yield (25-lb cartons/acre)[z]			
	Ext-Large	Large	Medium	Total
	1989			
No-Irr.	390	421	513	1324
0.5-pan	943	553	538	2034
10-cb	871	448	546	1865
15-cb	1064	619	517	2200
Signif.[y]				
No-Irr. vs Irr.	**	NS	NS	*
0.5-Pan vs Tens.	NS	NS	NS	NS
10-cb vs 15-cb	NS	*	NS	NS
	1990			
No-Irr.	182	261	500	942
0.5-pan	857	621	594	2072
10-cb	958	865	747	2569
15-cb	1088	659	637	2385
Signif.[y]				
No-Irr. vs Irr.	**	**	**	**
0.5-Pan vs Tens.	NS	NS	*	NS
10-cb vs 15-cb	NS	NS	NS	NS

[z]Mean fruit size for fruit categories were 7.3 oz for extra-large, 5.3 oz for large, and 4.1 oz for medium.
[y]F values for comparisons were significant at the 1% (**) level, 5% (*) level, or not significant (NS).

Tomato yields: Marketable tomato yields during the 1989 and 1990 crop years are shown in Table 2. Small fruit were classified as culls and not included in the total yields shown.

Yields of extra-large and total fruit were significantly greater with all treatments than with the no-irrigation control in both years. In 1990, yields of all marketable fruit sizes were significantly greater with irrigation than with the no-irrigation control. Total marketable fruit yields were increased over 50% by irrigation in 1989 and over 100% in 1990. These differences demonstrate the importance of irrigation in obtaining high fruit quality (more extra-large sized fruit) as well as large total yield differences.

In both years, total yields with the tensiometer-based treatments were not different from the 0.5-pan treatment yield, despite the smaller irrigation applications made with the tensiometer treatments. These results demonstrate that tensiometers can be effectively used to schedule irrigations based on soil moisture tension, conserving water by avoiding irrigations when the soil water status is adequate, especially early in the season when plant growth is slow.

In both crop years, marketable yields with the 10-cb treatments were not different than the 15-cb treatments, despite the consistently lower irrigation applications made with the 15-cb treatments. These results and the comparable yields with the 0.5-pan treatment demonstrate that irrigations should be scheduled in the 10 to 15 cb tension range when tensiometers are used for irrigation scheduling of tomatoes for production systems as described in this research.

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MULCHING AND PLANTING METHODS AFFECT PERFORMANCE OF SWEET CORN IN FLORIDA

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Abstract. **Polyethylene mulches and transplants were evaluated for their effects on earliness, total yields, and quality of sweet corn (*Zea mays* var *rugosa* Bonaf.) at Live Oak, FL. Black mulch increased total, but not early yield of sweet corn as compared with no mulch in both years of the study. Increases were due to larger yields of the highest quality No. 1 ears. Compared to direct-seeding, transplanting increased earliness but not total yields. Transplanting and mulching would be adaptable to market garden growers who could benefit from the extended season and to commercial vegetable growers who could double-crop other vegetables before or after mulched sweet corn.**

Sweet corn is produced on nearly 50,000 acres in Florida with most of the crop grown in southern and central Florida on the organic soils near Belle Glade and Zellwood, and on the marl and rockland soils near Homestead (34). Although most of the sweet corn acreage is in southern Florida, production is increasing in northern Florida, especially in the Alachua and Live Oak areas. Florida is currently the leading U.S. producer of fresh market sweet corn and the crop has a farm value in excess of $60 million (1).

Most of the sweet corn acreage is planted with super sweet cultivars based on the shrunken-2 (sh2) gene. These cultivars are noted for their increased sweetness and longer storage life after shipping. However, yields can be variable due to reduced plant stands resulting from the inherent poor seed quality of supersweet cultivars (5). Poor and erratic plant stands occur in cool soil conditions during winter plantings.

Attempts to increase plant stands, uniformity of harvest, and yields have revolved mostly around seed treatment with fungicides (4,6) and the use of higher seeding densities. Only a limited number of fungicides are available for seed treatment. Solutions for improved stand establishment for supersweet corns might be developed from breeding and cultural technological efforts in the future.

Cultural options for improved stand establishment might include transplanting and mulching of Florida sweet corn. These cultural practices might not only contribute to improved stands and yields, but also to earlier yields. The latter factor might be important particularly in northern Florida where competition with Georgia sweet corn is increasing.

Transplanting has been used to improve dependability and earliness of vegetables (19, 27, 31, 36) including those grown in Florida. Transplanting was considered to be the largest production factor in the improvement of net returns for Florida watermelons and muskmelons (24).

Polyethylene mulching has been reported to improve earliness and occasionally total yields of many vegetables (2,3,7,9,10,11,12,13,14,15,16,18,20,22,23,28,29,30). Mulching is standard production practice for several vegetables in Florida including tomatoes, peppers, eggplant, and melons.

Mulching has been shown to be beneficial for sweet corn in several northern areas (8,17,21,25,26,32,33). The major benefit from mulching was the earlier harvests compared with unmulched sweet corn. All of these studies were conducted with direct-seeded sweet corn. In a Tennessee study, sweet corn produced from transplants was earlier by 2 weeks compared with direct-seeded sweet corn (36). However, this study did not involve mulching.

These studies were conducted to determine the potential for production of Florida sweet corn using transplants

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