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USE OF RECLAIMED WATER FOR IRRIGATION AND FERTIGATION OF YOUNG 'REDBLUSH' GRAPEFRUIT TREES

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Abstract. **Four field experiments were conducted to determine the effects of reclaimed water, fertilization, and irrigation rate on the growth and development of newly planted 'Redblush' grapefruit trees (*Citrus paradisi* Macf.) on Swingle citrumelo rootstock. Two experiments were initiated in 1990 on flatwoods and Ridge-type soils and 1 each in 1991 and 1992 on a flatwoods-type soil. Experiments were arranged as a 3 × 3 factorial. Treatments included reclaimed water (1990) or reclaimed water plus granular fertilization (1991-92), reclaimed water plus fertigation, and well-water plus fertigation. In addition, irrigation rates of 20% soil water depletion, 0.75 and 1.00 inches/week were used. Trees receiving reclaimed water plus fertigation had significantly larger canopies and trunk diameter, than trees in all other treatments. Trees receiving reclaimed water were smallest, and they exhibited visual symptoms of N deficiency. Leaf tissue levels of Na and B were significantly higher, but below toxic concentrations, for all reclaimed water treated trees as compared to the well-water plus fertigation trees. Yield was significantly higher for the reclaimed water plus fertigation trees, followed by well-water plus fertigation, and reclaimed water alone; however, fruit quality was unaffected by treatments. Irrigation level did not affect tree growth or development.**

In Florida, 41% of all water is used for agricultural purposes (Fernald and Patton, 1984) with 34% of this water used to irrigate citrus (Smajstrala et al., 1992). Due to the increasing demand for water, water use for agricultural purposes has become strictly regulated by Florida's water management districts. Additionally, urban growth, especially in the coastal areas, has increased the need for efficient and environmentally safe disposal of reclaimed water. The Department of Environmental Regulation (DER) has restricted the disposal of municipal reclaimed water into lakes, rivers and streams, so alternative disposal sites need to be found.

The restrictions on water use for agriculture and the need for alternative disposal sites for municipal reclaimed water are concerns that may be partially alleviated by the use of reclaimed water for citrus irrigation. Reclaimed water has been successfully used to irrigate apples (Nielsen et al., 1989b), cherries (Neilsen et al., 1991), grapes (Neilsen et al., 1989a), peaches (Basiouny, 1984) and citrus (Kale and Bal, 1987; Koo and Zekri, 1989; Omran et al., 1988; Wheaton and Parsons, 1993; Zekri and Koo, 1990). Reclaimed water as an alternative water source for the irrigation of citrus trees has many potential advantages. Reclaimed water contains many nutrients essential for plant growth, and may have an effect similar to that of frequent fertigation with a dilute concentration of plant nutrients (Neilsen et al., 1989b). In addition, recycling these nutrients may prevent pollution of surface or ground water (Sanderson, 1986). The primary concern with the use of reclaimed water is the potential accumulation of phytotoxic levels of heavy metals (Omran et al., 1988). Salinity of reclaimed water is normally within acceptable ranges and often lower than other irrigation waters; however, levels may be acceptable only for under tree use (Basiouny, 1982).

Long term studies using reclaimed water to irrigate citrus for up to 60 years in Egypt found no adverse effects on tree growth as compared to well water (Omran et al., 1988). Similarly, irrigation with reclaimed water increased growth and yield of citrus on the Ridge area of Florida with no adverse affects (Koo and Zekri, 1989; Zekri and Koo, 1990). Similar results were observed for young citrus trees (Wheaton and Parsons, 1993). However, these studies were conducted on citrus trees growing on the well-drained sandy soils of the Ridge. Soil types and drainage patterns of the flatwoods vary considerably from those of the Ridge due to the presence of hardpans and high water table. The potential waterlogging of the flatwoods holds problems not associated with citrus grown on the Ridge. In addition, no studies have been conducted on newly planted, nonbearing citrus trees irrigated with reclaimed water.

The objective of these experiments was to evaluate the effects of reclaimed water on the growth and development of citrus trees during the first 3 years after planting on both well-drained and poorly drained soils.

Materials and Methods

Reclaimed water and well water irrigation on Arredondo fine sand (Expt. 1). Bare-rooted 'Redblush' grapefruit trees on Swingle citrumelo rootstock (≈ 2 years in the nursery) were obtained from A. Duda and Sons Citrus Nursery (LaBelle, Fla.) and planted on 6 April, 1990. Trees were planted at the University of Florida Fifield farm in Gainesville, Fla. and grown for three years. Soil type was Arredondo fine sand (Loamy, siliceous, hyperthermic, Grossarenic, Paludults). The soil had a volumetric field capacity of 10.2%, a permanent wilting point of 1.7% and 1.66 $oz \cdot inch^{-3}$ mean bulk density. Trees were planted in single rows spaced 15 ft within rows and 20 ft between rows.

Treatments were arranged as a 3 (water sources) × 3 (irrigation levels) factorial experiment with 10 single tree replicates per treatment based on previous studies (Marler and Davies, 1990). Treatments included reclaimed water (RCW), reclaimed water plus fertigation (RCW+F) and well-water plus fertigation (WW+F). The simulated reclaimed water (nutrient solution) was formulated based on a typical elemental water analysis from a secondary treatment facility in Vero Beach, Fla. (Table 1). The composition of the simulated reclaimed water was changed after 1990 to more accurately simulate that of the treatment facility (Table 1). Water samples were collected and analyzed by the Analyt-

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Table 1. Nutrient concentration and pH of well-water and simulated reclaimed waters for the Arredondo fine sand (Ridge) and Kanapaha fine sand (flatwoods), 1990-92.

	pH	EC	NH_4-N	NO_3-N	P	K	Ca	Mg	Na	Cl	Cu	Fe	Mn	Zn	B
							(ppm)								
Well water															
Expt. 1[z]	7.7	0.35	0.0	5.7	0.2	0.9	47.2	2.7	4.4	8.3	0.0	0.01	0.0	0.05	0.02
Expt. 2, 3 & 4[y]	7.5	0.45	0.0	0.8	0.2	0.6	59.9	14.0	6.6	7.3	0.0	0.01	0.0	0.04	0.05
Simulated reclaimed water[x]															
Expt. 1 & 2 1990	—[w]	—[w]	3.0	4.3	4.9	35.9	59.0	28.8	119	200	—[w]	—[w]	—[w]	0.06	0.26
Expt. 1 1991-1992	7.5	1.80	4.5	10.5	7.8	21.1	45.8	27.4	280	387	0.0	0.01	*0.01*	*0.10*	*0.81*
Expt. 2, 3 & 4 1991-1992	7.4	1.95	3.7	5.0	7.4	20.5	56.7	36.9	273	393	0.0	0.06	0.01	0.08	0.84

[z]Expt. 1 was conducted on the Arredondo fine sand (Ridge).
[y]Expt. 2, 3 and 4 were conducted on Kanapaha sand (flatwoods).
[x]Composition of the simulated reclaimed water was modified after 1990 to reflect levels obtained in a water treatment facility at Vero Beach, FL.
[w]Missing data.

ical Research Laboratory, University of Florida, Gainesville, Fla. Fertigation was applied every 3 weeks (10 times in 1990 and 11 times in 1991 and 1992). In-line 2% fixed Dosatron injectors (Dosatron International, Clearwater, Fla) were used to apply liquid fertilizer and the simulated reclaimed water. The liquid formulation analysis was (8 N-0 P-8 K) as ammonium nitrate and potassium chloride (Stauffer Chemical, Leesburg, Fla. in 1990 and 1991 and Chemical Dynamics, Plant City, Fla in 1992). Injectors were also used to apply the simulated reclaimed water with each irrigation. Irrigation was applied to all treatments during fertigation so that each tree received 7.8 gallons of water/tree. Total N/tree/yr for the RCW, RCW+F, and WW+F treatments was < 0.05, 0.5 and 0.5 lb, respectively, in 1990; < 0.08, 0.75 and 0.75 lb, respectively, in 1991; and < 0.1, 1.0, and 1.0 lb respectively, in 1992. Rates of 0.5, 0.75, and 1.0 lb N/tree/yr are currently within recommended ranges in Florida for 1-, 2- and 3-year old citrus trees, respectively (Koo et al., 1984).

Irrigation was applied when the soil reached 20% soil water depletion (SWD) as determined previously (Marler and Davies, 1990), or at 0.75 and 1.0 inches/week which simulates frequent irrigations associated with reclaimed water application. Trees received irrigation for 31, 39, and 37 weeks in 1990, 1991 and 1992, respectively. Total gallons of water/tree/yr for the three treatments were 125, 428, and 725 in 1990; 182, 538, and 913 in 1991; and 545, 993, and 1,685 in 1992. The 0.75 and 1.0 inches/week treatments were irrigated three times/week regardless of rainfall with a 1 day minimum between irrigations. Soil moisture was monitored with a Troxler 4300 neutron probe (Troxler, Raleigh, N.C.). Soil moisture measurements were taken 3 times/week just prior to irrigation. Four aluminum access tubes were placed 1 ft north of the trunks of four trees in each of the three irrigation levels in 1990, 1991 and 1992. Neutron probe readings were taken at a depth of 12 inches since 85% of young citrus tree roots are located from 6 to 18 inches of the soil surface (Marler and Davies, 1990).

Trees were irrigated for 3 weeks after planting for about 2 hr every other day using 10 gallon-hr^{-1} 90° microsprinklers located 3.25 ft northwest of the tree trunk in 1990 and 1991. In 1992 emitters were changed to 10 gallon-hr^{-1} 180° microsprinklers located 3.25 ft west of the tree trunk (Marler and Davies, 1989). Trees were wrapped with R-11 fiberglass tree wraps (Adaco, Inc. Clermont, Fla.) to reduce sprouting and provide freeze protection.

Between-row bahiagrass ground cover was mowed as needed and 6 ft within the tree rows was maintained weed free with herbicides. Pesticides were applied when necessary.

Reclaimed water and well water irrigation on Kanapaha fine sand (Expt. 2.). Bare-rooted 'Redblush' grapefruit trees on Swingle citrumelo rootstock (≈ 2 years in the nursery) were obtained from A. Duda and Sons (LaBelle, Fla.), planted 6 April, 1990 and grown for two seasons. Trees were planted at the University of Florida Horticultural Research Unit near Gainesville, Fla. on double row beds (55 ft width × 2-2.5 ft height × 275 ft length). Trees were spaced 11 ft within rows and 25 ft between rows on each double bed. Soil type was Kanapaha fine sand (loamy, siliceous, hyperthermic, Grossarenic, Paleaquults) with a loamy or clayey layer starting ≈ 4 ft below the top of the soil surface and a water table fluctuating between 1.4 and 5.0 ft from the top of the bed (Marler, 1988). The soil had a volumetric field capacity of 11.3%, a permanent wilting point of 2.0% and 1.56 oz·$inch^{-3}$ mean bulk density (Marler and Davies, 1989). Treatments were the same as Expt. 1, except that trees received 125, 428 and 725 gallons of water/tree/yr in 1990 and 193, 538 and 913 gallons of water/tree/yr in 1991.

Well water and reclaimed water irrigation comparing liquid vs granular fertilization (Expt. 3). Bare-rooted 'Redblush' grapefruit trees on a Swingle citrumelo rootstock (≈ 2 years in the nursery) were obtained from Florida Citrus Nursery (Avon Park, Fla.), planted 21 March, 1991 and grown for two seasons at the University of Florida Horticultural Research Unit near Gainesville, Fla. Site characteristics are the same as those for Expt. 2. Treatments were arranged as a 3 (water sources) × 3 (irrigation levels) factorial experiment with 10 single tree replicates per treatment. Trees were irrigated for two weeks prior to initiating treatments after planting. Treatments included reclaimed water plus granular fertilization (RCW+G), reclaimed water plus fertigation (RCW+F) and well-water plus fertigation (WW+F). Granular fertilizer was applied every 6 weeks within the tree drip-line in 5 equal applications at 0.5 and 0.751b N/tree/yr in 1991 and 1992, respectively. Formulated analysis was (8 N-2 P-8 K-2 Mg) as ammonium nitrate, diammonium phosphate, muriate of potash and magnesium sulfate (Seminole Marico Brand Fertilizer, Ocala, Fla.). Trees received 0.5 and 0.75 lb N/tree/yr in 1991 and 1992, respectively. In addition, irrigation was applied at 20% soil water depletion (SWD), 0.75 and 1.0 inches/week for 39 and 37 weeks in 1991 and 1992, respectively. Trees received 193, 538 and 913 gallons of water/tree/yr in 1991 and 308, 497 and 842 gallons of water/tree/yr in 1992.

Well water and reclaimed water irrigation comparing liquid vs granular fertilization (Expt. 4). Bare-rooted 'Redblush' grapefruit trees on Swingle citrumelo rootstock (≈ 2 years in the nursery) were obtained from Florida Citrus Nursery (Avon Park, Fla.) and planted 3 April, 1992 at the University of Florida Horticultural Research Unit near Gainesville, Fla. Site characteristics are the same as those for Expt. 2 and 3. Initiation of treatments began 4 days after planting. Design and treatments were the same as Expt. 3, except that trees received 261, 497 and 842 gallons of water/tree/yr in 1992.

Tree measurements included visual ratings based on canopy size and vigor at the end of each year and tree height taken at planting and again at the end of each growing season. Ratings ranged from 1 (a poorly growing, unhealthy tree) to 5 (a healthy, vigorous tree) in 1990, 1991, and 1992. However, for Expt. 1 in 1992 ratings ranged from 1 (a poorly growing, unhealthy tree) to 10 (a healthy, vigorous tree). Visual evaluations of new leaf flushes were taken weekly during the season to determine timing and number of flushes. Trunk diameters were measured about 12 inches above ground level after planting and after each growth flush. Successive leaf samples were taken at the end of each mature flush when leaves were fully expanded (≈ 3 months old) and a final analysis in Dec. on the final leaf flush in 1990 and 1991. In 1992, leaf samples were collected in Aug. from mature fully expanded spring flush leaves (≈ 5 months old) as recommended (Koo et al., 1984). A 10-leaf sample was collected from two trees (one replicate) and repeated four times for each treatment. Leaves were then washed in detergent (Dreft), rinsed with running tap water and four times in deionized water, dried at 160°F for a minimum of 48 hr and then ground to pass through a 40 mesh screen. Total N was determined by micro Kjeldahl procedure (Wolf, 1982) using a Rapid Flow Analyzer (RFA: Alpkem Corp., Clackamas, Ore.). Leaf P, K, Ca, Mg, Na, B, Cu, Fe, Mn and Zn were determined by ashing a 0.0176 oz sample in a muffle furnace at 932°F for 8 hr. The ash was then brought to a volume of 1.69 fl oz with 1N HCl and filtered. Samples were then analyzed on an Inductively Coupled Argon Plasma Spectrometer at the Analytical Research Laboratory, University of Florida, Gainesville, Fla. A Buchler-Cotlove chloridometer was used for Cl analysis.

Fruit yield and quality data were taken in Dec. 1992 only for Expt. 1. Fruit were harvested from each tree and processed on a roller type sizer (Food Machinery Corporation, Lakeland, Fla.). Fruit were then counted and weighed in each size category. Fruit weight, juice weight, peel thickness, total soluble solids (TSS) and titratable acid (TA) were determined on three 10-fruit samples from each treatment. Fruit were sectioned equatorially so that peel thickness could be measured and juice extracted by hand with a Sunkist motor driven extractor. TSS was determined with a temperature compensating refractometer and TA by titration of a 0.85 fl oz aliquot of juice with 0.3125N NaOH to a pH of 8.2.

Statistical analysis. Field studies were analyzed as factorial experiments with three water sources and three irrigation levels arranged in a completely random design. The SAS general linear model (GLM) procedure was used to perform analysis of variance (ANOVA). Trunk diameter and tree height were subject to analysis of covariance to standardize differences in initial plant measurements at planting. Orthogonal contrasts were used to determine trends in the data and to separate means. Contrasts were analyzed with the mean of the three irrigation levels combined for each water source.

Results and Discussion

Growth and development. Visual ratings of tree growth for Expt. 1 and 2 showed similar trends, with the RCW+F trees having the largest tree canopies (Table 2 and 3). In addition, mature leaves on the RCW trees showed visual symptoms of N deficiency and had yellowish-green leaves as compared to the dark-green leaves of the other treatments. In 1991, the RCW+F trees had significantly larger canopies than the RCW or WW+F trees for Expt. 1 and 2. For Expt. 1 in 1992, the RCW+F and WW+F trees had significantly larger canopies than the RCW trees. For Expt. 3 in 1991, the RCW+F trees had significantly larger canopies than the RCW+G or WW+F trees (Table 4). However, in 1992 all treatments had similar visual ratings for Expt. 3 and 4 (Table 4).

For Expt. 1 and 2 in 1990 all trees had 3 growth flushes. In contrast, in 1991 the RCW trees had 3 growth flushes for both Expt. 1 and 2, but the RCW+F and WW+F trees had a fourth growth flush (Data not shown). All trees had the same number and timing of growth flushes per season for Expt. 3 and 4.

Trees receiving RCW+F were significantly taller than either the RCW or WW+F tree for Expt. 1 in 1990, 1991, and 1992 (Table 2). A similar trend occurred for Expt. 2 in which the RCW+F trees were taller than the other treatments (Table 3). For Expt. 3, tree height was similar for all treatments in 1991; however, in 1992 the RCW+F trees were significantly taller than the other treatments (Table 4). Tree height was similar for all treatments in Expt. 4 (Table 4).

The RCW+F trees had significantly greater trunk diameters than the RCW or WW+F tree for Expt. 1 in 1990, 1991, and 1992 (Table 2). The same trend occurred for Expt. 2, in 1990 and 1991 with the largest trunk diameter for the RCW+F trees (Table 3). For Expt. 3 in 1991 and 1992, the RCW+F trees had significantly larger trunk diameters than the RCW+G or WW+F trees (Table 4). Similar results occurred in Expt. 4 (Table 4).

The use of reclaimed water alone was insufficient to support adequate growth of young citrus trees as seen by the visual rating of canopy size and symptoms of N deficiency. Results were similar for grapes (Neilsen et al., 1989a), apples (Neilsen et al., 1989b) and cherries (Neilsen et al., 1991). However, when adequate nutrition is supplied, the RCW+F trees had significantly larger trunk diameters and tree canopies than WW+F trees. These results are similar to those found by Koo and Zekri, (1989) and Wheaton and Parsons, (1993) for citrus trees. In addition, the increase in trunk diameter of RCW+F trees compared to the other treatments indicates that frequent fertigation may increase growth as observed by Willis et al., (1991). After 5 years, differences in tree growth were no longer observed for cherries (Neilsen et al., 1991), although in apples, tree growth was accelerated for less than or equal to 5 years using reclaimed water (Nielsen et al.,

Table 2. Visual rating, tree height, and trunk diameter measurements ot young 'Redblush' grapefruit trees as affected by water source and irrigation level in 1990-92, Expt. 1 (Arredondo sand, Ridge).

Treatments		Arredondo sand (Expt. 1)								
		Visual rating[y]			Tree Height[x] (ft)			Trunk diameter[x] (inches)		
Water source[z]	Irr. level	1990	1991	1992	1990	1991	1992	1990	1991	1992
RCW	20% SWD	2.1	2.6	3.5	3.0	5.7	7.4	0.83	1.64	2.58
RCW	0.75 in/wk	2.4	3.3	4.7	3.5	6.8	8.2	0.91	1.73	2.66
RCW	1.0 in/wk	2.7	3.2	5.5	3.4	6.9	8.6	0.93	1.83	2.83
RCW+F	20% SWD	2.9	3.7	6.8	3.7	7.3	8.7	0.99	2.17	3.22
RCW+F	0.75 in/wk	2.9	3.4	6.4	3.9	7.0	8.7	1.00	2.09	3.09
RCW+F	1.0 in/wk	2.9	3.5	6.5	3.7	7.3	8.8	1.03	2.13	3.10
WW+F	20% SWD	2.5	2.6	6.5	3.3	6.0	8.3	0.92	1.77	2.78
WW+F	0.75 in/wk	2.8	2.7	5.2	3.6	6.3	8.5	0.98	1.87	2.93
WW+F	1.0 in/wk	2.7	3.0	6.7	3.5	6.7	9.3	0.91	1.86	3.04
Significance										
Watersource		NS	***	***	*	***	**	***	***	***
Irr. level		NS	NS	NS	*	**	**	NS	NS	NS
Water × Irr.		NS	NS	NS	NS	*	NS	NS	NS	NS
Contrasts										
RCW vs RCW+F			**	***	**	***	**	***	***	***
RCW vs WW+F				***			**			**
RCW+F vs WW+F			***		*	***		*	***	**

[z]RCW = simulated reclaimed water; F = N-K fertigation; WW = well water; SWD = soil water depletion.
[y]Subjective visual ratings ranged from 1 (a poorly growing, unhealthy tree) to 5 (a healthy, vigorous tree) in 1990 and 1991 and 1 (a poorly growing, unhealthy tree) to 10 (a healthy, vigorous tree) in 1992.
[x]Data values represent the actual means, though data were statistically analyzed using analysis of covariance.
NS, *, **, ***Nonsignificant or significant at P ≤ 0.05, 0.01 or 0.001, respectively.

Table 3. Visual rating, tree height, and trunk diameter of young 'Redblush' grapefruit trees 1990-91 as affected by water source and irrigation level, Expt. 2 (Kanapaha sand, flatwoods).

Treatment		Visual rating[y]		Tree height[x] (ft)		Trunk diameter[x] (inches)	
Water source[z]	Irr. level	1990	1991	1990	1991	1990	1991
RCW	20% SWD	2.4	3.0	3.1	6.6	0.95	1.70
RCW	0.75 in/wk	2.3	3.2	3.1	6.8	0.94	1.73
RCW	1.0 in/wk	2.5	3.3	3.2	7.0	0.96	1.70
RCW+F	20% SWD	3.0	4.2	3.8	7.9	1.16	2.14
RCW+F	0.75 in/wk	3.3	4.4	4.0	7.8	1.20	2.21
RCW+F	1.0 in/wk	3.0	4.4	3.8	7.8	1.20	2.28
WW+F	20% SWD	2.6	3.1	3.4	7.0	1.03	1.83
WW+F	0.75 in/wk	2.6	3.7	3.6	7.4	1.04	1.98
WW+F	1.0 in/wk	2.7	3.7	3.4	7.4	1.06	2.06
Significance							
Watersource		***	***	***	***	***	***
Irr. level		NS	**	NS	NS	NS	NS
Water × Irr.		NS	NS	NS	NS	NS	NS
Contrasts							
RCW vs RCW+F		***	***	***	***	***	**
RCW vs WW+F			*	*		**	***
RCW+F vs WW+F		**	***	**	*	***	

[z]RCW = simulated reclaimed water; F = N-K fertigation; WW = well water; SWD = soil water depletion.
[y]Subjective visual ratings ranged from 1 (a poorly growing, unhealthy tree) to 5 (a healthy, vigorous tree).
[x]Data represent the actual means, though data were statistically analyzed with analysis of covariance.
NS, *, **, ***Nonsignificant or significant at P ≤ 0.05, 0.01 or 0.001, respectively.

1989b). On mature citrus trees (Zekri and Koo, 1990; Omran et al., 1988) and on peaches (Basiouny, 1984), reclaimed water produced a denser canopy and increased growth.

Leaf tissue analysis. Leaf N concentration for Expt. 1 had similar trends in 1990 and 1991, with the highest leaf N levels for the WW+F trees, followed in sequence, by RCW+F and RCW trees (Table 5). Even though the RCW leaf tissue N concentration would be in the optimum to excess range for mature citrus trees (Koo et al., 1984), these trees exhibited visual symptoms of N deficiency on the mature leaves and the younger leaves were not as dark-green in color as the other treatments. Failure to find N deficiency by tissue sample could be due to sampling the final flush leaves in Dec. 1990 and 1991, as N is reallocated from mature leaves to new leaves. In 1992, the RCW trees were significantly lower in leaf N concentration (deficient < 2.0%) (Koo et al., 1984) than either the RCW+F or WW+F trees, which were near or in the optimum range (2.5-2.7%) for mature citrus trees (Koo et al., 1984). WW+F trees had significantly higher leaf N concentrations in Expt. 2 in 1990, followed by the RCW+F and RCW trees (Table 5). However, in 1991, the WW+F and RCW+F trees had similar leaf N concentrations which were significantly higher than for the RCW trees. The WW+F trees had significantly higher leaf N concentrations then the RCW+G or RCW+F trees for Expt. 3 in 1991 and 1992. However, all treatments in 1991 were in the excess range (> 3.0%). In 1992, the RCW+G and RCW+F trees were in the optimum range while the WW+F trees had high leaf N (2.8-3.0%). Differences among the years may be attributed to time of leaf sampling in 1991, since leaves were sampled from the final growth flush in Dec. rather than from fully expanded mature spring flush leaves in Aug. or Sept. 1992 as recommended by Koo et al., 1984. In Expt. 4, leaf N concentrations were significantly lower for the RCW+F trees compared to the RCW+G and WW+F trees; however, all treatments were

Table 4. Visual rating, tree height and trunk diameter of young 'Redblush' grapefruit trees as affected by water source and irrigation level, Expt. 3 1991-92 and Expt. 4 1992 (Kanapaha sand, flatwoods).

Treatment		Expt. 3						Expt. 4		
		Visual rating[y]		Tree height[x] (ft)		Trunk diameter[x] (inches)		Visual rating[y]	Tree height[x] (ft)	Trunk diameter[x] (inches)
Water source[z]	Irr. level	1991	1992	1991	1992	1991	1992		1992	
RCW+G	20% SWD	2.5	4.0	4.0	7.5	1.00	2.08	2.1	2.1	0.72
RCW+G	0.75 in/wk	2.9	4.2	4.2	7.7	1.03	2.09	2.3	2.1	0.77
RCW+G	1.0 in/wk	2.5	3.8	3.8	7.3	0.98	2.06	2.7	2.1	0.72
RCW+F	20% SWD	3.1	3.9	4.2	7.9	1.11	2.17	2.6	2.1	0.82
RCW+F	0.75 in/wk	3.5	3.9	4.2	7.7	1.16	2.29	2.5	2.1	0.84
RCW+F	1.0 in/wk	3.3	4.4	4.5	8.1	1.13	2.26	2.6	2.2	0.86
WW+F	20% SWD	1.8	3.1	4.1	7.1	1.01	1.89	2.1	2.1	0.74
WW+F	0.75 in/wk	2.1	3.2	4.3	7.1	0.99	1.92	2.7	2.1	0.84
WW+F	1.0 in/wk	2.6	4.3	4.3	7.6	1.06	2.04	2.5	2.1	0.78
Significance										
Water source		***	NS	NS	***	***	***	NS	NS	***
Irr. level		NS	NS	NS	NS	NS	NS	NS	NS	NS
Water × Irr.		NS	NS	NS	NS	NS	NS	NS	NS	NS
Contrast										
RCW+G vs RCW+F		***			*	***	***			***
RCW+G vs WW+F		*					**			*
RCW+F vs WW+F		***			***	***	***			***

[z]RCW = simulated reclaimed water; G = N-P-K-Mg granular fertilizer; F = N-K fertigation; WW = well water; SWD = soil water depletion.
[y]Subjective visual rating ranged from 1 (a poorly growing, unhealthy tree) to 5 (a healthy, vigorous tree).
[x]Data represent actual means, though data were statistical analyzed by analysis of covariance.
NS, *, **, ***Nonsignificant or significant at $P \leq 0.05$, 0.01 or 0.001, respectively.

in the optimum to high range. No evidence of N deficiency was observed for Expt. 3 and 4.

Optimum leaf N concentration for mature citrus trees in Florida is 2.5-2.7% (Koo et al., 1984); however, our values for leaves sampled in 1990 and 1991 represent fully expanded leaves from the third growth flush taken in Dec. from young trees. Swietlik (1992) observed optimum leaf N averages from 2.7-2.8% for young grapefruit trees in Texas and Willis et al., (1990) found levels as high as 3.0% for leaves from 'Hamlin' orange trees sampled in Dec. Our experiments indicate that for final flush leaves sampled in Dec., leaf N levels of 3.0% or higher may be considered optimum for young citrus trees. However, for leaves sampled at the recommended time, N level standards of the

Table 5. Leaf tissue nitrogen analysis for young 'Redblush' grapefruit trees 1990-1992 as affected by water source and irrigation level, Expt. 1-4.[z]

Treatment		(N % dry wt.)							
Water	Irr.	Expt. 1[v]			Expt. 2[v]		Expt. 3[v]		Expt. 4[v]
source[y]	level	1990[x]	1991[x]	1992[w]	1990[x]	1991[x]	1991[x]	1992[w]	1992[w]
RCW (+G)[v]	20% SWD	2.5	2.9	1.8	2.1	2.1	3.2	2.4	3.0
RCW (+G)	0.75 in/wk	2.5	3.1	2.0	2.3	2.3	3.2	2.4	2.9
RCW (+G)	1.00 in/wk	2.6	3.2	2.1	2.4	2.4	3.2	2.4	2.8
RCW+F	20% SWD	3.3	3.5	2.5	3.2	2.7	3.2	2.4	2.6
RCW+F	0.75 in/wk	3.5	3.3	2.5	3.2	2.8	3.4	2.6	2.6
RCW+F	1.00 in/wk	3.0	3.5	2.4	3.3	2.9	3.5	2.4	2.6
WW+F	20% SWD	4.0	3.9	2.5	3.9	3.2	4.0	2.9	3.0
WW+F	0.75 in/wk	3.4	3.7	2.4	3.4	2.9	3.7	2.8	2.8
WW+F	1.00 in/wk	3.3	3.5	2.4	3.4	2.7	3.8	2.3	2.7
Significance									
Water source		***	***	***	***	***	***	**	***
Irr. level		**	NS	NS	NS	NS	NS	*	NS
Water × Irr.		**	**	*	*	*	NS	*	NS
Contrasts									
RCW (+G) vs RCW+F		***	***	***	***	***			***
RCW (+G) vs WW+F		***	***	***	***	***	***	**	
RCW+F vs WW+F		***	***		**		**	*	***

[z]Expt. 1 was conducted on an Arredondo fine sand (Ridge) and Expt. 2, 3 and 4 on a Kanapaha fine sand (flatwoods).
[y]RCW = simulated reclaimed water; G = N-P-K-Mg granular fertilization; F = N-K fertigation; WW = well water; SWD = soil water depletion.
[x]Leaf tissue samples were taken from fully expanded final flush leaves in Dec. in 1990 and 1991.
[w]Leaf tissue samples were taken from fully expanded spring flush leaves in Aug. 1992.
[v]The RCW treatment was used for Expt. 1 and 2 and the RCW+G treatment for Expt. 3 and 4.
NS, *, **, ***Nonsignificant or significant at $P \leq 0.05$, 0.01 or 0.001, respectively.

leaf tissue appear to be adequate for young citrus trees. Leaf samples taken in Dec. may be adequate for determining differences among treatments, but may not be suitable for comparisons to current standards.

The RCW trees had significantly higher leaf P concentrations (excess > 0.3%) than the RCW+F or WW+F trees for Expt. 1 in 1990 and 1992 (Table 6). RCW trees had excess P levels, while the other treatments were in the optimum range (0.12-0.16%) (Koo et al., 1984). In 1991, the RCW and WW+F trees had significantly higher leaf P than the RCW+F trees. Trees in Expt. 2 exhibited similar trends in leaf P as Expt. 1. For Expt. 3 and 4, the WW+F trees had significantly higher leaf P. Even though there were significant differences in leaf P for Expt. 3 and 4, levels were typically in the optimum to high range which may not be of practical significance to the plant. The elevated leaf P concentrations for the RCW trees in Expt. 1 and 2 may have been due to the reduced growth which concentrates P in the leaves. In addition, N competes with P in the soil and decreased N levels may account for elevated leaf P levels in citrus (Smith and Reuther, 1954).

Leaf K concentrations for Expt. 1 were similar among treatments in 1990 and 1992 (Table 7). However, in 1991, the RCW trees were significantly lower in leaf K than the RCW+F or WW+F trees. All treatments had similar leaf K concentrations for Expt. 2 in 1990. However, in 1991, the RCW trees had significantly lower leaf K than the other treatments. The higher level in leaf K for the RCW+F and WW+F trees may be attributed to these trees receiving additional K in the liquid fertilizer. Trees in Expt. 3 had similar trends in 1991 and 1992, significantly lower leaf K in the RCW+G trees than the other treatments, possibly due to frequency and form of K applied to these treatments. However, all treatments were in the optimum range (1.2-1.7%) for leaf K. Similar results were seen for Expt. 4, except leaf K was in the high range (1.8-2.3%) (Koo et al., 1984). Similar to leaf P, the levels of K were in the optimum to high range for citrus trees and, although statistically significant, may not be significant from a practical standpoint.

The WW+F trees for Expt. 1 in 1990 and 1992 had significantly lower leaf Na concentrations than the other treatments (Table 8). In 1991, all treatments were statistically significant; however, all treatments were within the exceptable level for leaf Na concentrations. For Expt. 2, all treatments were within the exceptable range even though statistically significant. The RCW+F trees had significantly higher leaf Na concentrations for Expt. 3 in 1991 and 1992. Similarly, for Expt. 4, the RCW+F trees had the highest leaf Na concentrations followed by RCW+G and WW+F. In general, the RCW, RCW+G, and RCW+F trees had higher leaf Na levels than the WW+F treatments. Results are similar to those observed for mature citrus trees irrigated with reclaimed water (Koo and Zekri, 1989). Although leaf Na concentrations were higher for the RCW, RCW+G and RCW+F treatments, no toxicity symptoms were observed.

Leaf B concentrations for Expt. 1 were similar for all three years, with the RCW and RCW+F trees significantly higher in leaf B than the WW+F trees (Table 9). A similar trend was seen in Expt. 2, 3, and 4. Even though the WW+F trees for all experiments were significantly lower in leaf B concentration, the leaf B levels were in the optimum range (36-100 ppm) (Koo et al., 1984). In contrast, the RCW, RCW+G, and RCW+F trees were usually in the high range (100-200 ppm). Rarely did levels reach excess (> 200 ppm) and no toxicity symptoms were observed. Similar increases in leaf B have been observed in peaches (Basiouny, 1984) and apples (Neilsen et al., 1989b) irrigated with reclaimed water.

Table 6. Leaf tissue phosphorus analysis for young 'Redblush' grapefruit trees 1990-1992 as affected by water source and irrigation level, Expt. 1-4.[z]

Treatment		(P % dry wt.)							
Water	Irr.	Expt. 1[v]			Expt. 2[v]		Expt. 3[v]		Expt. 4[v]
source[y]	level	1990[x]	1991[x]	1992[w]	1990[x]	1991[x]	1991[x]	1992[w]	1992[w]
RCW (+G)[v]	20% SWD	0.37	0.21	0.33	0.33	0.26	0.16	0.10	0.14
RCW (+G)	0.75 in/wk	0.42	0.19	0.34	0.47	0.27	0.16	0.11	0.14
RCW (+G)	1.00 in/wk	0.42	0.17	0.25	0.44	0.24	0.17	0.10	0.15
RCW+F	20% SWD	0.19	0.14	0.11	0.19	0.14	0.16	0.10	0.12
RCW+F	0.75 in/wk	0.19	0.14	0.12	0.18	0.15	0.16	0.11	0.15
RCW+F	1.00 in/wk	0.19	0.19	0.12	0.19	0.15	0.17	0.11	0.15
WW+F	20% SWD	0.20	0.19	0.11	0.20	0.18	0.21	0.12	0.19
WW+F	0.75 in/wk	0.19	0.18	0.13	0.19	0.16	0.19	0.12	0.15
WW+F	1.00 in/wk	0.20	0.17	0.13	0.19	0.16	0.17	0.12	0.17
Significance									
Water source		***	**	***	***	***	***	***	***
Irr. level		NS	NS	NS	NS	NS	NS	**	NS
Water × Irr.		NS	NS	NS	*	NS	NS	NS	NS
Contrasts									
RCW (+G) vs RCW+F		***	***	***	***	***			
RCW (+G) vs WW+F		***		***	***	***	***	***	***
RCW+F vs WW+F			**				**	***	***

[z]Expt. 1 was conducted on an Arredondo fine sand (Ridge) and Expt. 2, 3 and 4 on a Kanapaha fine sand (flatwoods).
[y]RCW = simulated reclaimed water; G = N-P-K-Mg granular fertilization; F = N-K fertigation; WW = well water; SWD = soil water depletion.
[x]Leaf tissue samples were taken from fully expanded final flush leaves in Dec. in 1990 and 1991.
[w]Leaf tissue samples were taken from fully expanded spring flush leaves in Aug. 1992.
[v]The RCW treatment was used for Expt. 1 and 2 and the RCW+G treatment for Expt. 3 and 4.
NS, *, **, ***Nonsignificant or significant at P ≤ 0.05, 0.01 or 0.001, respectively.

Table 7. Leaf tissue potassium analysis for young 'Redblush' grapefruit trees 1990-1992 as affected by water source and irrigation level, Expt. 1-4.[z]

Treatment		(K % dry wt.)							
Water source[y]	Irr. level	Expt. 1[v] 1990[x]	Expt. 1[v] 1991[x]	Expt. 1[v] 1992[w]	Expt. 2[v] 1990[x]	Expt. 2[v] 1991[x]	Expt. 3[v] 1991[x]	Expt. 3[v] 1992[w]	Expt. 4[v] 1992[w]
RCW (+G)[v]	20% SWD	1.4	1.1	1.3	1.7	1.1	1.3	1.3	1.9
RCW (+G)	0.75 in/wk	2.0	1.3	1.5	2.2	1.4	1.3	1.4	1.8
RCW (+G)	1.00 in/wk	2.0	1.3	1.5	2.0	1.3	1.3	1.5	1.7
RCW+F	20% SWD	1.8	1.6	1.3	1.8	1.3	1.5	1.5	1.9
RCW+F	0.75 in/wk	2.0	1.6	1.3	1.8	1.5	1.6	1.6	2.0
RCW+F	1.00 in/wk	1.9	1.4	1.3	1.9	1.4	1.6	1.5	2.1
WW+F	20% SWD	2.0	1.6	1.3	1.8	1.5	1.5	1.5	1.8
WW+F	0.75 in/wk	1.8	1.5	1.4	1.9	1.6	1.6	1.6	1.8
WW+F	1.00 in/wk	1.9	1.6	1.4	1.9	1.5	1.6	1.5	1.9
Significance									
Water source		NS	***	NS	NS	***	***	***	*
Irr. level		*	NS	NS	**	NS	NS	NS	NS
Water × Irr.		**	*	NS	NS	NS	NS	NS	*
Contrasts									
RCW (+G) vs RCW+F			***				***	***	**
RCW (+G) vs WW+F			***			***	***	**	
RCW+F vs WW+F						*			*

[z]Expt. 1 was conducted on an Arredondo fine sand (Ridge) and Expt. 2, 3 and 4 on a Kanapaha fine sand (flatwoods).
[y]RCW = simulated reclaimed water; G = N-P-K-Mg granular fertilization; F = N-K fertigation; WW = well water; SWD = soil water depletion.
[x]Leaf tissue samples were taken from fully expanded final flush leaves in Dec. in 1990 and 1991.
[w]Leaf tissue samples were taken from fully expanded spring flush leaves in Aug. 1992.
[v]The RCW treatment was used for Expt. 1 and 2 and the RCW+G treatment for Expt. 3 and 4.
NS, *, **, ***Nonsignificant or significant at $P \leq 0.05$, 0.01 or 0.001, respectively.

Leaf Ca was similar for all treatments and experiments with levels near or within the optimum range (3.0-4.9%) (Koo et al., 1984) (Data not shown). Leaf Mg concentrations for the RCW, RCW+G, and RCW+F treated trees were consistently higher (optimum, 0.30-0.49%) than the WW+F trees (low, 0.20-0.29) for all experiments (Data not shown). Leaf Cl concentrations were similar for all treatments due to the RCW, RCW+G, and RCW+F trees receiving Cl in the reclaimed water and the WW+F trees receiving Cl from fertigation (Data not shown). Leaf Cu and Mn were generally within the optimum range, while Fe was typically in the high range and Zn was in the low to deficient for all experiments and treatments (Koo et al., 1984) (Data not shown).

Fruit yield and quality. Bloom evaluations were based on 1 (no bloom) to 5 (75-100% full bloom). Bloom evaluations were similar for all treatments for Expt. 1 in 1991 (Data not shown). In 1992, bloom in the RCW+F trees was sig-

Table 8. Leaf tissue sodium analysis for young 'Redblush' grapefruit trees 1990-1992 as affected by water source and irrigation level, Expt. 1-4.[z]

Treatment		(Na % dry wt.)							
Water source[y]	Irr. level	Expt. 1[v] 1990[x]	Expt. 1[v] 1991[x]	Expt. 1[v] 1992[w]	Expt. 2[v] 1990[x]	Expt. 2[v] 1991[x]	Expt. 3[v] 1991[x]	Expt. 3[v] 1992[w]	Expt. 4[v] 1992[w]
RCW (+G)[v]	20% SWD	310	610	830	310	538	730	912	1470
RCW (+G)	0.75 in/wk	805	613	760	818	517	780	1040	1750
RCW (+G)	1.00 in/wk	1120	703	870	585	598	850	1240	2880
RCW+F	20% SWD	648	773	670	410	530	740	1140	2390
RCW+F	0.75 in/wk	983	785	780	708	538	1080	1200	2470
RCW+F	1.00 in/wk	835	930	1080	828	618	1400	1480	2740
WW+F	20% SWD	265	758	670	468	468	910	885	470
WW+F	0.75 in/wk	225	695	570	775	498	810	848	420
WW+F	1.00 in/wk	350	743	600	370	485	590	878	460
Significance									
Water source		***	***	***	NS	NS	***	***	***
Irr. level		**	*	*	***	NS	NS	**	NS
Water × Irr.		*	NS	*	NS	NS	***	NS	NS
Contrasts									
RCW (+G) vs RCW+F			***				**	**	
RCW (+G) vs WW+F		***	*	**			*	**	***
RCW+F vs WW+F		***	*	***			***	***	***

[z]Expt. 1 was conducted on an Arredondo fine sand (Ridge) and Expt. 2, 3 and 4 on a Kanapaha fine sand (flatwoods).
[y]RCW = simulated reclaimed water; G = N-P-K-Mg granular fertilization; F = N-K fertigation; WW = well water; SWD = soil water depletion.
[x]Leaf tissue samples were taken from fully expanded final flush leaves in Dec. in 1990 and 1991.
[w]Leaf tissue samples were taken from fully expanded spring flush leaves in Aug. 1992.
[v]The RCW treatment was used for Expt. 1 and 2 and the RCW+G treatment for Expt. 3 and 4.
NS, *, **, ***Nonsignificant or significant at $P \leq 0.05$, 0.01 or 0.001, respectively.

Table 9. Leaf tissue boron analysis for young 'Redblush' grapefruit trees 1990-1992 as affected by water source and irrigation level, Expt. 1-4.[z]

Treatment		(B ppm dry wt.)							
Water	Irr.	Expt. 1[v]			Expt. 2[v]		Expt. 3[v]		Expt. 4[v]
source[y]	level	1990[x]	1991[x]	1992[w]	1990[x]	1991[x]	1991[x]	1992[w]	1992[w]
RCW (+G)[v]	20% SWD	90	79	136	72	90	92	112	233
RCW (+G)	0.75 in/wk	104	88	140	109	107	111	121	221
RCW (+G)	1.00 in/wk	134	90	157	94	108	119	129	207
RCW+F	20% SWD	48	70	96	56	77	83	102	174
RCW+F	0.75 in/wk	81	96	131	78	116	103	113	188
RCW+F	1.00 in/wk	97	111	160	95	124	96	130	210
WW+F	20% SWD	80	37	29	38	43	42	51	56
WW+F	0.75 in/wk	22	26	26	43	70	46	39	121
WW+F	1.00 in/wk	19	30	28	30	35	41	32	64
Significance									
Water source		***	***	***	***	***	***	***	***
Irr. level		***	**	***	***	***	**	NS	NS
Water × Irr.		***	**	***	**	*	NS	***	NS
Contrasts									
RCW (+G) vs RCW+F		***		***	**		**		
RCW (+G) vs WW+F		***	***	***	***	***	***	***	***
RCW+F vs WW+F		***	***	***	***	***	***	***	***

[z]Expt. 1 was conducted on an Arredondo fine sand (Ridge) and Expt. 2, 3 and 4 on a Kanapaha fine sand (flatwoods).
[y]RCW = simulated reclaimed water; G = N-P-K-Mg granular fertilization; F = N-K fertigation; WW = well water; SWD = soil water depletion.
[x]Leaf tissue samples were taken from fully expanded final flush leaves in Dec. in 1990 and 1991.
[w]Leaf tissue samples were taken from fully expanded spring flush leaves in Aug. 1992.
[v]The RCW treatment was used for Expt. 1 and 2 and the RCW+G treatment for Expt. 3 and 4.
NS, *, **, ***Nonsignificant or significant at $P \leq 0.05$, 0.01 or 0.001, respectively.

nificantly increased compared to the RCW or WW+F trees. Bloom evaluation averages were 3.8, 1.5, and 1.2 for the RCW+F, WW+F and RCW, respectively. Similarly, yield was significantly greater for the RCW+F trees (169.9 lb/tree) followed by WW+F (24.9 lb/tree) and RCW (3.0 lb/tree) as was fruit number (194.0, 31.7 and 3.3 fruit/tree average for RCW+F, WW+F and RCW trees, respectively). Average fruit weight, juice weight, peel thickness, TSS, and TA (Data not shown) were similar for all treatments (Fruit quality was not analyzed for RCW treatments due to insufficient yield).

The substantial increase in bloom and yield for the RCW+F trees compared to the WW+F trees is difficult to explain. Similar yield increases have been reported for citrus (Koo and Zekri, 1989; Omran et al., 1988; Wheaton and Parsons, 1993), peaches (Basiouny, 1984), cherries (Neilsen et al., 1991) and apples (Neilsen et al., 1989a) from the use of reclaimed water. The RCW trees were obviously N deficient based on visual observations and leaf tissue analysis. However, the only consistent difference between the RCW+F and WW+F trees is the leaf B concentration. The leaf B concentration for the WW+F trees was in the low end of the optimum range, while leaf B was in the upper optimum to high range for the RCW+F trees. There is growing evidence that B may play a significant role in yield responses. In cherries (Hanson, 1991) and avocados (Robbertse et al., 1990), foliar sprays of B at bloom have significantly increased yield in trees considered to have optimum leaf B. Frequent application of B from reclaimed water treatments may provide a constant supply of B at critical times of fruit development. However, these data are from only one year and further research is necessary.

Preliminary data indicate that the use of reclaimed municipal wastewater has great potential in both the Ridge and flatwoods areas of Florida for newly planted citrus trees. Reclaimed water alone does not supply enough plant nutrients to support adequate tree growth. However, with additional fertilization, trees irrigated with RCW+F were consistently larger than those irrigated with well water regardless of fertilization method; fertigated trees were significantly larger than those fertilized with granular fertilizer. Reclaimed water increased Na, Cl, and B, but levels were not phytotoxic and no deleterious effects were observed. In addition, young citrus trees receiving the RCW+F had significant increases in bloom and yield. Identification of elements provided by reclaimed water should help provide a better understanding of which elements enhance tree growth and yield.

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A RECLAIMED WATER CITRUS IRRIGATION PROJECT

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Abstract. **Because there is an interest and concern in the use of municipal wastewater on crops intended for human consumption, research has been conducted to evaluate the long-term effects of applying treated wastewater on agricultural land with mature citrus trees in central Florida. For over 6 yr, the effects of irrigation with reclaimed municipal wastewater were compared to well water in terms of soil water content, soil chemical analysis, leaf mineral status, and fruit quality. Irrigation with reclaimed water increased mineral residues in the soil profile, altered leaf mineral concentration and fruit quality, and promoted better tree performance and more weed growth relative to irrigation with well water. Higher accumulation of P, Mg, and Na in soils irrigated with reclaimed water were reflected in leaf mineral status. The reclaimed water can supply all the needs of P, Mg, and B to citrus trees. Accumulation of N, K, and Ca in soils irrigated with reclaimed water were not reflected in leaf mineral status. Although leaf Na, Cl, and B concentrations were noticeably higher in reclaimed water treatments than in those of well water, they are still well below the toxicity levels set for citrus trees. This highly treated wastewater in central Florida has been found to be of good quality, non-toxic, and a good option for increasing water supplies, but not a major source of N and K to citrus trees.**

Both the need to conserve water and to safely and economically dispose of wastewater make the use of treated wastewater in agriculture a very feasible option. Furthermore, wastewater reuse may reduce fertilizer rates and provide a low cost source of irrigation water. However, depending upon their sources and treatments, sewage wastewaters may contain high concentrations of salts, heavy metals, bacteria, and viruses.

In many parts of the world, treated municipal wastewater has been successfully used for the irrigation of various crops including agronomical (Bielorai et al., 1984; Bole and Bell, 1978; Campbell et al., 1983; Feigin et al., 1984) and horticultural (Basiouny, 1984; Neilsen et al., 1989a,b,c; 1991) crops. Recently, in Florida, several projects involving the reuse of municipal wastewater for citrus irrigation have been initiated. The largest and longest established one is the Conserv II/Southwest Orange County Water Reclamation Project. This project which was initiated in 1986 provides over 40 million gallons of reclaimed water per day from the Orlando area to agricultural sites including 7,000 acres of citrus trees. Detailed information on the concept, design, benefits, and preliminary evaluations of the Conserv II project were reported by Koo and Zekri (1989) and Zekri and Koo (1990).

The objective of this research work was to study the long-term use of reclaimed wastewater for citrus irrigation by comparing the effects of well water and Conserv II water on soil chemical properties, weed growth, mineral residues in the soil profile, leaf mineral concentration, fruit quality, and visual appearance of citrus trees.

Materials and Methods

Thirty to thirty-two sites were selected in citrus groves located in Lake and Orange Counties in Florida to investigate the effects of reclaimed municipal wastewater (Conserv II) on citrus. Eight to nine of these sites were located in groves where well water was used for irrigation. Each site was about a half of an acre and consisted of 4 to 5 rows

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