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IMPACT OF A RAISED WATER TABLE ON DRIP-IRRIGATED TOMATOES

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Abstract. **A field experiment was conducted for 2 crop seasons to determine the effects of a sudden high water table on tomato (*Lycopersicon esculentum* Mill.) growth and yield with drip irrigation. The water table was raised from 0.9 m to 0.2 m and effects were observed for 5 and 8 day periods by measuring plant-height, dry matter accumulation, redox potential, and leaf temperature. Plant root distribution and root density were measured prior to and after raising the water table. Total root length density, dry matter accumulation, and plant height were not affected by water table treatment. An elevated leaf temperature was observed during the spring crop due to the raised water table. Redox potential at the 15- and 30-cm depths was reduced by the raised water table treatment. However, total tomato yield was not significantly ($P<0.05$) influenced by the near flooded conditions.**

Introduction

Southwest Florida has experienced a rapidly growing population along with expanding irrigated agriculture area. These conditions have strained available water supplies, making efficient irrigation essential to the sustainability of the region's agriculture. A significant portion of the irrigated area is in fresh market tomato production. The predominant irrigation method is water table management (seepage irrigation). Application efficiency of this irrigation method is low. Drip irrigation can be applied with increased control, therefore greater application efficiencies are common (5,9).

Heavy rains are frequent in southwest Florida, with a majority of the annual precipitation (1.4 m) coming from tropical and thunder storms (2). One of the major obstacles to the acceptance of drip irrigation by some growers has been a perception that drip irrigated tomato yields would be reduced from sudden high water tables associated with heavy rain. This concern arises from the assumption by some that root development with drip irrigation will be deeper when not limited by the perched water table that occurs with seepage irrigation. A sudden high water table that saturates the root zone may then reduce crop yields by depleting available oxygen to the plant roots. Tomato typically is considered to be one of the most sensitive vegetable species to excessive soil moisture (6).

Flooding plants reduces stomatal conductance and translocation of nutrients (1). Flooding soil results in a series of physical, chemical, and biological processes that can influence the quality of the soil as a medium for plant growth (8). During flooding, gas exchange between the soil and the air is drastically reduced (4). Soil microorganisms and plant roots may then absorb the available O_2. After flooding, plants often exhibit changes in metabolism and physiological processes. Reduced water absorption and closure of stomata are among the earliest plant responses (14).

Canopy temperature is a useful parameter in describing plant-water stress for many crops (7). The relationship between vapor pressure deficit (VPD) and the difference between canopy and air temperatures (T_c–T_a) has been developed as an environmentally responsive indicator of plant water stress and is termed the crop water stress index (CWSI) (12).

The objectives of this study were to determine the effects of a raised water table on tomato plants grown with drip irrigation.

Methods and Materials

The experiment was a randomized block with 4 replications. The experiment was conducted during the fall 1989 and the spring 1990 crop seasons. There were two water table treatments: 1) the non-raised water table (NRWT) maintained a 0.9-m depth to the water table; 2) while the other, the raised water table (RWT) also targeted a 0.9 m water table depth except for the 5 (fall) and 8 (spring) day periods when the water table was raised to the bottom of the 0.2 m plant bed. The raise in the water table occurred approximately 9 weeks after transplanting. Each treatment received approximately the same amount of irrigation water through the drip irrigation system.

The field study was conducted at the University of Florida, Institute of Food and Agricultural Sciences, Southwest Florida Research and Education Center near Immokalee, FL. Soil at the study site was predominately Immokalee fine sand (sandy, siliceous, hyperthermic Arenic Haplaquods).

A 1.25-m deep field rim ditch was established around the entire site and the water level was maintained in the rim ditch at or below a 1-m depth. The field had 0.6-m deep lateral ditches at 7.6-m intervals. Between the lateral ditches were 3 raised (0.2-m high) plant beds, covered with polyethylene mulch (0.125 mm). Each experimental plot was separated by a 7.6-m wide planted buffer area. The lateral ditches were used for drainage, irrigation for bed preparation, and water conveyance for raising the water table. Water was conveyed to the lateral field ditches through an underground piping system.

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Tomato seedlings 'Sunny' were transplanted in single row beds on 0.38-m centers with plant beds 0.75 m wide and 0.2 m high, which were spaced 1.8-m apart. A line source drip irrigation tube was placed on the top of the bed (under the polyethylene mulch) approximately 0.25 m from the plant row. The lateral tube had emitters on a 0.3-m spacing and a discharge of approximately 1.3 liters hr^{-1} at 70 Kpa per emitter. The drip irrigation system was installed with 8 separate headers consisting of a solenoid valve, flowmeter, pressure regulator, and pressure gauge.

In the fall crop, fertilizer was applied at 199-48-265 kg ha^{-1} of N-P-K. All the P, and approximately 25 percent of N and K were incorporated preplant during bedding. The remainder of the N and K was injected into the drip irrigation system on a weekly schedule (13). Due to a longer growing season, approximately 25 percent additional N and K were injected during the spring crop.

Tensiometers were placed at 3 depths (0.15, 0.3, 0.45-m) between the irrigation tubing and the plant row in each plot to monitor soil water status. They were observed daily at about 1500 hr. Irrigations were scheduled to maintain soil-water potential (SWP) above −15 kPa. Water-table level indicators were located in the middle of each plot. After the tomato seedlings were transplanted, readings of the plot flowmeters were recorded (Mon. through Fri.). Irrigation durations were set to ensure that each plot received the same total irrigation water.

Raising the water table was initiated at 8 and 9 weeks after transplanting for the fall and spring crops, respectively. Lateral field ditches on both sides of each raised water table plot were diked. Water was discharged to the lateral ditches at a rate that allowed the water table to rise to the ground surface level between the beds within approximately 24 hours.

Minirhizotrons were used to observe tomato plant root growth in a nondestructive manner (10). Two clear plastic observation tubes were placed in each plot after planting. The tubes were installed at a 30-degree angle from the vertical, and the direction of insertion was parallel to the plant row approximately 0.20 m away from the plants. Root growth observations were made by inserting a borescope down the observation tube and viewing out the side of the tube toward the plant at a right angle. A grid was inscribed on the viewing head, live and health root intersections with the tube were counted through the grid in 0.15-m depth increments down to 0.6 m below the top of the bed (15). Viewings through the tubes were made just prior and several days after the raised water table period each session.

Soil O_2 diffusion rate or redox potential was measured by installing platinum electrodes at 0.15- and 0.30-m depths in the raised water table plots and in the non-raised water table plots for comparison (11). Redox potential were measured daily just prior, during, and immediately after the raised water table period as Eh on a standard pH meter using a calomel reference electrode.

The canopy and air temperature were measured with an infrared sensing device (Scheduler[1]). This instrument could also measure the vapor pressure deficit. Thus, the CWSI was determined (3):

$$CWSI = [((T_a - T_c) - MIN)/(Max - MIN)] * 10$$

where,

T_a = Air Temperature, °C
T_c = Crop Temperature, °C
VPD = Vapor Pressure Deficit, MPa
Max = Maximum observed $(T_a - T_c)$ for crop, °C (a and b are constants for the specific crop)
MIN = Lower baseline [a + (b*VPD)]
a,b = Slope and intercept of the lower baseline

Measurements of daily CWSI were made between 1100 and 1400 hrs. Since CWSI was most reliable when at least 60% of maximum solar radiation was available, only data obtained under those conditions were reported.

Plant heights were measured weekly beginning 4 weeks after transplanting from 10 plants in each plot. Plant dry matter was determined before and after flooding by removing 2 plants from each plot and oven drying at 60C.

Each season, fruit from 20 tomato plants in each plot were harvested for yield. There were 2 harvests for the fall crop and 3 for the spring crop. A major freeze occurred on 25 Dec. 1989, approximately 5 days before the scheduled second fall harvest, in which all plants were killed. Two days following the freeze, fruit of marketable size were picked and weighed. Grading and sizing were not done since most of the fruit were immature.

Results and Discussion

Components of the simplified water budget are given in Table 1. Drip irrigation amounts did not include the water used for field prep, flooding treatments, or freeze protect. Average irrigation amounts were 18 and 23 cm for the fall and spring crops, respectively. The ratio of pan evaporation to irrigation water applied was approximately 1:2 in the fall and 1:3 in the spring. The total rainfall amount was 15 and 23 cm for the fall and spring seasons, respectively.

In the RWT plots, the water table was raised to pond water in the middles between the plant bed. Due to the lateral movement of water, the water table in the NRWT plots was influenced and gradually raised to approximately 0.5-m on the last day of flooding each year. Prior to raising the water table, it was normally kept below 0.9-m from the top of the plant bed. However, due to rainfall early in both years, the water table was temporarily raised. In the fall of 1989, after the flooding period, the water table was raised 4 times for freeze protection. Differences were observed in SWP due to the RWT treatment.

The average CWSI data for NRWT and RWT treatments for the spring are shown in Fig. 1. An elevated CWSI was observed in the spring crop on days 5, 7 and 8 on the RWT plots. However, negative values indicate non-stressed conditions (3). Therefore, only on day 7 was moderate stress observed on the tomato plants in the RWT plots. During the fall no difference in CWSI was observed.

Table 1. Components of the simplified water budget.

Crop	Water applied[z]	Pan evaporation	Rainfall
	cm		
Fall 89	18	35	15
Spring 90	23	70	23

[z]Water applied through the drip irrigation system does not include water applied for field preparation, flooding, or freeze protection.

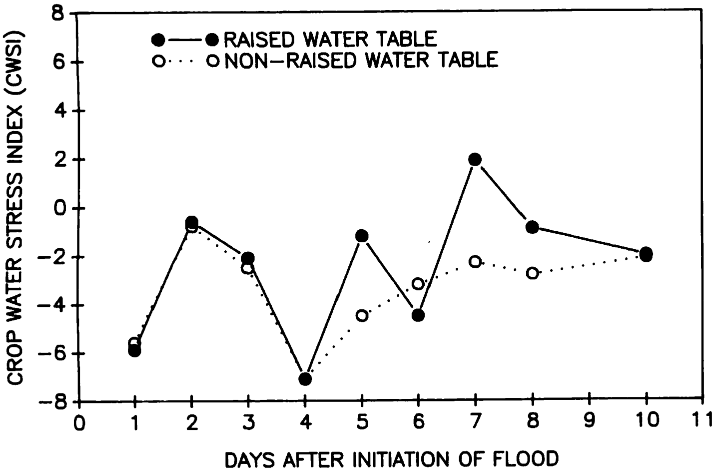

Fig. 1. Average CWSI for the spring 1990.

Redox potential during the spring raised water table period for the 0.15-m and 0.3-m depths are shown in Figs. 2 and 3. In each season the redox levels in the RWT plots decreased as the water table was raised and then increased when the water table was lowered. This phenomenon was observed at both 0.15- and 0.30-m depths. For the RWT treatments, the redox levels decreased from an Eh of approximately +125 to −110 mV and from +100 to −.00 mV for 0.15 and 0.30-m depths, respectively, indicating a reduced O_2 supply. A critical value for Eh depends on soil water, texture, temperature, pH, and salt content (11).

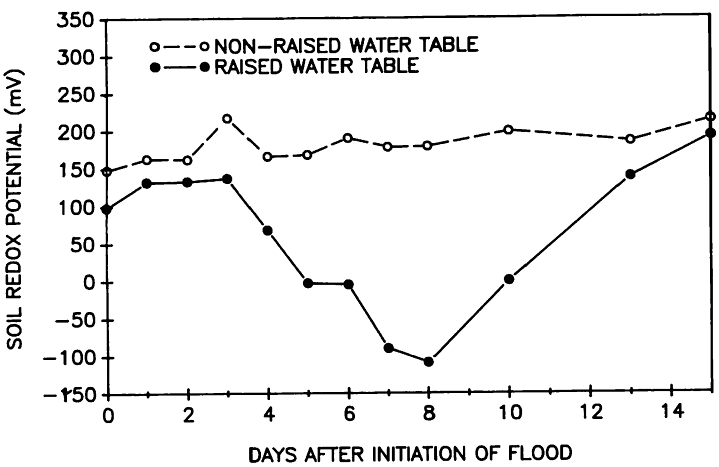

Fig. 2. Average redox potential (mV) at the 0.15-m depth for the spring 1990.

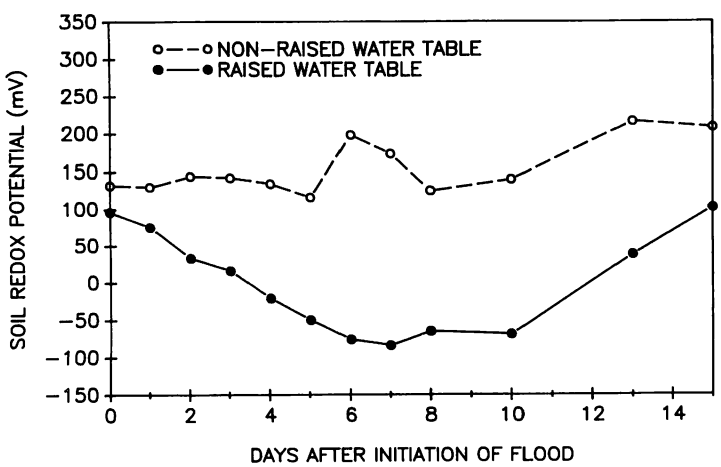

Fig. 3. Average redox potential (mV) at the 0.3-m depth for the spring 1990.

Root length density was significantly different between the RWT and NRWT treatments at the 0.45 to 0.60-m depth increment (Table 2). However, the overall effect of the raised water table on root length density was not significant.

Treatment did not significantly affect plant height during either crop season. The average dry matter accumulations per plant, sampled prior to and after flooding are shown in Table 3. There was no statistical difference in dry weight due to the raised water table.

Tomato yield data are shown in Table 4. There was a significant effect ($P<0.05$) on yield by the raised water table for the third picking of the spring crop. Mean yields for the fall and spring crop were 76.1 and 79.9 Mg ha^{-1}, for the RWT and the NRWT treatments, respectively. Total yield was not statistically affected by treatment.

Given these results, the question arises: why have tomato growers reported crop damage due to high water levels (flooded conditions)? The following is a possible explanation: With seepage irrigation, all of fertilizer salts are added to the plant bed to carry the crop through the entire season. Fertilizer rates as high as 336 kg ha^{-1} of water-soluble N and K or higher are commonly used by commercial growers. When the water table rises following a heavy rain, salts may concentrate near the soil surface where the majority of the tomato roots exist. The high salt concentration may damage the plant root system and reduce the soil osmotic potential, resulting in crop damage. With drip irri-

Table 2. Root length density (cm cm^{-3}) as measured with the minirhizotron technique.

Depth (m)	RWT	NRWT
	cm roots/cm³ soil	
0.00-0.15	0.40 a[z]	0.36 a
0.15-0.30	0.82 a	0.79 a
0.30-0.45	0.88 a	1.03 a
0.45-0.60	0.68 a	1.03 b
Mean	0.69 a	0.80 a

[z]Means within rows followed by the same letter in the same row were not significantly different ($P<0.05$)

Table 3. Mean[z] dry matter accumulation per plant prior to and after raising the water table.

Treatment	Dry matter accumulation (g) Plant	Fruit	Total
	Pre-flood		
NRWT	151	26	177
RWT	139	27	166
	Post-flood		
NRWT	159	53	211
RWT	154	55	209

[z]Mean values were not different ($P<0.05$) (T-test, SAS).

Table 4. Average yield for fall 1989 and spring 1990 crops.

	Average yield (Mg ha^{-1})	
	Fall 1989[z]	
1st pick	43.8 a	41.3 a
2nd pick	34.1 a	38.2 a
Sub-total	77.9 a	79.5 a
	Spring 1990[y]	
1st pick	40.0 a	41.3 a
2nd pick	28.3 a	29.6 a
3rd pick	6.3 b	9.4 a
Sub-total	74.5 a	80.4 a
2-Season Average	76.1 a[x]	79.9 a

[z]Yields include 7% culls
[y]Yields include 17% culls
[x]Values followed by the same letter in the same row were not significantly different ($P<0.05$)
(1 Mg ha^{-1} = 0.44 TON ac^{-1})

gation, fertilizer is added as the crop requires it, thus high salt concentrations are not present.

During the spring crop this hypothesis was examined. In an adjacent field, a seepage irrigated plot (0.15 ha) was planted and fertilized following commercial practices. In this plot the water table was raised at the same time as the drip irrigated plots. The result was a crop failure in the seepage irrigated plot with approximately 50 percent plant mortality. Salt concentrations measured before and after flooding were found to be several times higher in the seepage than the drip irrigated field. More research is needed to document this phenomenon.

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PLANT BED CONFIGURATION, FERTILIZATION RATE AND APPLICATION METHOD, AND CULTIVAR EFFECTS ON SWEET ONION PRODUCTION

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Abstract. **Yields of 'Texas Granex 429' onion (*Allium cepa* L.) were increased by 78.6% over yields with standard practice by changing plant bed configuration and increasing plant population. The standard 40-inch bed with a single row of onions was compared to an 80-inch bed with 3, 4, and 5 rows of onions. With the 80-inch bed, 47,000, 62,800, and 78,400 plants per acre were planted with the 3, 4, and 5 row treatments, respectively. Yields with the 40-inch bed averaged 15 ton/acre compared to 25 ton/acre with the 80-in bed with 5 rows. A positive significant linear effect in yield and number of large size onions (3 inches or greater) was observed as number of rows on 80-inch bed increased. The average size of harvested onion bulbs decreased significantly as bed size and the number of rows increased. Application of additional N (50 and 100 lb/acre) to the basic rate of 100 lb N/acre at planting had no effect on yield or size. In 1989, two culivars, Granex 33 and Granex 429, three rates of N (100, 200, 300 lb per acre) three rates of K (0, 42, 84 lb per acre) and three fertilizer application methods (25%, 50%, and 75% at planting) were studied. The only significant difference in treatment was that 'Texas Granex 429' yielded more than 'Texas Granex 33'.**

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