IRRIGATION WITH RECLAIMED MUNICIPAL WASTEWATER

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The City of Orlando and Orange County wastewater treatment plants historically have discharged their effluent into Shingle Creek, a tributary of Lake Tohopekaliga. Faced with the need to expand wastewater treatment volume and a state requirement to eliminate discharge of treated effluent to surface waters, both the City and the County entered a negotiated settlement with the Florida Department of Environmental Regulation (FDER) and the United States Environmental Protection Agency (EPA) to cease effluent discharge into Shingle Creek by March, 1988. To facilitate this, Orange County and the City of Orlando jointly developed an innovative water reclamation program.

The Water Conserv II/Southwest Orange County Water Reclamation Project involves the use of highly treated wastewater (reclaimed water) for citrus irrigation and groundwater recharge through Rapid Infiltration Basins (RIBS). It is one of the largest water reuse projects in the United States and the first reuse program permitted in Florida that involves irrigation of crops intended for human consumption. The program, which became fully operational in January, 1987, currently supplies about 25 million gallons per day (mgd) of reclaimed municipal wastewater to irrigate about 7,000 acres of citrus. The program is designed to provide up to 50 mgd for irrigation of 15,000 acres of citrus.

Citrus groves in western Orange and eastern Lake Counties were selected for the Conserv II project because of their high demand for irrigation water and soil types which have high permeability. This area is a primary aquifer recharging area. Use of reclaimed wastewater for irrigation, in lieu of previous surface water discharges, benefits the urban sector by reducing competition from the agricultural demand for potable water and by increasing available groundwater supplies through supplementing natural recharge of the aquifer.

The agricultural sector benefits from the project in the following ways:

1. The project provides citrus growers with a long-term source of water that will increase (not decrease) with urban growth.

2. The water is provided to growers free of charge at pressures adequate for operation of under-tree irrigation systems (40 lb. per square inch minimum).

3. Growers who would have obtained water from deep wells can save well construction and energy costs of pumping water. It is estimated that growers could save as much as $100 per acre per year in irrigation pumping cost.

Due to the size of the project and the intended use of reclaimed wastewater for irrigation of a crop that is consumed by people, the Florida Department of Health and Rehabilitative Services (HRS) had extensive input in establishing safe water quality guidelines. The HRS was primarily concerned about removal of bacteriological and virological pathogens at the treatment plants prior to delivery to the growers.

In addition, the application of treated wastewater on land is regulated by Florida Department of Environmental Regulations (FDER) which is mainly concerned that wastewater meets minimum standards to minimize ground water-pollution.

To evaluate the effects of reclaimed municipal wastewater on citrus, 30 observation stations were established in the Conserv II citrus groves covering about 4,000 acres. Soils in the area are deep well-drained sands, mostly classified as Chandler fine sand (hyperthermic, uncoated Typic Quartzipsamments), with a depth to clay pan of more than 9 ft at all stations except one where sand-clay mixture was found at a 7.5 ft depth.

'Valencia' and 'Hamlin' oranges on rough lemon and Carrizo citrange rootstocks were the principal cultivars. Nine of the 30 stations were designated as controls; they were located in blocks where well water was used for irrigation.

Composition of reclaimed municipal wastewater

Characteristics and chemical composition of reclaimed municipal wastewater are summarized in Table 1. Only major and minor nutrients that are known to be important to citrus are listed in Table 1. This reclaimed water was highly treated having relatively low biological oxygen demand (BOD) and mineral nutrient contents. The average concentration for most elements over a 2-yr period was considerably lower than the maximum allowable limits except for sodium (Na) and chloride (Cl). The Na concentration in water was approaching the maximum allowable limit. The average concentration of the Cl was higher than that of Na but levels fluctuated within less than 70% of the allowable limits, while Na levels were close to 90% of allowable limits.

Soil Water Content Level

Monthly soil water content levels for both the Conserv II and control stations are plotted in Figs. 1, 2 and 3. Rainfall data were obtained from U.S. Weather Bureau records in Clermont, Florida. Soil water content data to a depth of 66 inches (168 cm) were expressed as acre-inches. Monthly fluctuations in soil water content followed rainfall distribution both in 1987, 1988 and 1989. In general, growers in the project followed sound irrigation practices. In 1987 and 1989, soil water content in Conserv II groves was higher than in the control groves while in 1988, soil water content in both Conserv II and control groves was similar. This was caused by a decrease in water applied to the Conserv II groves and an increase in the control groves. Changes in irrigation practices were influenced by the effects of water on fruit production and quality. Higher soil water content was maintained in the young bearing tree blocks where soil moisture measurements showed values above field capacity for most of 1987 and 1988.

Leaf and Soil Analyses

Leaf and soil samples were collected from 1986 to 1989. Normally, soil samples are collected from the 0 to 6 inch depth only. In this study, however, soil samples were collected at 6-inch (15 cm) increments from 0 to 66 inch (168 cm) depths. While the surface soil did not show consistent trends due to reclaimed water, these trends became more apparent when the soil profile in the root zone was examined. For example, no difference in soil pH was observed in the 0-6 inch depth between the control and the Conserv II blocks. When the entire soil profile (0-66 inch) was examined, the soil pH was consistently higher in Conserv II blocks than the Control blocks (Table 2).

The 1986 samples were collected prior to the introduction of reclaimed water. Since 1987, trees receiving reclaimed water had higher leaf and soil N, P and Na contents than the control blocks which were irrigated with well water (Table 3). No consistent difference was found in leaf K, Ca and Mg contents between the two groups although the Conserv II blocks were higher in soil K, Ca and Mg. Although leaf Na content from trees irrigated with reclaimed water was twice as high as trees irrigated with well water, leaf Na content was within the optimum standard values for citrus. We are keeping close watch on the Na content in leaves.

The average concentration of micronutrients present in the reclaimed wastewater was very low ranging from 0.01 to 0.18 mg/l (Table 1). Trees irrigated with reclaimed water had lower leaf Mn and Zn and higher Fe than trees irrigated with well water. No difference in Cu was found between the 2 groups (Table 4). The differences in leaf Mn and Zn contents could be attributed to growers' practice of nutritional sprays. Iron is not a recommended component of nutritional or fungicidal sprays in citrus. The higher leaf Fe content found in groves irrigated with reclaimed wastewater could have resulted from Fe present in the reclaimed wastewater.

Fruit Quality and Fruit Production

Fruit from trees irrigated with reclaimed water had lower soluble solids and acid contents than fruit from control trees (Table 5). The difference was especially apparent in 1987 when fruit from the reclaimed water groves was about 0.75 lb. lower in soluble solids per box than that from the control groves. Such effects of irrigation on juice quality are well-documented. In 1987, the soil water content was considerably higher in the reclaimed water groves than the control groves (Fig. 1) resulting in lower soluble solids. In 1988, soil water content in the reclaimed water groves was only slightly higher than the control groves (Fig. 2) and differences in soluble solids were not detected. In 1989, soil water content in groves irrigated with reclaimed water was higher (Fig. 3) and soluble solids per box were about 0.25 lb. lower than those of the control (data not shown).

The relationship between soil water content and soluble solids can best be illustrated in Table 6 where a wide range of soil moisture was maintained. In young bearing 'Hamlin' orange groves where soil water content was maintained above field capacity for most of 1988, soluble solids dropped dramatically when compared to mature bearing trees where a lower soil water content was maintained. Data in Table 6 also indicated that the frequency of attainment of soil moisture levels above field capacity influenced soluble solids in addition to the average soil water content throughout the year.

While no attempt was made to collect fruit production data from the 7,000 plus acres, growers have reported increases in fruit production from 10 to 30% over years prior to receiving water from the Conserv II project. A small number of trees from 2 stations adjacent to each other was selected for fruit production estimations. These 2 stations have same age trees of the same scion and rootstock ('Hamlin'/rough lemon) and are under the same management. The only difference was that one side was irrigated with reclaimed water and the other was irrigated with well water. Data collected from these 2 stations on soil moisture, leaf, soil and fruit analyses were comparable to data reported in Tables 1 to 5. Fruit size and weight were measured from fruit samples collected. Number of fruit per tree was counted and fruit production was calculated (Table 7). Trees on reclaimed water had larger, heavier fruit and more fruit than the control trees. Fruit production was 23% higher from trees on reclaimed water than those irrigated with well water, an observation in agreement with grower reports.

Tree Growth

Tree height and width measurements made in 1987 and 1989 in the 'Hamlin' and the 'Washington' navel blocks showed tremendous growth in 2 years (Table 8). Canopy growth for the 2 varieties were 225% and 443%, respectively, when compared to 174% for 'Valencia' on the well water program. Differences in tree growth due to varietal characteristics should be considered. Nevertheless, the rate of canopy growth for the 2 blocks on reclaimed water program is higher than typical young tree groves in the area.

Observations and data collected in 1987, 1988, and 1989 indicated that the use of reclaimed water for citrus irrigation was a horticulturally sound practice. Reclaimed water used in the Conserv II program is a highly treated wastewater and relatively low in mineral elements. There are indications that reclaimed water is supplying N, P, and other nutrients to the trees but not enough data are available to quantify the nutrient levels supplied. Further investigation is therefore justified.

References

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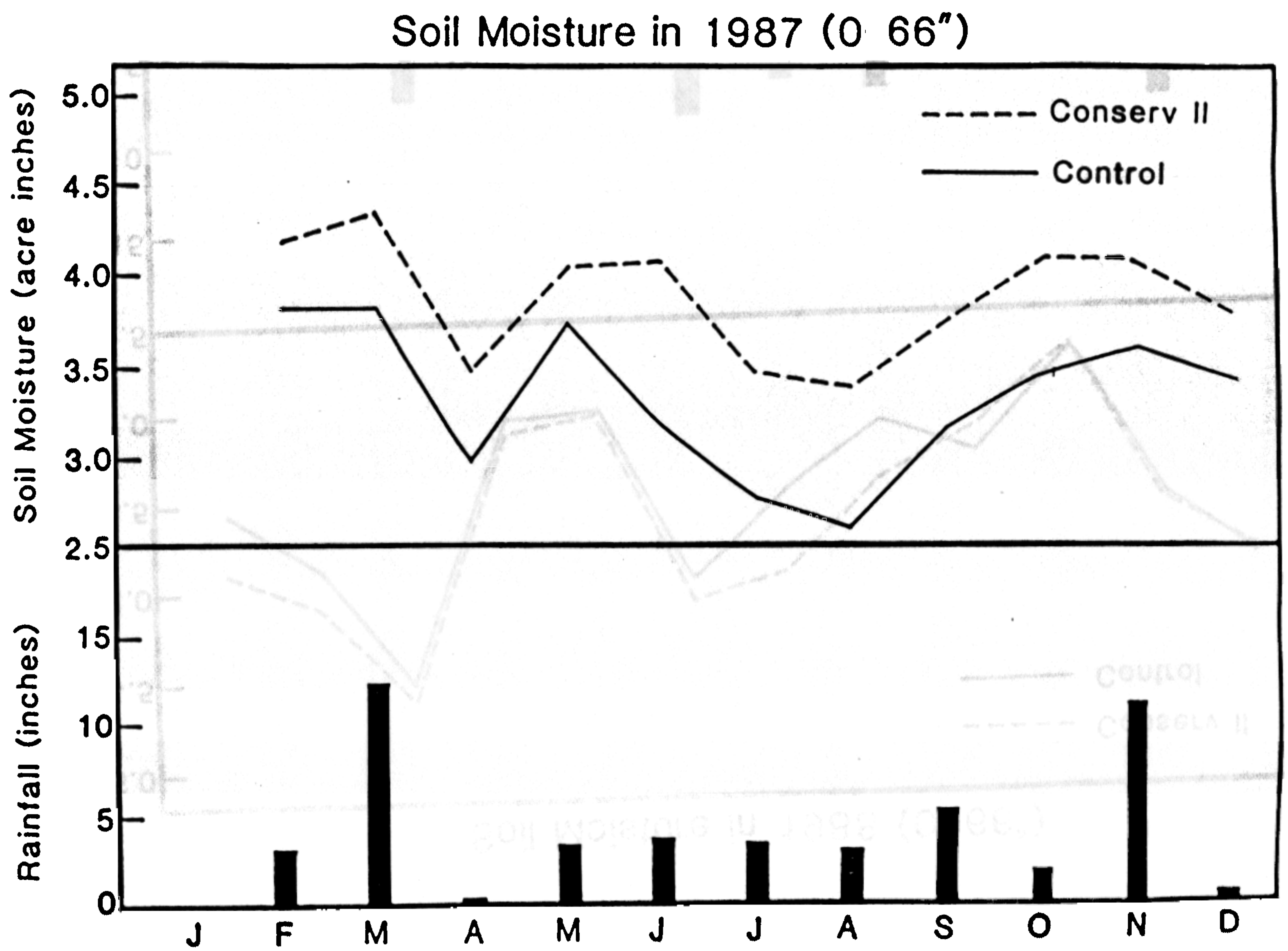

Fig. Soil water content and rainfall distribution in 1987.

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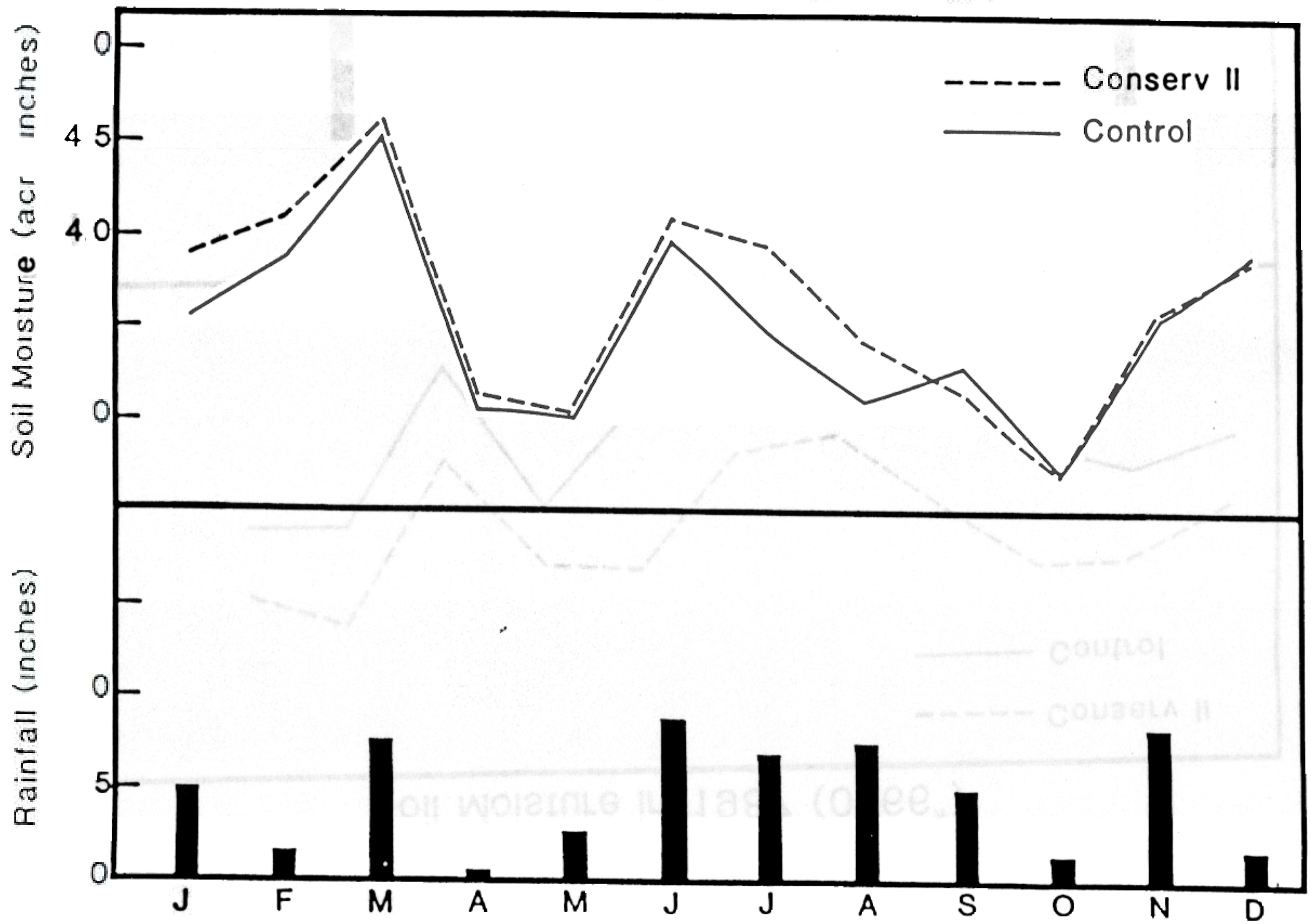

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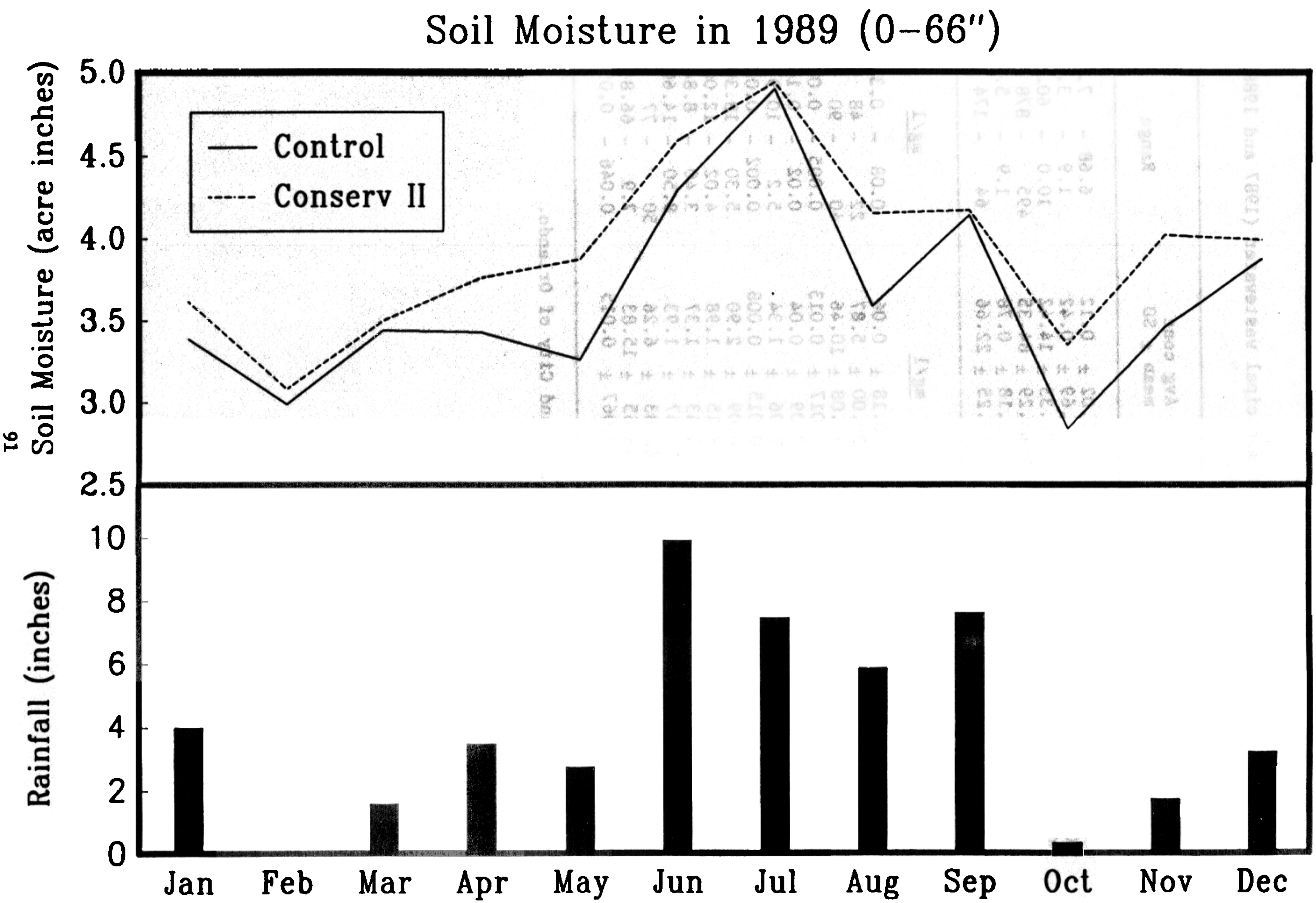

Fig. 3. Soil water content and rainfall distribution in 1989.

Table 1. Composition of reclaimed municipal wastewater (1987 and 1988). (Average of 24 monthly samples)

Characteristics	Max conc limits	Avg conc mean ± SD	Range
pH	6.5 - 8.4	7.02 ± 0.12	6.68 - 7.72
BOD	30	2.69 ± 0.42	1.9 - 3.5
COD	120	24.33 ± 14.42	10.0 - 60.0
ECw (µmhos/cm)	1100	668.29 ± 84.35	495 - 878
TSS (mg/l)	5	3.18 ± 0.78	1.9 - 5.2
Bicarbonate (mg/l)	200	97.25 ± 22.66	64 - 174
Elements	**mg/l**	**mg/l**	**mg/l**
Boron	1.0	0.18 ± 0.06	0.08 - 0.32
Calcium	200	39.00 ± 5.87	22 - 48
Chloride	120	79.08 ± 10.46	40 - 90
Copper	0.20	0.017 ± 0.013	0.005 - 0.070
Iron	5.0	0.09 ± 0.04	0.02 - 0.16
Magnesium	25.0	8.96 ± 1.34	5.2 - 10.9
Manganese	0.20	0.015 ± 0.008	0.002 - 0.036
Nitrogen	30	10.09 ± 2.90	5.30 - 18.30
Nitrate		8.15 ± 1.98	4.02 - 12.00
Phosphorus	10	5.43 ± 1.37	3.40 - 8.84
Potassium	30	11.47 ± 1.93	8.50 - 14.60
Sodium	70	62.83 ± 6.26	50 - 77
Sulfates	100	43.65 ± 15.83	7.9 - 66.8
Zinc	1.0	0.067 ± 0.015	0.046 - 0.096

Source: Metcalf & Eddy Services, Inc. and City of Orlando.

Table 2. Effects of reclaimed municipal water on soil pH.

Year	0-6 inch		0-66 inch	
	Control	Conserv II	Control	Conserv II
1986[a]	7.13	7.22	5.82	5.73
1987	6.72	7.11	5.36	6.18
1988	6.71	6.76	5.72	5.89
1989	6.70	6.69	5.46	5.76

[a]1986 samples were pre-Conserv II samples.

Table 3. Effects of reclaimed municipal water on mineral composition of leaves and soil.

Element	Year	Leaf		Soil (0-66 in.)	
		Control	Conserv II	Control	Conserv II
		%	%	lb/A	lb/A
Nitrogen (N)	1986[a]	2.99		2368	2104
	1987	3.00	3.02	2405	2170
	1988	2.87	2.95	2480	2754
	1989	2.82	2.90	1506	1569
Phosphorus (P)	1986	0.145		628	578
	1987	0.128	0.144	591	542
	1988	0.123	0.136	406	621
	1989	0.131	0.138	406	595
Potassium (K)	1986	1.38		200	185
	1987	1.55	1.51	217	259
	1988	1.23	1.41	407	418
	1989	1.37	1.32	228	284
Calcium (Ca)	1986	3.29		1888	1947
	1987	3.12	3.14	2049	2330
	1988	3.81	3.53	2071	2085
	1989	3.24	3.13	1805	2003
Magnesium (Mg)	1986	0.440		227	275
	1987	0.365	0.395	240	323
	1988	0.413	0.391	298	318
	1989	0.356	0.350	291	328
Sodium (Na)	1986	0.05		262	278
	1987	0.04	0.09	377	338
	1988	0.04	0.07	422	485
	1989	0.04	0.11	257	329

[a]1986 are pre-Conserv II samples from both leaf and soil.

Table 4. Effects of reclaimed municipal water on micronutrient content of citrus leaves.

Element	Treatment	Year			
		1986[a]	1987	1988	1989
		ppm	ppm	ppm	ppm
Manganese (Mn)	Control	18	45	43	34
	Conserv II		27	25	23
Zinc (Zn)	Control	26	47	77	22
	Conserv II		30	47	22
Copper (Cu)	Control	12	14	19	21
	Conserv II		15	18	21
Iron (Fe)	Control	85	54	76	67
	Conserv II		68	82	78

1986 samples were pre-Conserv II samples.

Table 5. Effects of reclaimed water on juice quality of 'Hamlin' and 'Valencia' oranges.

Measurement	Treatment	Hamlin 1987	Hamlin 1988	Valencia 1987	Valencia 1988
Juice (%)	Conserv II	57.24	57.63	59.27	60.32
	Control	60.10	55.92	59.41	57.34
Sol. solids (%)	Conserv II	10.92	11.54	11.02	12.15
	Control	11.97	11.73	12.28	13.10
Acid (%)	Conserv II	0.80	0.80	0.79	0.86
	Control	0.88	0.84	0.90	0.89
SS/A ratio	Conserv II	13.62	14.44	13.86	14.00
	Control	13.60	14.00	13.67	14.71
Solids (lb./box)	Conserv II	5.66	5.97	5.82	6.59
	Control	6.47	5.89	6.56	6.77

Number of samples:	Hamlin	Conserv II	1987	5	1988	8
		Control	1987	1	1988	5
	Valencia	Conserv II	1987	4	1988	4
		Control	1987	4	1988	4

Table 6. Relationship between soil water content and soluble solids of 'Hamlin' and 'Valencia' oranges (1988).

Cultivar	Treatments	Number stations	Soil moisture[z] Average	Above FC	Soluble solids
			inch	%	lb./box
Hamlin	Control	5	3.58	23	5.89
	Conserv II	8	3.49	18	5.97
	Young trees	4	4.32	60	5.22
Valencia	Control	4	3.43	24	6.77
	Conserv II	4	3.23	26	6.59

[z]Average soil water content per acre represents 0 to 66 inch depth Percent (measurement) above field capacity (FC) is based on 22 measurements. Field capacity 0 to 66 inch depth = 4.24 inches.

Table 7. Effects of reclaimed water on fruit production and fruit size of 'Hamlin' oranges (1988).

Measurements	Conserv II	Control
Fruit diam (cm)	6.81	6.49
Fruit wt (g)	187	174
Fruit/tree (No.)	1434	1254
Production (box/tree)	6.56	5.34
Increase (%)	23	

Table 8. Effects of reclaimed and well water on young tree growth.

Treatment	Variety[z]	Date	Height	Width[y]	Canopy surface	Growth
			ft	ft	ft^2	%
Reclaimed water	Hamlin	5-21-87	4.8	7.3	72	
		6-28-89	10.3	10.9	234	225
	Navel	5-21-87	3.5	6.9	49	
		6-28-89	10.9	11.8	266	
Well water	Valencia	5-21-87	4.8	4.1	42	
		7-28-89	7.5	7.3	115	

[z]'Hamlin' and Navel trees were approximately 3 yr old in May, 1987 and the 'Valencia' trees were about 2 yr old.

[y]Width is the average of north-south and east-west measurements