Micro Irrigation for Fresh-Market Tomatoes on a High-Water-Table Soil in the Southeastern Coastal Plain

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ABSTRACT

Two tomato cultivars were evaluated for two years on a southeastern Coastal Plain soil that had a high, fluctuating water table. Treatments included micro irrigation vs. no irrigation and two cultivars. No consistent water table differences in either water table depth or in gradient between adjacent wells were measured among seven wells on the site. Water table contribution to crop water requirement could not be measured in this experiment, but a relatively small amount of irrigation (78 and 82 mm) significantly increased tomato fruit size and yield in both years. The 'Tempo' cultivar produced larger fruit, a higher yield, and matured earlier than the 'FloraDade' cultivar, partly because of reduced incidence of disease. The 'soft-fruit syndrome' storage problem experienced by many growers in this region was not observed in this study. The management system used has higher input costs but provides increased profitability for fresh-market tomato production.

INTRODUCTION

Tomato production in the southeastern Coastal Plain supplies most of the fresh-market tomatoes for northern cities during June of each year. Much of this production occurs on soils with water tables that often fluctuate near the root zone. Cultural practices for tomato production in the region have changed significantly during the past fifteen years and now include practices such as full-bed mulching with black polyethylene, staking and pruning, and irrigation. Sprinkler irrigation is often used, but is sometimes mismanaged, and is not practical when used with full-bed mulches that interfere with uniform infiltration of irrigation water. Recently, micro irrigation has become the irrigation system of choice.

Geraldson (1975) evaluated tomato production in Florida for various cultural practices, including a gradient-mulch system which used a concentrated source of nutrients, a constant water table 0.40-0.45 m deep, and/or micro irrigation. More recent results suggest a water table depth of 0.30 m will provide a more desirable soil water content at the 0.05-0.10-m depth and will increase yield (Geraldson, 1982). Stanley et al. (1981) reported no difference in tomato yield between conventional ditch drainage and subsurface drainage-subirrigation on a high water table soil in Florida; however, the ditch system required about twice as much water to maintain soil water content. Soliman et al. (1978) found significantly higher tomato yields were produced in lysimeters with water table depths of 0.7 and 1.0 m on calcareous and sandy clay loam soils, respectively.

Objectives

Objectives of this experiment were to evaluate effects of micro irrigation, cultivars, and N and K fertilization rates on production of mulched, fresh-market tomatoes on a soil with a high water table. Results related to N and K fertilization rate were reported by Karlen et al. (1985) and are not included in this paper.

METHODS AND MATERIALS

The experiment was located near Charleston, SC and was rotated each year between adjacent sites of Yonges loamy fine sand (Typic Ochraqualfs) with inclusions of Scranton loamy fine sand which has permeable fine sandy layers at the 0.3- to 0.9-m depths. Treatments included two water management regimes (irrigated and nonirrigated), two tomato cultivars, and nine N and K fertilization levels arranged in a randomized, complete block design with four replications. Three rates of N (67, 134, and 202 kg/ha) and three rates of K (46, 140, and 280 kg/ha) were compared in all combinations each year. Yield data in this paper are means of all fertilization treatments. Irrigation was initiated manually when soil water potential at the 0.3-m depth in any two of the four irrigated plots reached -25 kPa. The equivalent of 8 mm of rainfall for the total area was applied to the row area (about 25% of the total area) during each irrigation event.

Soil preparation included fall disking, turn plowing in the spring to a depth of about 0.2 m, disking, and bedding rows 1.8 m apart. Beds were then subsoiled to a depth of 0.45 m using three subsoiling shanks spaced 0.3 m apart for each bed. Fertilizer was applied broadcast to the beds and incorporated to a depth of 0.15 m. Immediately following the injection of 280-390 kg/ha of a methyl bromide-chloropicrin mixture into the beds, the beds were shaped (about 1.5 m wide and 0.2 m high), micro-irrigation tubing was installed 0.05-0.10 m deep and 0.15 m from the row, and the beds were covered with

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black polyethylene mulch. The micro-irrigation tubing was Chapin Twin-Wall* with emitters spaced 0.3 m apart and a delivery rate of 6.5 L/min per 100 m length. 'Tempo' and 'FloraDade' tomatoes were transplanted at a spacing of 0.45 m on 26 March 1980 and 27 March 1981, which was two to three weeks following fumigation. Rye was planted on a row every 9 m to provide protection from the wind during the early spring and was destroyed by mowing when it was no longer needed. Mature-green, breaker, and ripe fruit were harvested three or four times each season from the 12 center plants of each plot, a single row 7.3 m long. Harvest dates were 9, 18, and 26 June and 8 July in 1980, and 9, 16, and 24 June in 1981. Internal fruit firmness was measured after storing six mature-green fruit in a constant temperature room at 20C for 12-15 days to allow ripening. Ripe fruit were then sliced in half, and resistance of the flesh to crushing was determined with a penetrometer, which had a 100-mm^2 flat tip.

Seven wells about 2 m deep were installed in the experimental area to provide continuous water table measurements. Water stage recorders were installed on each cased well and were operated throughout the year except for a period of about four to six weeks in the early spring when they were removed for land preparation. Because the research site was located within 1 km of a tidal marsh and the effect of ocean tides on the water table was not known, recorder charts were initially changed weekly. After it was determined that improved measurement resolution with respect to time provided by the weekly chart frequency was unnecessary, all recorder charts were converted to a monthly interval. Tensiometers were installed at depths of 0.15, 0.3, 0.6, and 0.9 m in both irrigated and nonirrigated treatments. Tensiometer measurements were recorded at least twice weekly. A recording rain gauge on site continuously measured rainfall throughout the year. Irrigation water applied to all irrigated treatments was measured with in-line positive displacement water meters.

Differences in water table elevations among the seven wells were determined using variance, correlation, interpolation, and regression techniques. Analog water table recorder chart traces were first digitized and stored in computer files. Hourly values were then interpolated from these digitized data points so that data for all wells were consistent with respect to time. Water table elevations for each of the seven wells were then compared for a selected time each day of record using paired correlation analyses. Differences between water elevation in individual wells and the mean water elevation for all seven wells were calculated and graphed for each well during the season. Water-table-elevation gradients between adjacent wells (in all combinations) were calculated from elevation differences at a specified time each day and the appropriate distance between wells. Both magnitude and direction of all gradients were then compared for each day throughout the season.

RESULTS AND DISCUSSION

Water table elevations in the seven wells were very similar during both years of the study, although there were small but consistent differences in water levels among the wells. Water table elevations determined from interpolation of digitized analog data were very similar to those determined from digitized analog data both years. Mean water table depths computed from interpolated water table elevation data for the seven wells in 1980 and 1981 are shown in Figs. 1 and 2, respectively. The water table during the 1980 growing season (26 March-8 July) was 1.0 - 1.5 m below the soil surface most of the time, although it did rise to within 0.7 m of the soil surface on one occasion following a 55-mm rainfall during the last part of May. One very large rainfall event (285 mm) following harvest in late July caused the water table to rise from about 1.6 m to 0.6 m deep over a very short period of time (Fig. 1). In 1981, the water table was higher throughout the growing season (27 March-24 June), dropping below the 1-m depth only during May. High rainfall frequency and amounts in June, July, and August kept the water table between the 0.5- and 1-m depths most of the time and caused frequent fluctuation. As rainfall decreased during the period September through December, the water table gradually dropped to a depth of about 1.7 m.

The mean data show that fluctuations in water table depth were generally small except following significant

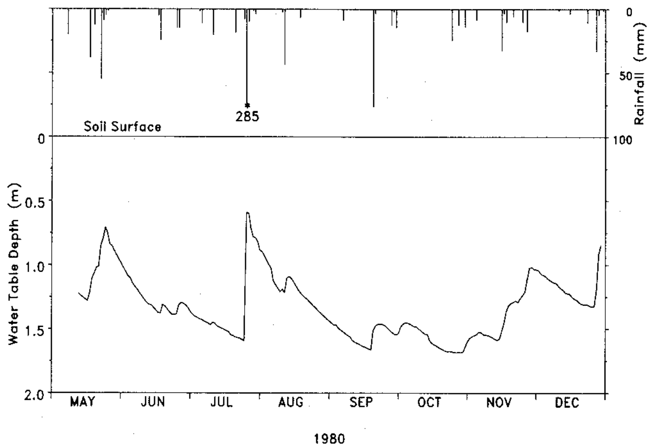

Fig. 1—Mean water table depth for seven wells on a southeastern Coastal Plain soil for 1980. Numbers annotated below rainfall lines indicate off-scale data values.

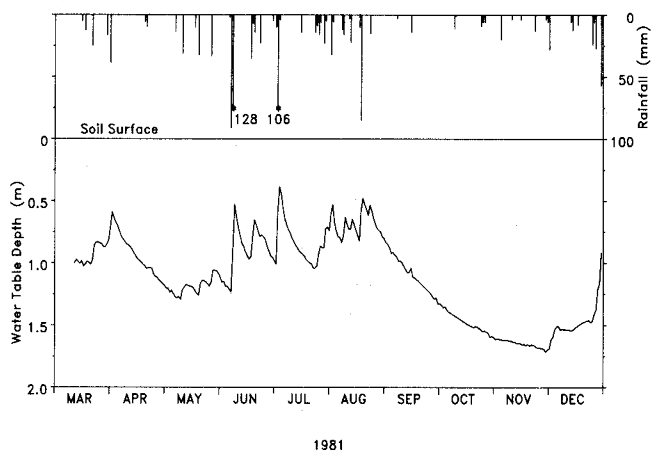

Fig. 2—Mean water table depth for seven wells on a southeastern Coastal Plain soil for 1981. Numbers annotated below rainfall lines indicate off-scale data values.

*Mention of a proprietary product does not constitute endorsement or a recommendation for its use by the USDA.

TABLE 1. Growing-season rainfall and irrigation amounts for fresh-market tomatoes during 1980-81 on a Coastal Plain soil

Year	Rainfall	Irrigation	Total
	mm		
1980	328 (25)*	78 (9)	406
1981	490 (16)	82 (9)	572

*Numbers in parentheses refer to the number of rainfall or irrigation events.

rainfall. Consequently, we have concluded that the water table at this site was influenced predominantly by rainfall. Any influence of daily tides on the water table elevation was very small in comparison to rainfall, if it existed at all. Similarly, deviations from the mean water table elevations were relatively small for the individual wells. Paired correlation analyses of daily water table values for all combinations of wells provided correlation coefficient values ranging from 0.959 to 0.999 in 1980 and from 0.962 to 0.996 in 1981, and all probability values were less than or equal to 0.0001.

Calculated water table gradients between adjacent wells were extremely variable, both among wells and with time through the season. The magnitude of this variation was greatest immediately following rainfall events, probably reflecting differences in response time among wells. Variation in gradient values, both in magnitude and direction, appeared to be random and without pattern with respect to time or space. Consequently, we concluded that mean water table data adequately represent the water table at this experimental site.

Growing-season rainfall and irrigation amounts and the number of events for both 1980 and 1981 are shown in Table 1. Daily rainfall distributions for both years are shown in Figs. 1 and 2. Rainfall was higher in 1981, primarily because of two large events. Total irrigation applied each growing season was about equal, although more rainfall occurred, and the water table was at least 0.5 m closer to the soil surface for most of the 1981 growing season. Tensiometer data indicate that soil at the 0.3-m depth was much wetter for the irrigated treatments. Soil matric potential was generally wetter than the target level of −25 kPa in the irrigated treatment and near −40 kPa in the nonirrigated treatment most of the growing season both years (Fig. 3 and 4). The higher water table in 1981 probably did not have a significant effect on soil matric potential at the 0.3-m depth, although the soil was slightly wetter. The water table may have affected the soil at the 0.6- and 0.9-m depths and possibly could have provided water for uptake by tomato roots. Positive matric potential values at deeper soil depths confirm that the water table was above the deeper tensiometers. Soil at the 0.3-m depth generally did not reflect the effect of water table, but because irrigation was managed using tensiometer readings at that depth, it is possible that some excess irrigation water could have been applied. However, the amount of excess irrigation water should have been small because most water is withdrawn from the surface 0.3-m layer of soil.

Marketable tomato yields for 1980 and 1981 are shown in Table 2 for the micro-irrigated and nonirrigated treatments. Irrigation significantly increased total

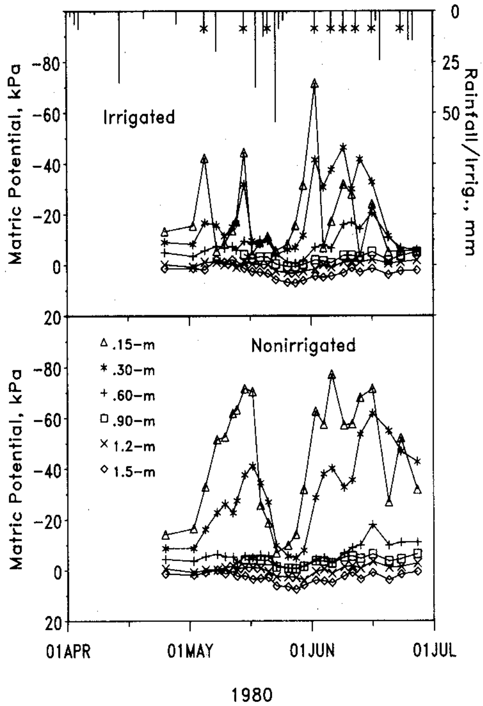

Fig. 3—Daily rainfall and irrigation amounts and soil matric potential at six soil depths for irrigated and nonirrigated treatments on a southeastern Coastal Plain soil during the tomato growing season in 1980. Irrigation events are indicated with an asterisk.

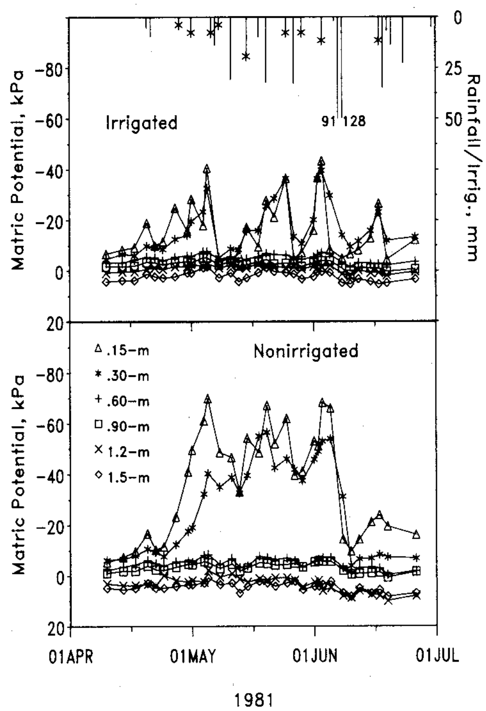

Fig. 4—Daily rainfall and irrigation amounts and soil matric potential at six soil depths for irrigated and nonirrigated treatments on a southeastern Coastal Plain soil during the tomato growing season in 1981. Irrigation events are indicated with an asterisk. Numbers annotated below rainfall lines indicate off-scale data values.

tomato yield both years. Furthermore, the higher yield occurred in the two larger size classes, extra large and large. There were no significant differences in total fruit yield in 1980 between the two cultivars, but the 'Tempo' cultivar produced significantly higher fruit yield in 1981 (Table 2). The 'Tempo' cultivar produced significantly

TABLE 2. Total marketable tomato fruit yield by size class for two water management treatments and two cultivars on a silt loam soil in the southeastern Coastal Plain during 1980-81

Treatment	Year	Marketable tomato yield, Mg/ha				
		Tomato size class *				
		XL	L	M	S	Total
Water management						
Irrigated	1980	18.21 a†	24.98 a	3.99 a	0.84 a	48.01 a
Nonirrigated	1980	13.74 b	21.62 b	3.65 a	0.73 a	39.74 b
Irrigated	1981	32.91 a	23.08 a	2.47 a	0.38 a	58.84 a
Nonirrigated	1981	21.02 b	16.39 b	2.35 a	0.19 a	39.95 b
Cultivar						
FloraDade	1980	11.30 b†	27.24 a	4.39 a	0.68 b	43.61 a
Tempo	1980	20.66 a	19.36 b	3.24 b	0.90 a	44.15 a
FloraDade	1981	18.51 b	21.21 a	2.88 a	0.21 a	42.81 b
Tempo	1981	34.20 a	18.10 b	1.99 b	0.34 a	54.63 a

* XL = extra large > 73mm; L = large 64-73 mm; M = medium 59-64 mm; S = small 54-58 mm; Total = sum of all sizes.
† Means followed by the same letter within a column for the same year are not significantly different at 0.05 level using least squares differences and analysis of variance.

higher yield of extra large fruit both years, but 'Flora Dade' produced a higher yield of large fruit. In 1981, the 'Tempo' cultivar produced almost twice as much extra-large fruit as the 'Flora Dade' cultivar. The higher yield of 'Tempo' in 1981 may have been caused by a lower incidence of southern blight in this cultivar, which is caused by *Sclerotium rolfsii*. Field observations and yield data show that tomato plants in treatments with irrigation and a high nitrogen level had a lower incidence to this disease than other treatments (Karlen, et al., 1985), especially in 1981 with the moderately severe infestation of southern blight.

Tomato fruit yields at first harvest each year are shown in Table 3. The quantity and size distribution of fruit at first harvest are important because prices are generally best for the earliest harvest and larger fruit benefit from a premium price. There was no significant difference in total fruit yield or yield by size classes in 1980 between irrigated and nonirrigated treatments for the first harvest. In 1981, the nonirrigated treatment produced significantly more fruit yield at first harvest, with increases in the large and medium size classes. The 'Tempo' cultivar produced significantly more total fruit yield and more in the extra-large size class at first harvest both years. This indicates earlier maturity and a higher percentage of more profitable fruit (Table 3). Precise cost/benefit comparisons for this management system are difficult because of the volatile nature of fresh-market tomato prices, both within and among growing seasons; however, tangible evidence of its profitability is grower acceptance. Approximately 75% of the 1989 fresh-market tomato crop in South Carolina will use this system (W. P. Cook, 1989, personal communication, Clemson Univ. Cooperative Extension Service, Charleston, SC).

TABLE 3. Marketable tomato fruit yield at first harvest by size class for two water management treatments and two cultivars on a silt loam soil in the southeastern Coastal Plain during 1980-81

Treatment	Year	Marketable tomato yield, Mg/ha				
		Tomato size class *				
		XL	L	M	S	Total
Water management						
Irrigated	1980	7.71 a†	6.51 a	0.33 a	0	14.55 a
Nonirrigated	1980	7.00 a	6.53 a	0.24 a	0	13.78 a
Irrigated	1981	5.42 a	3.91 b	0.56 b	0.25 a	10.14 b
Nonirrigated	1981	5.94 a	4.84 a	0.70 a	0.10 a	11.58 a
Cultivar						
FloraDade	1980	3.67 b†	6.97 a	0.42 a	0	11.06 b
Tempo	1980	11.05 a	6.07 a	0.14 b	0	17.26 a
FloraDade	1981	3.11 b	5.65 a	0.88 a	0.10 a	9.74 b
Tempo	1981	8.06 a	3.25 b	0.40 b	0.24 a	11.95 a

* Abbreviations and sizes are the same as defined in Table 2.
† Same as defined in Table 2.

Tomato growers in this region have encountered a 'soft-fruit syndrome' storage problem which some have suggested may be caused by excessive soil water and/or poor N fertility management. Excessive soil water could be caused by heavy rainfall, high water table, excessive irrigation, or a combination of these factors. Karlen et al. (1983) were able to induce similar symptoms by flooding tomatoes grown in a greenhouse, but 'soft-fruit syndrome' characteristics were not induced in this field experiment. In this experiment, the soil water status was monitored with tensiometers and water table recorders, and excessive water was neither applied nor received through rainfall. Internal firmness of similar fruit after 10 to 15 days of storage at 20° C showed no N or K fertilizer rate or water management effects. There were significant differences in fruit firmness for the two cultivars (Table 4), but the differences were not sufficient to indicate a 'soft-fruit syndrome' problem. Differences in fruit firmness were apparently caused by a genetic variation rather than a response to water management or fertilizer practices.

SUMMARY AND CONCLUSIONS

An experiment was conducted for a two-year period in which N and K fertilization rate, tomato cultivar, and water management effects were evaluated for a southeastern Coastal Plain soil with a fluctuating water table. Tomato fruit yield was higher when irrigation was provided although, in both years, the water table often

TABLE 4. Cultivar effects on firmness of tomato fruit harvested mature green and ripened 12 to 15 days at 20°C in 1980 and 1981.

Cultivar	1980 Harvests				1981 Harvests		
	1	2	3	4	1	2	3
	kg/cm²*						
FloraDade	1.90a†	2.78a	3.22a	2.48a	1.93a	—	3.37a
Tempo	1.34b	1.77b	1.98b	1.72b	1.59b	—	2.41b

* Resistance to crushing measured with 100-mm² flat-tip penetrometer.
† Means followed by the same letter within a column are not significantly different at 0.05 level using least squares differences and analysis of variance.

fluctuated within 1 m of the soil surface during the growing season. Analysis of water table data collected from seven wells indicated no consistent differences in water table depth among the wells; consequently, water table depth at this site can be represented by the mean water table depth of the seven wells. The water table responded predominantly to rainfall amount with no measurable tidal effect. Any contribution to the crop water requirement by the water table could not be measured in this experiment; however, the relative small amount of irrigation water applied (78 and 82 mm) each growing season resulted in larger fruit and higher yields. A higher percentage of large fruit is important because of the premium price received for extra-large and large fruit. With the management system used in this study, the 'Tempo' cultivar produced a higher yield and larger fruit, and matured earlier than the 'FloraDade' cultivar. Some of this yield advantage is probably a result of a lower incidence of disease in 'Tempo'. The 'soft-fruit syndrome' thought to be associated with excessive soil wetness and/or N fertilization was not induced in this experiment. Although input costs are higher, the management system used in this study provides increased profitability for fresh-market tomato production in the southeastern Coastal Plain.

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