Table 4. Main effect of fertilizer at planting and municipal solid waste (MSW) rates on snap beans yield (Experiment 2).

Treatment	Bean yield ($t \cdot ha^{-1}$)
Fertilizer	
At planting[y]	12.9
Not at planting	10.7
F test[z]	*
MSW	
($t \cdot ha^{-1}$)	
0	10.8
90	13.2
134	11.1
Regression[z]	Q*

[z]Significant at P<0.05 and regression was quadratic (Q).
[y]40-35.5-55.5 (kg N-P-K·ha^{-1}).

were increased from 10 to 448 t·ha^{-1}. The addition of MSW compost to the soil provides N almost completely in organic forms, therefore availability occurs only over an extended period of time. However, incorporation of inorganic fertilizer which is mainly water-soluble and is almost immediately available to the crops. For Experiment one, shoot fresh weight was higher when 90 t·ha^{-1} of MSW was incorporated as a soil amendment. For Experiment 2, the greatest effects of compost in plant population were seen in those treatments where no fertilizer was applied at planting and 90 t·ha^{-1} of MSW was used. Snap bean yield was higher when fertilizer was used at planting than no fertilizer at planting. The application of compost increased bean yield, with the highest yield at the rate of 90 t·ha^{-1} of MSW.

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SURFACE VS. SUBSURFACE DRIP IRRIGATION OF TOMATOES ON A SANDY SOIL

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Abstract. **Tomatoes (*Lycopersicon esculentum* Mill.) were produced using drip irrigation during the spring 1993 season on an EauGallie fine sand to evaluate the effects of drip irrigation tubing placement on yield. Tubes were placed on the soil surface and at a depth of 12 inches in the bed center. Daily irrigation application amounts were based on crop growth and estimations of ETo from a nearby weather station. Fertilizer rates of 192-122-183 and 279-122-279 lb/acre of N-P-K were also evaluated. Tomato plant growth and fruit production were not affected by the two fertilizer rates. However, plant size and fruit yield were lower with the drip tube placed at 12 inches than with the tube placed on the soil surface.**

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The need for conservative irrigation methods and management practices is increasing for all Florida commodities. In southwest Florida, commercial vegetable producers are one of the larger target groups that are affected by current and impending reductions in water allocations. The Southwest Florida Water Management District is encouraging growers to adopt and convert ditch conveyance subirrigation systems to either fully enclosed subirrigation systems (Clark and Stanley, 1992) or to drip irrigation (Clark et al., 1993).

One substantial benefit of drip irrigation for tomato production in Florida is the reduced water and fertilizer requirements as compared to other irrigation methods

(Locascio et al., 1989; Locascio and Smajstrla, 1989; Dangler and Locascio, 1990; Smajstrla and Locascio, 1990; Clark et al., 1991; and Pitts and Clark, 1991). Other benefits include multiple cropping (Stanley et al., 1991) and reduced bed widths as compared to subirrigation requirements (Maynard and Clark, 1990; and Clark and Maynard, 1992). However, costs of drip irrigation are generally higher than less conservative irrigation systems (Prevatt et al., 1981; and Prevatt et al., 1992).

While management of the drip system is very important, other elements critical to the success of drip irrigation for vegetable production include proper design and installation. Elements of design include pipeline and pumping plant sizing and selection, as well as selection and placement of the drip irrigation laterals and emitter spacing. Several studies that investigated the use of two drip irrigation lateral tubes per plant bed as compared to one tube per bed reported no yield advantage from the additional tube (Csizinszky and Overman, 1979; Csizinszky and Stanley, 1984; Randall and Locascio, 1988; and Pitts et al., 1989).

Subsurface drip irrigation is defined as the "application of water below the soil surface through emitters, with discharge rates generally in the same range as drip irrigation" (American Society of Agricultural Engineers, 1992). Many of the drip irrigation tubes are positioned 1 to 2 inches below the soil surface in Florida vegetable production systems and would be considered as subsurface drip, even though the tube is retrieved after each season. However, much of the "subsurface drip" research involves tubes positioned at depths of 16 to 20 inches as permanent installations (Ayars et al., 1992; Camp et al., 1992; and Phene et al., 1992). Lateral wetting of the soil from point sources (i.e., drip emitters) is related to the type of soil and particle size distribution. Because sandy soils have large particle sizes and large pores, lateral wetting from a point source is limited and may range from 6 to 12 inches (Victor and Clark, 1991; and Clark and Stanley 1992). Therefore, deep tube positions in subsurface drip applications may not provide water to the soil surface or into the root zone of shallow rooted crops.

The objective of this work was to evaluate the effects of shallow tube placement (drip irrigation) versus deep tube placement (subsurface drip irrigation) at two fertilizer application rates on yield and size of fresh market tomato production. Successful subsurface drip irrigation would allow multiple season use of a single drip tube without retrieval and replacement between seasons.

Methods and Materials

Tomatoes ('Sunny') were produced during the spring of 1993 on an EauGallie fine sand (sandy, silicaceous, hypothermic Alfic Haploquod) at the Gulf Coast Research and Education Center, Bradenton. Treatments involved factorial combinations of two tube placements, shallow (S, 1 inch deep) and deep (D, 12 inches deep), and two fertilizer applications (F1:192-122-183 and F2:279-122-279 lb/acre N-P-K) in a randomized block design. Drip irrigation tubes (T-Tape, 12 inch emitter spacing, 15 GPH per 100 ft at 10 psi) were placed in shallow trenches (8 to 10 inches deep) under each planned bed row in Jan. 1993 (subsurface position, D). These drip tubes were used to subirrigate the field area to establish sufficient soil moisture for bed formation and to maintain a water table at approximately 18 inches deep following bed formation and foi the first 3 weeks of plant establishment.

Beds were formed on 5 ft centers, 6 to 8 inches high with 24 inch wide tops, and were fumigated with methyl bromide chloropicrin 67:33 (350 lb per fumigated acre) on 15 Feb. 1993. During bed formation, additional drip irrigation tubes (the same type as used for the subsurface position) were placed centered on the bed in a surface position, approximately 1 inch deep, prior to application of the black polyethylene mulch. A "low flow" drip tube was selected to allow for longer application times and thus allow a longer time for upflux to occur by capillarity.

In all plots the P fertilizer was applied as pre-plant broadcast to the bed area and the N and K rates were applied in banded form placed 6 inches off of the bed center at 87-0-96 (F1) lb/acre and 174-0-192 (F2) lb/acre N-P-K. All treatments received the remaining 105-0-87 lb/acre of the N-P-K fertilizer in bi-weekly liquid injections with the irrigation water.

Transplants were set on 1 Mar. 1993 on 24-inch centers with the plant row 4 to 6 inches off of the bed center opposite the fertilizer band. On 24 Mar., the subirrigation management was stopped. The subsurface tubes in the subsurface plots were disconnected and the surface tubes were connected to those manifolds to initiate the surface and subsurface drip irrigation treatments. Irrigations were scheduled based upon crop coefficients and measured weather data.

Mature green and ripe fruit were harvested and graded for size grade and yield analysis on 27 May, 8 June and 15 June 1993. Fresh weights of leaves and stems minus all fruits of four plants per plot were obtained on 22 June for dry matter analysis. A subsample of each set of four plants was sealed in a plastic bag, taken into the lab, weighed, and then oven dried and re-weighed. Leaf samples from the fourth petiole from the top of three plants within each plot were also analyzed for tissue N content at the end of the season (Kjeldahl nitrogen, Kjeltec system 1026).

Results and Discussion

Measurements of air temperature, wind run, and solar radiation were downloaded weekly from an electronic logging weather station. Weather data were used to calculate daily reference evapotranspiration (Table 1, ETo) using

Table 1. Spring 1993 weekly rainfall (RAIN) and number of events (), Penman reference evapotranspiration (ETo), estimated tomato plant ET (ETc), scheduled drip irrigation (SCHED), and applied drip irrigation (APPL) amounts.

Week of season	Water (inches/week)				
	RAIN	ETo	ETc	SCHED	APPL
29/3-04/4	1.80 (1)	1.05	0.26	0.77	0.97
05/4-11/4	0.91 (2)	1.12	0.50	0.77	0.48
12/4-18/4	1.52 (1)	1.12	0.62	0.77	0.56
19/4-25/4	0	1.26	0.82	0.77	0.59
26/4-02/5	0.10 (1)	1.26	1.07	0.77	0.61
03/5-09/5	0.14 (1)	1.33	1.26	1.16	0.83
10/5-16/5	0.09 (2)	1.40	1.33	1.55	1.24
17/5-23/5	0.15 (1)	1.47	1.40	1.55	1.48
24/5-30/5	1.03 (2)	1.26	1.07	1.55	1.53
31/5-06/6	0.31 (2)	1.54	1.23	1.55	1.61
07/6-14/6	0	1.61	1.29	1.55	1.70
Totals	6.05	14.42	10.85	12.76	11.60

the Penman method (Jones et al., 1984). Average weekly ETo data were used to help schedule irrigations by estimating tomato crop evapotranspiration (Table 1, ETc) using crop coefficients (unpublished data) with the ETo data. Scheduled irrigation amounts (Table 1, SCHED) were based upon the ETc data and soil wetting characteristics. Applied irrigation water (Table 1, APPL) based on plot meter readings varied from the scheduled amounts possibly due to slight variations in tube lengths, and periodic leaks or decreased operating pressure from the supply system.

Weekly rainfall was limited to one or two events for weeks that received rainfall. Due to the limited root zone of the plants and low water holding capacity of the soil, infrequent and unpredictable rainfall events generally do not interrupt the irrigation schedule of drip irrigated fields that do not have soil moisture feedback and control capabilities.

The two applied fertilizer rates had no affect on fruit size or early or total marketable yields of tomatoes (data not shown). In addition, early yield of extra large and total marketable fruit were not significantly affected by tube position (Table 2). However, the total yield of extra large fruit (5% level) and total fruit (1% level) were significantly greater with surface positioned tubes than with subsurface positioned tubes (Table 2).

Above ground plant dry matter (leaves and stems) averaged 0.80 lb/plant for plants with the surface positioned tubes and 0.53 lb/plant for plants with the subsurface positioned tubes. Differences were highly significant (1% level) and agreed with the fruit yield results.

Leaf N concentration at final harvest averaged 1.81% with the lower fertilizer (F1) application and 2.05% with the higher fertilizer (F2) and were statistically different at the 5% level of significance. However, tube placement had no effect on leaf N concentration. Thus, differences in plant growth and yield were perhaps affected more by availability of water than fertilizer.

In these studies, spring 1993 tomato plant growth and fruit yield (size and total) were lower with subsurface drip irrigation (tubes at a 12 inch depth) than with surface positioned drip irrigation tubes. The two applied fertilizer rates had no effect on yields of extra large and total marketable tomato fruit.

Table 2. Early yield (first two harvests) and total yield (all three harvests) of extra large (X-LARGE) and total (TOTAL) marketable tomato fruit as affected by drip tubing position.

	X-LARGE		TOTAL	
Tube Position	(carton/ac)[z]	c.v.[y]	(carton/ac)	c.v.
Early Yield				
Surface	511	0.227	988	0.263
Subsurface	488	0.444	903	0.351
Significance[x]	NS		NS	
Total Yield				
Surface	1232	0.146	2810	0.076
Subsurface	856	0.461	1941	0.303
Significance[x]	*		**	

[z]25 lb. cartons per acre; 8712 linear bed ft per acre.
[y]Coefficient of variation (standard deviation/mean).
[x]F value for comparisons were significant at the 1% (**) level, 5% (*) level, or not significant (NS).

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