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RESPONSE OF 'MARSH' GRAPEFRUIT TREES TO DRIP, UNDER TREE SPRAY AND SPRINKLER IRRIGATION

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Abstract. **A 4-year study was conducted to compare drip, undertree spray jet and permanent overhead sprinkler irrigation systems at 3 rates (6, 12 and 18 inches/year) on 'Marsh' grapefruit trees grown on Astatula fine sand. Comparing irrigation systems, fruit production increases over no irrigation control ranged from 8% by drip to 20% by jet and 72% by sprinkler irrigations. The effect of irrigation rate on fruit production was less consistent, ranging from 20 to 43% over the no irrigation control. Fruit production was greater for the 12-inch rate than for the 6- and 18-inch rates. Juice quality measurements showed that irrigation resulted in fruit with lower soluble solids, acid, and soluble solids-acid ratio than fruit from the no irrigation control. Tree growth responded more to sprinkler irrigation than drip or jet irrigation systems indicating the importance of irrigation water coverage on well-drained sandy soil. The potential for water conservation by use of drip, jet and sprinkler irrigation in citrus production is discussed.**

Trickle irrigation has become an increasingly popular method of irrigation for citrus in Florida. Most of the irrigation systems installed in recent years are either drip or under-tree spray jets. This has occurred because these systems are relatively low in cost and offer potential savings in water and energy by irrigating only a portion of the tree root system at a lower water pressure. Studies have shown that on well-drained sandy soils, fruit production was increased by increasing the ground area covered by trickle irrigation around the tree (3, 8). The question of what proportion of the tree root system should be irrigated for optimum fruit production remains unanswered.

This study was initiated in 1980 to evaluate tree response to different surface area coverage and different rates of irrigation. By using drip, under tree spray jet and permanent overhead sprinkler irrigation systems, we were able to establish a range of ground coverage from 10 to 100% in the same block. This paper summarizes the data on irrigation rates, fruit production and horticultural responses of the trees over a 4-yr period.

Materials and Methods

The study was conducted on mature 'Marsh' grapefruit [*Citrus paradisi* Macf.] trees on rough lemon rootstock (*Citrus jambhiri* Lush) in central Florida. The soil was Astatula fine sand, a hyperthermic, uncoated Typic Quartzipsamments. The trees were planted in 1961 at a spacing of 25 × 25 ft making a total of 70 trees per acre. Treatments involved 3 types of irrigation systems and 3 rates of irrigation arranged in a factorial design making a total of 9 treatments. The 10th treatment was a no irrigation control. All treatments were replicated 4 times in 4-tree plots. There were no guard trees surrounding the drip or the spray jet treatments because the irrigation water was confined to an area under the tree canopies. Triple guard rows were used to separate the permanent overhead sprinkler irrigation treatments.

In drip irrigation treatments, 4 emitters per tree were used. Each dripper emitted 1.2 gal/hr at 15 lb./sq. inch (psi). Two spray jets per tree with a discharge rate of 13 gal/hr per jet at 15 psi were used. Sprinkler irrigation operated at 45 psi and discharged 33 gal per sprinkler per hour.

Irrigation rates involved were up to 6, 12 and 18 acre inches per year. To achieve these rates, the different irrigation treatments were applied at different frequencies and durations by using electric time clocks. Daily irrigation was practiced for the high rate (18 inch) of drip and under-tree spray jet systems.

Irrigation treatments were initiated in Oct. 1980 but the Jan. 1981 freeze damaged leaves and fruit. Treatments were restarted in Apr. 1981. Irrigation was not applied after each freeze until new leaves started to emerge. No irrigation was applied after the Dec. 1983 freeze until Mar. 1984. Soil moisture was measured in the area wetted by the emitters to a depth of 66 inches with a neutron probe at weekly intervals between 1982-1984. Soil moisture was maintained near field capacity in 1983 and 1984 by adjusting irrigation scheduling and the quantity of water applied. Water that percolated to a depth below 66 inches was arbitrarily considered lost to the tree. Percolation was calculated from soil moisture measurements (5).

Tree canopy surface area was calculated annually by measuring the height and width from 2 directions (north-south and east-west) of the tree (1). Leaf and fruit samples were collected annually and fruit yield data were taken at the time of fruit harvest.

Data were analyzed each year by analysis of variance where applicable. Means from the no irrigation control treatment were not included in the analyses. Only the main effects and the average of 4 yrs are presented for most measurements because of the large volume of data accumulated. Annual data are presented where significant yearly trends were involved as in fruit production.

Results and Discussion

Irrigation rates, coverage and percolation. Table 1 shows the ground area covered by the irrigation systems in terms of both the percentage of total land and the area under the tree canopy covered by the different irrigaton systems. There was no difference between land and tree canopy coverage in sprinkler irrigation because the entire area was covered. Spray jets at 2 per tree irrigated about 4.5 times the ground area as 4 drippers per tree.

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Table 1. Area covered by irrigation systems.

Treatments	Emitter	Irrigated area Under canopy	Total land
	No./tree	%	%
Drip	4	13.9	8.1
Jet	2	63.7	37.0
Sprinkler	¼	100.0	100.0

The quantity of water applied by different irrigation treatments are summarized in Table 2. More water was used in the sprinkler irrigation treatments than the jet or drip irrigation treatments although similar irrigation rates were designed for all 3 systems. We had difficulty in achieving the high application rate (18 inches) of drip irrigation without significant water loss by percolation because of the small area covered by drip emitters. Wetted area refers to the quantity of irrigation water that went through the columns of soil based on coverage by the different irrigation systems. Since the ground area covered by the 3 irrigation systems are different (Table 1), the same irrigation rate for a system with small ground area coverage would have more water going through the soil column than a system with large ground area coverage. Hence, one inch of water application for the sprinkler irrigation treatment is equivalent to 2.7 and 12.3 inches in the jet and drip treatments, respectively.

A substantial quantity of the irrigation water percolated through the root zone especially in the drip irrigation treatments (Table 2). An attempt was made in 1983 and 1984 to maintain the soil moisture content below field capacity to reduce the loss of water below the root zone. Thus, the amount of water applied in 1983 and 1984 was greatly reduced especially in the drip and jet treatments. As a result, percolation loss decreased to levels comparable to that of the no irrigaton control.

Tree response. Trees responded positively to all irrigation treatments especially that of the sprinkler irrigation (Table 3). The sprinkler-irrigated trees were larger in size, had denser foliage and larger leaves than the jet-and drip-irrigated trees. These differences were observed in all 4 yr. Although more water was applied in the sprinkler irrigaton treatments, it appeared that ground area coverage contributed the most to the differences in tree response. Tree

Table 2. Water applied and percolation as influenced by irrigation treatments.

Year	Measurements	Drip (inches) 6	12	18	Jet (inches) 6	12	18	Sprinkler (inches) 6	12	18	No. irrigations	Rainfall
					inches per year							
1981	Irrigation applied	4.4	6.1	7.6	5.9	8.2	13.1	7.2	13.3	18.3	0	40.5
	Wetted area[z]	54.0	75.4	94.8	18.9	24.1	37.2	7.2	13.3	18.3	0	
	Percolation[y]	–	–	–	–	–	–	–	–	–	–	
1982	Irrigation applied	7.6	11.8	13.1	8.5	15.0	17.9	7.3	15.8	19.7	0	56.8
	Wetted area	93.9	145.6	161.4	23.1	40.7	48.4	7.3	15.8	19.7	0	
	Percolation	7.3	7.0	16.6	2.9	2.4	7.5	4.1	4.7	4.3	2.1	
1983	Irrigation applied	3.6	4.2	6.5	2.9	4.0	5.1	5.2	10.4	12.1	0	62.0
	Wetted area	44.0	51.7	80.2	7.9	10.8	13.7	5.2	10.4	12.1	0	
	Percolation	0.6	1.8	3.0	1.5	1.4	2.7	3.0	2.7	2.5	1.5	
1984	Irrigation applied	0.9	0.7	1.3	1.1	1.5	3.9	3.9	5.4	9.6	0	46.7
	Wetted area	11.0	8.5	15.2	3.0	4.2	10.7	3.9	5.4	9.6	0	
	Percolation	0	0	1.2	0	0	0.4	0.2	0.7	0.3	0.5	

[z]Wetted area is based on the observation that each dripper irrigated an area of 4 ft in diameter (4 drippers per tree). Each jet irrigated an area 12.1 ft in diameter (2 jets per tree).
[y]Percolation was calculated from soil moisture measurements. Water moved below the 66 inch depth was considered lost to the tree. Percolation was not calculated for 1981.

Table 3. Tree response to drip, jet and sprinkler irrigation treatments.

Irrigation treatment	Tree canopy Surface area	Density[z]	wt/80 leaf	Freeze injury Tree pruned 1981	Diameter of cut 1981	Damaged leaves 1983	1985
	ft^2		g	%	inch	%	%
No irrigation[y]	527	2.62	39.6	81	1.34	50.5	72.1
Irrigation system							
Drip	539	2.57	41.2	71	1.14	47.4	69.7
Jet	553	2.78	44.2	62	1.26	45.7	67.6
Sprinkler	638	3.47	48.7	6	0.06	37.9	45.8
Significance	**[x]	**	**	**	**	**	**
Irrigation rate (inches)							
6	568	2.70	43.0	46	0.86	42.0	63.1
12	585	3.06	46.0	42	0.70	44.0	60.4
18	578	3.07	45.2	50	0.90	45.1	59.6
Significance	n.s.[x]	*	n.s.	n.s.	n.s.	n.s.	n.s.

[z]Canopy density standard: 1 to 5. 1 = sparsely foliated to 5 = cannot see through canopy.
[y]Means of no irrigation control are not included in statistical analysis.
[x]n.s. = not significant; * = difference significant at 5% level; ** = difference significant at 1% level.

response to different rates of irrigation was not significantly different in most measurements and indicated irrigation rates were not as critical as irrigation coverage. Similar trends were reported in previous studies (3, 6, 7).

The importance of irrigation coverage was further demonstrated in the ability of the trees to withstand low temperatures. Trees in the sprinkler irrigation treatments sustained less damage from the 1981, 1982, 1983 and 1985 freezes than the jet-and drip-treated trees. The sprinkler-irrigated trees came through these freezes with less leaf and wood damage and fewer trees needed pruning (Table 3). These findings are in agreement with previous observations (4).

Fruit quality and fruit production. Both soluble solids and acid concentration in fruit decreased with irrigation treatments (Table 4). Trends in both irrigation coverage and rates were consistent, but the effect to irrigation rates was not significant. These observations were consistent with results from earlier studies (6, 7). The only exception was in the juice acid concentration of the sprinkler-irrigated trees which had a higher acid content than the drip-or jet-irrigated trees. The infrequent sprinkler irrigation may partially contribute to the higher acid concentration. This should be further studied. Juice quality was not influenced by irrigation rates.

Table 4. Effects of irrigation treatments on fruit quality of 'Marsh' grapefruit.

Irrigation treatment	Juice by wt	Sol. solids	Acid	SS/A ratio	Wt/ fruit
	%	%	%		g
No irrigation[z]	49.4	9.4	1.27	7.4	425
Irrigation system					
Drip	48.3	9.1	1.23	7.4	462
Jet	48.7	8.8	1.20	7.4	468
Sprinkler	48.9	8.6	1.24	7.0	464
Significance (yr/yr)[y]	0/4	2/4	4/4	3/4	2/4
Irrigation rate (inches)					
6	48.2	8.9	1.24	7.3	467
12	48.8	8.8	1.23	7.2	464
18	49.1	8.7	1.20	7.3	463
Significance (yr/yr)[y]	1/4	0/4	1/4	0/4	0/4

[z]Means of no irrigation control are not included in the statistical analysis.
[y]No. of years data showed significant difference over no. of years data collected.

Irrigation treatments increased fruit production from 8 to 72% over the no irrigation control (Table 5). The increase was again related to the ground coverage by the different irrigation treatments. Sprinkler-irrigated trees had the highest fruit production, followed by jet-irrigated trees. The drip-irrigated trees had the lowest fruit production increase compared to the no irrigation control. The differential increase in fruit production by the irrigation treatments may have been due in part to the impact of the periodic freezes. Trees irrigated with a system that covered 100% of the ground came through the freezes better than trees irrigated with partial ground coverage, which, undoubtedly influenced the fruit production.

There was no difference in fruit production among the irrigation rates in 1981 and 1982 indicating sufficient water was being supplied by the low (6 inch) rate. Additional water did not further increase fruit production. Soil moisture measurements indicated that we were over irrigating with the 2 higher rates (12 and 18 inches) in the jet and drip treatments where only part of the ground was irrigated. As previously discussed, we reduced the irrigation rates in 1983 and 1984 to maintain soil moisture levels below field capacity and differences in fruit production resulted from the different irrigation rates.

The present study showed on well-drained sandy soil such as Astatula fine sand, irrigation coverage is the most important consideration from the standpoint of tree health and fruit production. Irrigation systems with partial ground coverage once installed cannot make up for the limitation in coverage by increasing irrigation frequency or duration. While it was better than no irrigation, 4 drip emitters per tree in a wide spacing grove was not enough to substantially increase fruit production. Therefore, irrigation systems should be designed to cover as much ground surface as practicable.

The fact that no difference in fruit production was found between the 2 higher rates (12 and 18 inches) indicated substantial water conservation can be practiced in all 3 irrigation systems. Irrigation at the two lower rates in the spring months has consistently increased fruit production (2). Based on the current study, it seems that annual application of 12 inches for sprinkler irrigation and 6 inches for jet and drip would be sufficient for good fruit production for most years.

Table 5. Effects of irrigation treatments on fruit production of 'Marsh' grapefruit.

Irrigation treatment	Fruit production				4-yr	Increase	Increase/inch irrigation	
	1981	1982	1983	1984	avg.		1981-82	1983-84
			Boxes/Acre			%	Boxes/acre	
No irrigation[y]	446	322	323	308	350	–	–	–
Irrigation system								
Drip	479	258	404	367	377	7.7	0	24
Jet	449	316	483	433	421	20.3	0	46
Sprinkler	867	454	632	451	601	71.7	20	29
Significance	**[z]	**	**	n.s.	–	–	–	–
Irrigation rate (inches)								
6	582	320	467	344	420	20.0	10	31
12	634	366	539	460	500	42.8	10	42
18	421	337	513	449	470	34.3	5	26
Significane	n.s.[z]	n.s.	*	*	–	–	–	–

[z]n.s. = not significant; * = difference significant at 5% level; ** = difference significant at 1% level.
[y]Means of no irrigation control are not included in the statistical analysis.

Flexibility in scheduling is one of the advantages jet and drip irrigation systems have over the sprinkler irrigation system, which should increase the efficiency of irrigation. This was shown in the increase of fruit production with irrigation water applied (Table 5). In 1983 and 1984, jet irrigation produced 46 boxes of fruit per acre for every inch of water applied over no irrigation control as compared to 29 boxes for sprinkler and 24 boxes for drip irrigation, respectively. We feel that the efficiency in drip irrigation would be increased if more drip emitters per tree had been installed. There was no increase in fruit production in jet and drip treatments in 1981 and 1982 probably indicating too much water was being applied. The objective of citrus irrigation is to obtain maximum fruit production with the least quantity of water. All 3 irrigation systems have the potential to reach that goal through design and management. Studies are in progress to achieve optimum coverage and scheduling of irrigation.

Literature Cited

1. Koo, R. C. J. 1967. Effects of soil amendments on soil moisture and growth of young orange trees. Proc. Fla. State Hort. Soc. 80:26-32.
2. Koo, R. C. J. 1969. Evapotranspiration and soil moisture determination as guides to citrus irrigation. Proc. First Intern. Citrus Symp. 3:1725-1730.
3. Koo, R. C. J. 1978. Response of densely planted 'Hamlin' orange on two rootstocks to low volume irrigation. Proc. Fla. State Hort. Soc. 91:8-10.
4. Koo, R. C. J. 1981. The effects of fall irrigation on freeze damage to citrus. Proc. Fla. State Hort. Soc. 94:37-39.
5. Koo, R. C. J. and J. W. Sites. 1955. Results of research and response of citrus to supplemental irrigation. Proc. Soil Sci. Soc. Fla. 15:180-190.
6. Koo, R. C. J. and A. G. Smajstrla. 1984. Effects of trickle irrigation and fertigation on fruit production and juice quality of 'Valencia' orange. Proc. Fla. State Hort. Soc. 97:8-10.
7. Sites, J. W., H. J. Reitz, and E. J. Deszyck. 1951. Some results with irrigation research with Florida citrus. Proc. Fla. State Hort. Soc. 64:71-79.
8. Smajstrla, A. G. and R. C. J. Koo. 1984. Effects of trickle irrigation methods and amounts of water applied on citrus yields. Proc. Fla. State Hort. Soc. 97:3-7.

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SHALLOW WATER TABLE FLUCTUATION IN RESPONSE TO RAINFALL, IRRIGATION, AND EVAPOTRANSPIRATION IN FLATWOODS CITRUS

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Abstract. **Subsurface soil layers which are restrictive to water flow often give rise to shallow water tables under citrus grown on flatwoods soils. The level at which this water table exists can have a direct influence on the vigor and productivity of bedded citrus trees. In 1984 and 1985, the level and fluctuation of a shallow water table was recorded in a bedded, drip-irrigated citrus grove in the Indian River area. Rainfall amounts as low as 0.15 inches and irrigation amounts as low as 22 gal/tree caused a measureable rise of the shallow water table. Heavy rains brought the water table as high as 14 inches below the top of the beds, and the drainage rate following this was determined to be about 4.5 inches/day. A greater rate of water table decline during the hours of maximum evapotranspiration (ET) suggested that some of the free water was being made available to the citrus trees through upward flux into the root zone. Some current irrigation scheduling models in use in Florida do not take into account water from upward flux. The data collected suggest that this water can contribute significantly to the ET demand of citrus on bedded soils.**

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Most soils in the flatwoods citrus-growing region of Florida are poorly drained due to low land elevation and the existence of a slowly-permeable subsurface layer. This layer can be either argillic or spodic in nature, with saturated hydraulic conductivity often below 0.2 inches/hr (7). Shallow water tables can exist above this layer during periods of consistent rainfall. Citrus grown on flatwoods soils must be planted on raised beds in order to create enough unsaturated soil volume for adequate root growth and development (4).

Even with bedding and artificial drainage, the shallow water table can still exist close enough to the root zone to have a direct influence on the vigor and productivity of citrus trees. Rainfall and subirrigation can have an immediate impact on the level of the shallow water table in the upward direction, while topographical elevation, depth to the restrictive layer, and quality of artificial drainage can have an immediate effect in the downward direction. If the upper boundary of free water remains within the root zone for a period of several days, anaerobic conditions arise and root damage can occur (2). A water table situated just below the root zone will not cause root damage but should be a source of available water for citrus trees through upward capillary movement. This process has been shown to occur in the laboratory with soil cores and in situ with other crops (1, 8). Thus, a matter of a few inches in water level can mean the difference between healthy and unhealthy trees.

Data illustrating the fluctuation of the shallow water table in response to rainfall, irrigation, drainage, and evapotranspiration (ET) are useful in determining the drainage capability of a soil and a suitable citrus irrigation schedule. The objectives of this study were to observe the rise and fall of a shallow water table as affected by the above environmental factors in a mature citrus grove and