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The effects of two drip irrigation rates and two emitter placements on tomato production

A. Navarro and J. Newman

UVI Agricultural Experiment Station, St. Croix, USVI 00850

The effects of two drip irrigation rates and two emitter placements (surface and subsurface) on the production of tomatoes were investigated in the U.S. Virgin Islands. There was significant ($P<0.05$) difference in yields between irrigation rates but none with emitter placements. Using tomato variety N-69, marketable production of 45 tons/ha was obtained from the treatment which was irrigated at the weekly rate of 5.5 mm while marketable production of 55 tons/ha was obtained from the treatment supplying 10.4 mm water per week. The relationship of production to rainfall and potential evapotranspiration is discussed.

Keywords: Drip Irrigation; Tomato

Introduction

The climate of the US Virgin Islands is characterized by constant wind movement ranging from 5 to 15 miles per hour, by high temperatures, and by low and often erratic rainfall (Jordan, 1975; Rivera et al. 1970). The average yearly rainfall is approximately 44 inches but most of it is lost to the atmosphere by evaporation. It is estimated that only 1-3 inches of the rainfall enters the underground aquifer and about an inch flows overland into the ocean(Bowden, 1968; Rivera et al.,1970).

The limited water resource, aggravated by long periods of dry weather during the year, is one of the most important obstacles in increasing food production in the U.S.Virgin Islands. Without irrigation, it is almost impossible to obtain reasonable yields particularly from vegetable crops. Since water is a limited resource and therefore expensive, its application for irrigation can only be economically justified if it is used efficiently on high value crops.

The drip method of irrigation is the most efficient method known today. It has been reported that with the drip method, irrigation can be reduced by 50% or more without impairing yield or quality of production (Furt et al., 1980). The efficiency of the method can possibly be enhanced by using it in combination with other water conservation methods such as strict monitoring of water application and minimizing evaporation.

This study was conducted to evaluate the influence of two different rates of water application and emitter placement on tomato production in St. Croix, U.S. Virgin Islands.

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Materials and Methods

The study was conducted at the UVI Agricultural Experiment Station in St. Croix. The soil is Fredensborg clay loam. The irrigation system comprised mainlines and submains of 12.7 mm polyethylene tubes. The laterals were 12.7 mm bi-wall tubing, with orifices spaced 46 cm apart.

Tomato seeds (cv. N-69 from Hawaii) were sown on 2.54-cm jiffy pellets on December 29, 1986. Approximately 22 days after sowing, the seedlings were transplanted. Spacing was 46 cm between plants and 91 cm between the rows. Each row was 9 meters long. There were four rows to a treatment. After transplanting, one tensiometer was installed per treatment, approximately 10 cm away from the plant at a depth of approximately 15 cm.

The treatments were two levels of water, low (I1) and high (I2) in the high water level treatment, the tensiometer readings were maintained most of the time between 20-30 centibars. In the low water level treatment, tensiometer readings were maintained most of the time between 40-50 centibars. The other treatments were emitter placement, either surface (S1) or sub-surface (S2). For the S2 treatment, the bi-wall laterals were buried about 8-10 cm under the ground. Under the two levels of irrigation, the amount of water was divided between the two emitter placements. The treatments were arranged in a split-plot design, with water levels as main plots and emitter placements, the subplots. There were three replications.

A week after transplanting, the plants were fertilized with a 20-20-20 mixture at the rate of 1/2 tablespoon per plant. The fertilizers were applied around each plant and covered with soil. When about fifty percent of the plants started to flower, the same fertilizer mixture was applied at the rate of 1 tablespoonful per plant in the same manner as the first application.

The tomatoes were harvested at the ripe and turning stage. Eight harvests were made. The first harvest was on March 4, 1987, approximately 64 days from transplanting and 86 days from sowing. The last harvest was done on April 6, 1987. At harvest, the weight and number of fruits were recorded.

Results and Discussion

The highest amount of irrigation, as shown in Table 1 was applied during the month of January which was 13.4 and 22.4 liters per plant for I1 and I2 treatments respectively. During the first two weeks of January, irrigation was maintained at the highest level permissible under the two treatments in order to help the plants get better established.

Table 1 also shows that during the three-month cropping period, the amount of water applied for the I2 treatment is almost twice the amount that was used for the I1 treatment. During January and February the amount of water used for the I1 treatment was approximately 60% and 53% of the amount used for the I2 treatment respectively. During March, the difference in the amount of irrigation water applied between the two treatments is much greater, the low level treatment using approximately 41% of the high level treatment.

The precipitation which occurred during the period reduced the differences in the amount of water available to the plants between the two treatments (Table 2). In January, February and March, the total amounts of water available to plants in the I1 treatment were respectively, 78%, 72% and 78% of the water available to the plants in the I2 treatment.

The amounts of irrigation applied per plant are shown in Table 3. In the I1 treatment, an average of 5.5 mm of water was used per week during the cropping period. For the same period, water use in the I2 treatment averaged 10.4 mm per week.

Table 1 Frequency and amount (litres/plant) of irrigation supplied during the cropping period.

Date	Cropping period					
	January		February		March	
	Low level	High level	Low level	High level	Low level	High level
1	2.3	4.2	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.6	3.6
3	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	1.5	2.3	1.2	1.9
6	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0
10	2.0	3.2	0.9	1.7	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0
12	3.2	5.0	1.1	1.4	1.8	4.2
13	0.0	0.0	0.0	0.0	0.0	0.0
14	0.0	0.0	0.0	0.0	0.0	0.0
15	0.0	0.0	0.0	0.0	0.0	0.0
16	3.7	5.2	0.0	0.0	0.0	0.0
17	0.0	0.0	0.0	0.0	0.0	0.0
18	0.0	0.0	0.0	0.0	0.0	0.0
19	0.0	0.0	0.0	0.0	0.0	0.0
20	0.0	0.0	0.0	0.0	0.0	0.0
21	0.0	0.0	2.0	1.7	0.0	0.0
22	0.0	0.0	1.2	1.9	0.0	0.0
23	0.0	0.0	0.0	0.0	0.0	0.0
24	0.0	0.0	0.6	2.2	0.0	0.0
25	0.0	0.0	0.0	0.0	0.0	0.0
26	0.0	0.0	1.0	2.5	0.0	0.0
27	0.7	2.2	0.0	0.0	1.9	3.8
28	0.0	0.0	0.9	3.7	0.0	0.0
29	0.5	2.6			0.0	0.0
30	1.0	0.0			0.0	0.0
31	0.0	0.0			0.0	0.0
Total	13.4	22.4	9.2	17.4	5.5	13.5

Crop water use in the present study is slightly lower than in a study done in the same location in 1982 (Navarro,1982). This study involved two field experiments, where weekly irrigation rates of 6.4, 6.6 and 17.3 mm of water were applied to maintain tensiometer suction pressures at 60, 40 and 20 centibars. Best yields were obtained with 6.4 mm of water/ week (Trial 1, cv. Royal Chico) and 14.7 mm/ week (Trial 2, cv. Tropic).

Table 2 Precipitation and sum of precipitation and irrigat during the cropping period (liters/plant)

Date	Precipitation			Precipitation plus irrigation					
	Jan	Feb	Mar	Jan		Feb		Mar	
				Low	High	low	High	low	High
1	0.0	0.0	0.0	2.3	4.2	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	3.6
3	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.4	0.4
4	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.4	0.4
5	2.2	0.4	0.0	2.2	2.2	1.9	2.7	1.2	1.9
6	0.0	0.0	2.3	0.0	0.0	0.0	0.0	2.3	2.3
7	8.3	0.0	0.0	8.3	8.3	0.0	0.0	0.0	0.0
8	0.8	0.0	0.0	0.8	0.8	0.0	0.0	0.0	0.0
9	0.4	0.0	0.4	0.4	0.4	0.0	0.0	0.4	0.4
10	0.0	0.0	0.0	2.0	3.2	0.9	1.7	0.0	0.0
11	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.4	0.4
12	0.0	0.2	0.4	3.2	5.0	1.3	1.6	2.2	4.6
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14	0.2	6.7	0.0	0.2	0.2	6.7	6.7	0.0	0.0
15	0.0	0.0	6.4	0.0	0.0	0.0	0.0	6.4	6.4
16	0.0	0.0	0.0	3.7	5.2	0.0	0.0	0.0	0.0
17	0.0	0.0	9.5	0.0	0.0	0.0	0.0	9.5	9.5
18	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20	2.5	0.0	0.0	2.5	2.5	0.0	0.0	0.0	0.0
21	0.0	0.0	0.0	0.0	0.0	2.0	1.7	0.0	0.0
22	0.0	0.0	0.0	0.0	0.0	1.2	1.9	0.0	0.0
23	0.7	0.2	0.0	0.7	0.7	0.2	0.2	0.0	0.0
24	0.0	0.0	0.0	0.0	0.0	0.6	2.2	0.0	0.0
25	0.0	0.0	2.0	0.0	0.0	0.0	0.0	2.0	2.0
26	0.7	0.0	0.0	0.7	0.7	1.0	2.5	0.0	0.0
27	0.0	0.3	0.0	0.7	2.2	0.3	0.3	1.9	3.8
28	0.2	3.7	0.0	0.2	0.2	4.6	7.4	0.0	0.0
29	0.0		0.0	0.5	2.6			0.0	0.0
30	1.0		0.0	3.5	2.5			0.0	0.0
31	0.0		0.0	0.0	0.0			0.0	0.0
Total	18.5	11.5	22.2	31.9	40.9	20.7	28.9	27.7	35.7

Hoare, et al. (1974) presented a simplified formula for determining the rate of potential evapotranspiration as follows:

$$E_t = f_1 Eo$$

Where E_t = rate of potential evapotranspiration
f_1 = crop coefficient
E_0 = U.S. Class A pan evaporation.

Hoare et al. reported f1 for tomatoes as 1. The authors adjusted f1 in accordance with the fraction of the ground covered by the plants. The formula is as follows:

$$f^1 = f_1 \; [GC + 1/2 \; (1 - GC)]$$

Where f^1= corrected f_1 and GC = fraction of the ground covered by the plants.

Table 3 Average weekly values for applied irrigation, (I) irrigation plus precipitation (I+P) and computed crop potential evapotranspiration (ET) (in mm) for the cropping period[a].

Treatment	January			February			March		
	I	I&P	Et	I	I&P	Et	I	I&P	Et
			12.6			17.1			21.4
I1	7.6	18.0		5.7	12.6		3.1	15.7	
I2	12.7	23.2		10.9	16.2		7.6	20.2	

a) Average weekly U.S. Class A Pan evaporation rates for January, February and March were 28.1, 28.6 and 32.0 mm respectively. Et was calculated by the method of Hoare et al. (1974).

Based on the observation of Fleming (1964), these workers determined E_0 using the following relationship: $E_0 = 0.8\ E_{pan}$. Applying the above method and using GC values of 12%, 50% and 67% for January, February and March, respectively, Et values were computed and are shown in Table 3. It can be seen that, except during the month of January, the Et values are much greater than the amount of water made available by irrigation.

The rainfall during the cropping period contributed substantially to increasing the amount of moisture available to the plants. As a result, the I2 treatment showed only marginal water deficits in February and March. In the low water treatment however, water deficits were 4.5 mm in February and 5.7 mm in March. Surprisingly, in spite of the moisture deficits, the treatment with the lower rate of irrigation still managed to produce reasonable yields (Table 4) This suggests that tomatoes, or at least this particular variety, can tolerate considerable moisture stress and still maintain the capacity to produce reasonable yields. In addition, moisture conditions in the deeper layers of the soil may need to be observed to see if the plants are drawing water from these regions which were not accounted for.

Table 4 shows that yields obtained from the higher rate of irrigation were statistically greater than those obtained from the lower rate of irrigation. Emitter placement however did not show any significant influence on yield. The shallow placement of the emitters may have allowed the moisture to rise to the ground surface. Davis et al. (1985) reported a case in which yield and evapotranspiration rates of tomatoes were not affected by surface or subsurface emitter placement when irrigation frequencies and volumes were the same as in this study. The lack of effect of placement cannot be explained on the assumption that water was not limiting, since in the present study this was not the case.

In order to determine the efficiency of water use in each treatment, the production was expressed as weight of marketable fruit per liter of water applied (Table 5). The I1 treatment was significantly more efficient. A similar observation was made by English (1982), who stated that by under-irrigating a field crop, the yields may be reduced but capital outlay and operating costs associated with irrigation may also be reduced. The net result can be increased income to the farmer.

Table 4 Marketable tomato production (t/ha) as influenced by rate of irrigation and emitter placement

Irrigation Treatment (Average application) (mm/week)	Emitter Placement		Mean[1)]
	Subsurface	Surface	
Low level (5.5)	43.9	46.9	45.4[a]
High level (10.4)	54.3	55.0	54.6[b]
Mean	49.1	51.0	

1) Means with different letter superscripts are significantly different (P = 0.05).

Table 5 Average production of tomatoes (g) per liter of irrigation water applied (Water Use Efficiency)

Irrigation rate	Water Use Efficiency (g/liter)		
	Subsurface	Surface	Mean[1)]
Low level	124	133	128 [a]
High level	81	82	82 [b]
Mean	102	108	

1) Differences between means with different letter superscripts are significant at 1% level.

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