Table 3. Main effects of irrigation method and plant spacing on N concentration in watermelon leaves at Leesburg and Gainesville.

Treatment	Leaf N (%)[z] Leesburg A	Leesburg B	Gainesville A	Gainesville B	Gainesville C
Irrigation					
None	4.1	3.7	4.7	4.1	4.1 a
Overhead –[y]	3.9	4.0	4.5	4.0	3.7 b
Overhead +	4.0	4.1	4.6	4.2	3.6 b
Drip	4.0	4.0	4.5	4.2	4.0 a
F[x]	N.S.	N.S.	N.S.	N.S.	**
Plant spacing (ft)					
2.5 x 10	4.0	3.9	4.6	4.0	3.8
5.0 x 10	4.0	3.9	4.5	4.2	3.8
F	N.S.	N.S.	N.S.	*	N.S.

[z]Leaves were sampled at Leesburg on May 14 (A) and June 11 (B), and at Gainesville on May 14 (A), June 10 (B), and July 2 (C).
[y]Overhead irrigation without fertilizer injection (–) and with fertilizer injection (+).
[x]F values were significant at the 5% (*) and 1% (**) level and means were separated by orthogonal comparisons or F values were not significant (N.S.).

An additional benefit of drip irrigation, besides the savings in water used, was the restricted growth of weeds. Continuous wetting of the soil surface of the overhead-irrigated plots allowed weed seed germination and provided adequate moisture for prolific weed growth over the entire plot area. Weed growth with drip irrigation was limited to a narrow band down the row middle.

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Proc. Fla. State Hort. Soc. 94:163-166. 1981.

QUANTITY AND RATE OF WATER APPLICATION FOR DRIP IRRIGATED TOMATOES[1]

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Additional index words. Lycopersicon esculentum, trickle irrigation, water requirement, N, P, K, greenhouse.

Abstract. **The effects of emitter location, quantity and rate of water application with drip irrigation were evaluated on tomato** (Lycopersicon esculentum) **plant growth and fruit production. Greenhouse studies were conducted in ground beds of Chipley fine sandy soil during 2 seasons. The rate of water application/emitter, from 0.5 to 2.0 gal/hr had no effect on plant growth and fruit yield. However, fruit yields were significantly influenced by the quantity of water applied in both seasons. During the 1977-78 season, the number of marketable fruit was 16% greater with a water application quantity of 1.0 compared to 2.0 times pan evaporation. However, fruit size was larger with the higher water quantity and total marketable fruit yield increased only 6% over that obtained with the 1 pan treatment. In the second season, marketable fruit yield was 30% greater with 1.0 pan than 0.5 pan with 2 drip lines/bed. With 1 drip line/bed, yields were similar with both water quantities. Leaf tissue nutrient data indicated that N and K concentration were not different with the 1.0 and 2.0 pan irrigation quantities. Leaf N was higher and P lower with 0.5 than 1.0 pan water quantity in the second season.**

Overhead and subsurface irrigation systems currently are the most extensively used systems for tomato production in Florida. Generally about 15 to 20 or 45 to 60 inches/acre of water are used per season with the 2 systems, respectively (2, 5). In recent studies, tomato production was similar to or higher with one-half as much water from drip as with overhead irrigation (2, 6, 7). Nutrients are easily leached from the plant root zone with drip irrigation (1) and soluble fertilizers must be applied with the irrigation water to obtain highest yields (6). The quantity, rate of water application, and placement of emitters has been shown to influence soil water distribution, nutrient uptake (1, 3, 4) and tomato root growth (3). Precise control of these factors is necessary to prevent excessive nutrient leaching and to produce maximum yields.

These studies were conducted to evaluate the effects of water quantity, rate of application and drip emitter location on tomato leaf tissue composition and fruit yield.

Experimental Procedures

Experiments were conducted in a fiberglass greenhouse

[1]Florida Agricultural Experiment Stations Journal Series No. 3415.

located in Gainesville during 2 seasons. In 1977-78, treatments were a 2x3 factorial arrangement of 2 water quantities (1.0 and 2.0 times pan evaporation) and 3 rates of emitter water application (0.5, 1.0, and 2.0 gal/hr/emitter) by drip lines placed between 2 plant rows. In 1978-79, treatments were 2 water quantities, 0.5 pan and 1.0 pan, and 2 rates of emitter water application 0.5 and 2.0 gal/hr/emitter arranged factorially with 1 drip line per plot. Two additional treatments were 0.5 pan and 1.0 pan applied at 2.0 gal/hr/emitter with 2 drip lines/plot. These drip lines were placed about 2 inches away from and along the plant rows with an emitter inserted adjacent to each plant. Emitters were of a commercial type with capacity ratings of 0.5, 1.0 or 2 gal/hr. Pressures were controlled to attain the discharge rate required. All emitters were spaced 1.5 ft apart along the drip lines. Treatments were replicated 4 times in 3 x 6 ft ground bed plots of Chipley fine sandy soil. Between plot rows, a 2-foot wide border was provided that was included in the plot area for fertilizer and yield calculations but not for water application. In the first season, the soil pH was adjusted to approximately 6.5 with 6 tons/acre of dolomitic limestone. In each season, the soil was fumigated with methyl-bromide at 1 lb/70 ft^2. Preplant fertilizer was applied broadcast before planting at 18-60-18-24 lb/acre N-P-K-micronutrients from ammonium nitrate, triple superphosphate, potassium sulfate and F.T.E. 503.

'Tropic' tomatoes were transplanted on November 8, 1977, and on October 20, 1978, in 2 rows/plot spaced 1.5 ft apart between and within rows. Water was applied every other day early in the season and then daily as the season progressed in the required amounts according to measured pan evaporation. A standard Class A pan was used to determine pan evaporation in the greenhouse and averaged about 1 inch/week and range from 0.70 inches to 1.60 inches/week. The total depths of water applied in 1977-78 were 15.67 and 31.34 inches, for the 1.0 pan and 2.0 pan treatments, respectively, and in 1978-79, for the 0.5 pan and 1.0 pan treatments, 11.73 and 23.46 inches were applied, respectively. Fertilizer was applied with the drip irrigation water at 5-0-5 lb N-P-K/acre/application. In the first season, 11 weekly applications were made and beginning in February, 16 bi-weekly applications were made. The latter fertilizer applications included 1.5 lb Ca and 0.5 lb Mg/acre from calcium chloride and magnesium sulfate. In the second season, 22 weekly applications of 5-0-5 lb/acre were applied.

Recently matured leaves were taken at monthly intervals for elemental analyses. Nitrogen was determined by the micro-Kjeldahl method, P colorimetrically, by the ascorbic acid molybdate method, and K by atomic absorption spectrophotometry. Plant stem diameters were measured in the 1978-79 season at the time of first fruit harvest at each flower cluster and fruit set on each cluster was counted. Fruit were harvested twice weekly, at the 'pink' stage of maturity.

Results and Discussion

Tomato plant stem diameter was significantly influenced by water quantity and number of drip lines/plant bed during the 1978-79 season (Table 1). With 1 drip line placed between the 2 plant rows, stem diameters below each of the 4 flower clusters were 15 to 25% larger with the 1.0 pan than the 0.5 pan water quantity. A similar pattern of increased stem diameter was obtained with the higher over the lower water quantity with 2 drip lines/bed. However, stem diameters were significantly greater with 1 than with 2 drip lines/bed. At flower cluster 2 and 3, stem diameters were 9 and 14%, larger with 1 than with 2 drip line/bed, respectively. Since the same amount of water and nutrients were applied with both treatments, probably a greater water use efficiency was achieved with 1 wetting front as compared to 2 wetting fronts. Two lines/bed probably gave twice the wetted soil surface area as with 1 line, while a single line wets the irrigated soil volume to a greater depth than with 2 lines/bed. Both of these factors contribute to greater evaporation losses for 2 lines/bed as compared to single line treatments.

Table 1. Main effects of water quantity and number of drip lines/bed on tomato stem diameter 1978-79.

Irrigation treatment: Water quantity (pan)	Drip line/bed	Stem diameter (inches) at flower cluster: 1	2	3	4
0.5	1	0.50	0.51	0.42	0.37
1.0	1	0.59	0.66	0.57	0.48
F[z]		**	**	**	*
0.5	2	0.49	0.44	0.34	0.37
1.0	2	0.56	0.59	0.52	0.45
F		*	**	**	N.S.
0.5 + 1.0[y]	1	0.54	0.56	0.49	0.44
0.5 + 1.0	2	0.54	0.52	0.43	0.41
F		N.S.	**	**	N.S.

[z]F values were significant at the 1% (**), 5% (*), levels or not significant (N.S.).
[y]Data are mean of both water quantities and with a 2.0 gal/emitter/hr application rate.

The number of fruit set on the first flower cluster was not influenced by the quantity of water applied or the number of drip lines/bed (Table 2). The average number of fruit set on clusters 2 and 3 were significantly greater with the higher than with the lower water quantity with 1 drip line/bed. With 2 lines/bed, the higher water quantity gave significantly more fruit set only at cluster 3. Fruit set counts were not significantly influenced by the number of drip lines/bed. Apparently, the larger plant size obtained with 1 line/bed was not associated with an increase in fruit set as previously shown by Kaftafi and Bar-Yosef (4).

Table 2. Main effects of water quantity and number of drip lines/bed on the number of fruit set/flower cluster, 1978-79.

Irrigation treatment: Water quantity (pan)	Drip line/bed	Stem diameter (inches) at flower cluster: 1	2	3	4
0.5	1	3.2	3.8	2.7	2.1
1.0	1	3.2	4.2	3.1	1.8
F[z]		N.S.	**	*	N.S.
0.5	2	3.4	3.9	2.5	1.8
1.0	2	3.4	4.0	3.7	2.5
F		N.S.	N.S.	**	N.S.
0.5 + 1.0[y]	1	3.1	3.9	2.9	1.8
0.5 + 1.0	2	3.4	4.0	3.1	2.2
F		N.S.	N.S.	N.S.	N.S.

[z]F values were significant (N.S.) or significant at the 1% (**) or 5% (*) levels.
[y]Data are mean of both water quantities and with a 2.0 gal/emitter/hr application rate.

The marketable yield of tomato fruit was influenced by water quantity (Table 3). In 1977-78, the number of total marketable fruit harvested was significantly higher with the 1.0 pan than the 2.0 pan water quantity. Also, the early and mid season, and total marketable yields were greater with the lower quantity irrigation treatment, but these differences were not significant due to the counteracting influence of the increase in fruit size obtained with the higher water quantity. In 1978-79, fruit yields were not influenced by water quantity when irrigation was applied with 1 drip line/bed. With 2 drip lines/bed and the higher water quantity, significantly greater numbers and weights of marketable fruit were produced at the early and mid season harvests. Also, the total weight of fruit produced was significantly greater with the high than a low water quantity. Fruit size also tended to be larger with the higher water quantity. In this experiment, the number of drip lines/bed was not a significant factor in terms of marketable yield. However, with the 1.0 pan irrigation treatment, yields were slightly higher with 2 than 1 drip line/plot.

The rates of water application (0.5, 1.0 and 2.0 gal/emitter/hr) had no effect on plant growth parameters in both experiments.

The quantity of water applied in 1 drip line/bed during the 2 seasons had little significant effect on tomato leaf tissue K concentrations (Fig. 1) in samples taken 1 to 5 months after transplanting (December through April). In the 1977-78 season, K concentrations were lower than in 1978-79. Even though 6 tons/acre of dolomite was applied preplant, plants exhibited Mg deficiency symptoms. Concentrations of Mg and Ca, which were low in January, 0.44 and 1.08% respectively, were effectively increased by additions of Mg and Ca. with drip irrigation water. The Mg concentration was 0.85% and Ca was 3.45% in the April samples. This increased application of competitive cations apparently resulted in the very low K concentrations obtained even though K was being applied biweekly.

During both seasons, tissue P concentrations were significantly higher in plants that obtained the higher water quantities. Kafkafi and Bar-Yosef (4) showed that increased P absorption occurs with an increase in soil moisture. The leaf N concentration was not influenced by water quantities of 1.0 and 2.0 pan during the 1977-78 season. In the 1978-79 season, N concentrations were similar in the December and January tissue samples but were significantly higher with the 0.5 pan than 1.0 pan water quantity treatments for the remainder of the season.

With 2 drip lines/bed (1978-79), K and N were slightly higher and P concentration were lower with 0.5 than 1.0-pan treatments (Fig. 2). Also, K and N tissue concentrations were slightly higher and P lower with 2 than 1 drip lines/bed. Concentrations of N and P were similar to those previously reported with drip irrigation (1, 4). The K concentrations were low, particularly late in the season and may have reduced yield (4, 8). Further work is needed to determine the K concentration needed for maximum yield with drip irrigation.

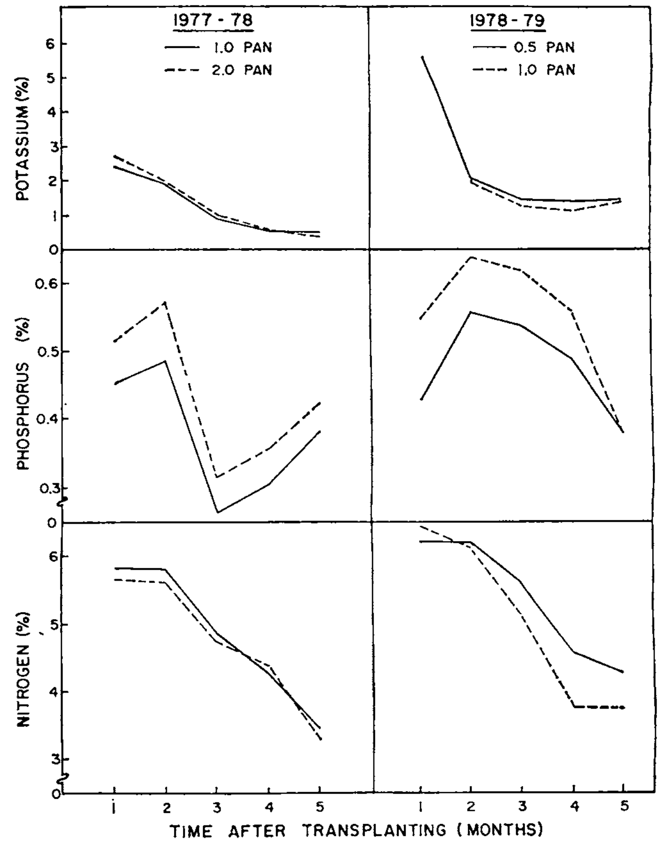

Fig. 1. Effect of water quantity on tomato leaf tissue N, P, and K concentration 1 to 5 months after transplanting during the 1977-78 (left) and 1978-79 (right) seasons.

In these studies, the quantity of water applied was a more significant factor on tomato plant growth than the rate of emitter discharge. Other studies (1, 3) have shown

Table 3. Main effects of water quantity and number of drip lines on marketable number, weight and average tomato fruit weight.

Irrigation treatment: Water quantity (pan)	Irrigation treatment: Drip line/bed	Marketable yield, Early and mid season: No./acre x 10^3	Early and mid season: ton/acre	Early and mid season: oz/fruit[y]	Season total: No./acre x 10^3	Season total: ton/acre	Season total: oz/fruit
			1977 - 78				
1.0	1	214	40.1	6.0^{y}	251	45.5	5.8
2.0	1	182	37.0	6.5	217	42.6	6.3
F^{z}		*	N.S.		**	N.S.	
			1978 - 79				
0.5	1	158	27.8	5.6	221	38.5	5.6
1.0	1	154	29.7	6.2	215	38.5	5.7
F		N.S.	N.S.		N.S.	N.S.	
0.5	2	132	22.9	5.6	197	32.4	5.3
1.0	2	160	32.2	6.4	215	42.3	6.3
F		*	**		N.S.	*	
0.5 + 1.0^{w}	1	157	29.0	5.9	219	38.6	5.6
0.5 + 1.0	2	146	27.6	6.0	206	37.3	5.8
F		N.S.	N.S.		N.S.	N.S.	

[z]Differences between treatment were significant at the 1% (**), 5% (*) levels or not significant (N.S.).
[y]Fruit size data were not statistically analyzed.
[w]Data are mean of 2 water quantities and a 2.0 gal/emitter/hr application rate.

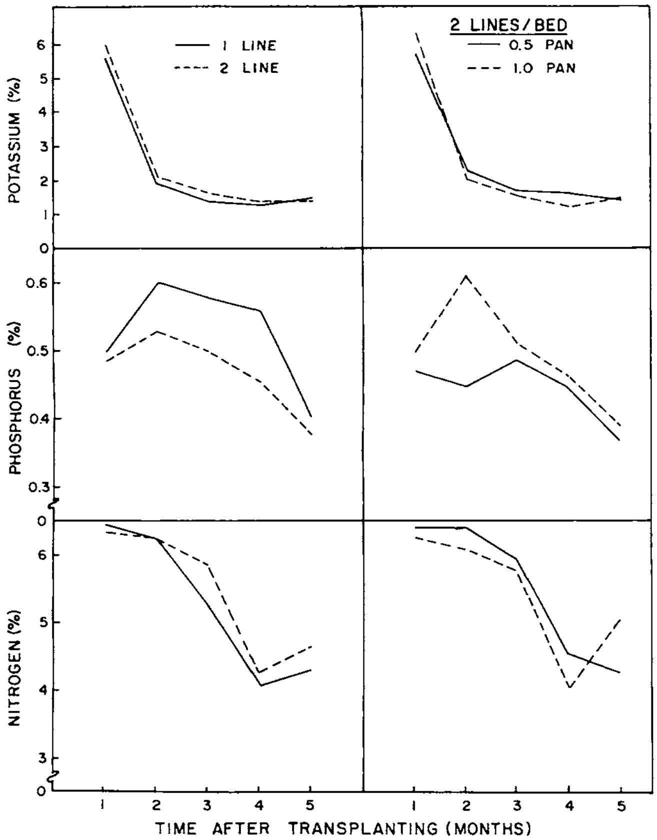

Fig. 2. Effect of number of drip lines/bed (1 or 2/bed) shown on the left and the quantity of water applied with 2 drip lines/bed (on right) on tomato leaf tissue N, P, and K concentration 1978-79.

that the rate of emitter discharge influences water and nutrient flow patterns. However, results from this study indicate that emitter discharge rates of 0.5, 1.0 and 2 gal/hr provided adequate water and nutrient distribution for greenhouse tomatoes to obtain similar plant growth and production parameters. Some effects were noted on movements of nutrients in the soil.

The water quantity associated with the highest yield in both seasons was 1.0-pan. With 1 drip line/bed, tomato production was similar with 0.5 and 1.0 pan. However, with 2 drip lines/bed, yields were significantly greater with 1.0-pan than the 0.5-pan treatment. This indicates that the larger volume of water applied between the plants was more effective in reducing water stress than a smaller amount of water applied near each plant.

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Proc. Fla. State Hort. Soc. 94:166-169. 1981.

AN ECONOMIC EVALUATION OF THREE IRRIGATION SYSTEMS FOR TOMATO PRODUCTION[1]

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Additional index words. investment costs, variable costs, fixed costs, replacement decision, seepage, subsurface drain, trickle.

Abstract. **Three hypothetical irrigation systems, seepage (modified furrow), subsurface drain, and trickle, were evaluated for soils with naturally high water tables to determine comparative irrigation costs for tomato production. Variable (operating) and fixed (ownership) costs were estimated for each irrigation system. The investment costs of the subsurface drain and trickle systems were significantly larger than the capital requirements for the seepage irrigation system. The variable costs, however, for subsurface drain and trickle systems were less than the seepage system due to the lower volume of water used by these systems. The seepage irrigation system was determined to be the most economical tomato irrigation system under present conditions.**

Increasing demand for water and higher energy costs have prompted many tomato producers to seek irrigation systems that more efficiently distribute and utilize water. Recently much interest has been generated in tomato irrigation systems that supply low volumes of water to designated areas for plant use. The use of these low volume systems would substantially reduce total water use and energy costs incurred in pumping water [1, 6].

The decision to invest in a particular irrigation system is based on whether the system is adaptable to the producer's resource situation and if the capital investment is a feasible alternative. These considerations constitute a man-

[1]Florida Agricultural Experiment Stations Journal Series No. 3397.
[2]The authors wish to acknowledge the help of producers, IFAS personnel and industry representatives who provided the technical information needed to develop the irrigation systems, and industry representatives of area pipe and pump companies who contributed the cost data.