Ornamental Plant Response to Percentage of Reclaimed Water Irrigation

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Abstract. *Vinca* [*Catharanthus roseus* (L.) G. Don], *salvia* (*Salvia splendens* F. Sellow ex Roem. and Schult.), Dwarf Yaupon holly (*Ilex vomitoria* Ait. 'Nana'), and 'Helleri' holly (*Ilex crenata* Thunb. 'Helleri') were grown in 2.3-L containers with soilless substrates in a greenhouse. Irrigation was applied as needed to the substrate surface or applied to the substrate surface and applied over plant foliage. Irrigation for both application methods was composed of 0%, 25%, 50%, 75%, or 100% reclaimed water (processed sewage) with deionized water composing the remainder. Shoot dry weights of marketable-sized plants were either larger or similar when 100% reclaimed water was used compared with 0% reclaimed water (deionized). Root dry weights exhibited a similar response except for *salvia* roots that were smaller with 100% reclaimed water irrigation regardless of application method. Leachate NO₃-N, phosphorus (P), and potassium (K) generally decreased throughout the experiments for *vinca* and Dwarf Yaupon holly and were highest at experiment midpoint for 'Helleri' holly and lowest for *salvia*. Leachate electrical conductivities (ECs) were generally highest at experiment termination for *vinca* and *salvia*, whereas ECs of Dwarf Yaupon and 'Helleri' holly tended to peak at experimental midpoint and then decrease slightly at termination. ECs were usually less than 2 dS·m⁻¹ except at experimental midpoint (4.5 months) for 'Helleri' holly. Based on the response of plants in this research, high-quality reclaimed water is a viable water source for annual and woody container-grown nursery crops.

The use of reclaimed water as an irrigation source for nursery crops is of increasing importance because many nurseries are located near urban areas that have experienced rapid population growth. Population growth results in increased demand for water as well as increased production of potentially reclaimable sewage water. Reclaimed water could replace potable water used for irrigation. In addition, reclaimed water use by nurseries may provide an alternative to reclaimed water discharge to the environment.

The literature regarding ornamental plant responses to reclaimed water is mostly about evaluations of plants grown in landscapes rather than commercial container plant production. Southern Indian hybrid azaleas (*Rhododendron* L. spp.) irrigated overhead with reclaimed water in the landscape had smaller sizes than when reclaimed water was soil-applied, potable water was applied overhead, or potable water was applied to the soil (Robinson and Parnell, 1989). The treatment that received overhead reclaimed water exhibited leaf burn, probably as a result of high levels of chloride (Cl) in reclaimed water. There was 300 mg·L⁻¹ Cl in the reclaimed water

compared with 6 mg·L⁻¹ Cl in potable water. Overhead and soil-surface applications of reclaimed water resulted in 20% and 24% plant deaths, respectively, compared with similar applications of potable water. Dwarf azalea hybrids (*Rhododendron* L. spp.) irrigated with reclaimed water and those that received potable water applied overhead did not have different size indices (Robinson and Parnell, 1989); however, leaf burn was observed when irrigated overhead with reclaimed water. According to Wu et al. (1995), crops that have higher tissue levels of Cl are more sensitive to reclaimed water irrigation, although tissue Cl levels were not reported by Robinson and Parnell (1989). The dwarf azalea hybrids that received soil-surface-applied reclaimed water had the highest mortality (82%) as did the Southern Indian hybrids (Robinson and Parnell, 1989).

The impact of sprinkler-irrigating various landscape trees with reclaimed water was the subject of an investigation conducted in Nevada (Devitt et al., 2003) where oak (*Quercus virginiana* Mill. 'Heritage'), desert willow (*Chilopsis linearis* Cav. Sweet), flowering plum (*Prunus cerasifera* Ehrh. 'Atropurpurea'), and Chinese pistache (*Pistacia chinensis* Bunge) were evaluated for response to: 1) sprinkler application of reclaimed water followed by a post-irrigation rinse of fresh water; 2) acidified reclaimed water that was aerated and passed through a carbon filter; 3) 25% fresh water dilution; and 4) 50% fresh water dilution. They concluded that no single treatment worked best for all species and that species selection at the time of landscape planning was an important strategy for avoiding negative impacts of reclaimed water irrigation.

Similar to landscape tree evaluations, reclaimed water has been used for irrigation of citrus trees. Conserv II is a project in central Florida where high-quality reclaimed water is used primarily for citrus tree irrigation (Parsons et al., 1995). In one study, the effect

of reclaimed water on visual evaluations of canopy appearance and leaf color of 'Hamlin' orange [*Citrus sinensis* (L.) Osb.], 'Valencia' orange [*C. sinensis* (L.) Osb.], and 'Orlando tangelo' (*C. paradise* Macf. × *C. reticulata* Blanco) was compared with trees irrigated with well water. Overall, trees irrigated with Conserv II water had similar canopy appearance and leaf color as trees irrigated with well water (Zekri and Koo, 1994). No detrimental effects were found after 6 years of continuous applications of Conserv II water (Zekri and Koo, 1994) to Astatula fine sand. Zekri and Koo (1994) also determined that Conserv II water resulted in about twice the sodium, Cl, and boron (B) tissue concentrations compared with plants irrigated with well water. The precise amount by which Conserv II water can reduce the need for Cl and B should be studied more extensively. A different study with Conserv II water applied at different irrigation rates to 'Hamlin' orange [*C. sinensis* (L.) Osb.] and 'Orlando tangelo' (*C. paradisi* Macf. × *C. reticulata* Blanco) with a combination of the four rootstocks: Carrizo citrange [*Citrus sinensis* (L.) Osb. × *Poncirus trifoliata* (L.) Raf.], Cleopatra mandarin [*C. reticulata* Blanco], sour orange [*C. aurantium* (L.)], and Swingle citrumelo (*C. paradisi* × *P. trifoliata*) demonstrated other benefits of reclaimed water use (Parsons et al., 2001). At the high irrigation rate of 2500 mm/year compared with 400 mm/year, soluble solids concentrations in the juice were lower, whereas total soluble solids per hectare increased as a result of increased fruit production per hectare. The 2500 mm/year irrigation did not result in disease or flooding problems as expected as a result of excellent drainage of the sandy soil. This study shows that a high application rate of reclaimed water can be applied successfully to citrus on well-drained soils. In Spain, citrus [*C. sinensis* (L.) Osb.] trees flood-irrigated with reclaimed water and those irrigated with groundwater

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for 3 years did not exhibit differences in tree height or trunk diameter (Reboll et al., 2000).

A study conducted in Egypt using navel orange trees provided information on the effects of long-term irrigation with sewage water (Omran et al., 1988). Five soil sites irrigated with sewage water for 10, 20, 30, 40, and 60 years were chosen to study the effects of long-term irrigation on heavy metal accumulation. Overall, leaves were shown to contain the highest heavy metal concentrations and juice contained the lowest concentration. Concentrations tended to become greater with longer sewage application times, but heavy metal levels always remained within permissible limits and below toxic levels for humans and plants.

The effects of reclaimed water on the growth of young apple trees in British Columbia, Canada, were investigated using 'Macspur McIntosh' (*Malus xdomestica* Borkh.) and 'Redchief Delicious' apple varieties on a M.7a rootstock. Either reclaimed water or well water was applied to these cultivars from 1983 to 1987 along with three different rates of surface nitrogen (N) fertilization (0, 200, 400 g $\text{NH}_4\text{NO}_3/\text{tree}/\text{year}$). Reclaimed water irrigation resulted in increased trunk diameter for all years and increased fruit number in 1985 and 1986 for both cultivars (Neilsen et al., 1989b). Reclaimed water irrigation of Okanagan Riesling grapes (*Vitis* L. spp.) resulted in a slight increase in soluble solids and juice pH the second year and resulted in increased yield the first and third year (Neilsen et al., 1989a). The effect of reclaimed water irrigation on yield of vegetables was also investigated in British Columbia. Yields of tomato (*Lycopersicon esculentum* L.), sweet pepper (*Capsicum annuum* L.), onion (*Allium cepa* L.), cucumber (*Cucumis sativus* L.), bush bean (*Phaseolus vulgaris* L.), and melon (*Cucumis melo* L.) irrigated with reclaimed water were greater than or similar to yields obtained with well water (Neilsen et al., 1989c). Kim et al. (2009) determined that three vegetable crops and three ornamentals exhibited "moderate growth and photosynthetic capacity" in response to reclaimed water from King County Washington and research by Gori et al. (2000) in Italy indicated a species-specific response to reclaimed water for container-grown ornamentals.

In conclusion, reclaimed water has been successfully used on many horticultural crops. Further research is needed to determine effects of reclaimed water irrigation on ornamental plants grown in soilless container substrates.

The objective of our research was to evaluate the plant growth response of container-grown ornamentals to reclaimed water as an alternative irrigation source for nursery production.

MATERIALS AND METHODS

General procedures

The following research used reclaimed water as defined in Part III of Chapter 62-610 F.A.C. (Florida Administrative Code, 2007), which outlines the criteria for high-quality reclaimed water deemed suitable for land application. Reclaimed water was obtained as needed from the Kanapaha Wastewater Treatment Facility in Gainesville, FL, for irrigation of ornamental crops that included: vinca [*Catharanthus roseus* (L.) G. Don], salvia (*Salvia splendens* F. Sellow ex Roem. and Schult.), Dwarf Yaupon holly (*Ilex vomitoria* Ait. 'Nana'), and 'Helleri' holly (*I. crenata* Thunb. 'Helleri'). These plants were chosen because of their varying levels of salt tolerance and varying durations to maturity or marketable size. Vinca (Tjia and Rose, 1987) and Dwarf Yaupon holly (Black, 2003; Watkins and Sheehan, 1988) are accepted as more salt-tolerant than salvia (Black, 1994) and 'Helleri' holly (Watkins and Sheehan, 1988). Vinca and salvia are annuals typically grown in the nursery for 6 to 8 weeks, whereas Dwarf Yaupon holly and 'Helleri' holly are woody perennials grown for 6 to 8 months in the nursery to produce a plant in a 2.3-L container.

The experiments were conducted in Gainesville, FL (long. 82.35° W, lat. 29.69° N) during 2001 to 2003 in a glass greenhouse with temperature set points of 28 °C day/18 °C night with radiation averaging 695 and 865 $\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$ during fall/winter and spring/summer, respectively. The treatments applied consisted of a combination of varying percentages of reclaimed water and deionized water: 1) 100% deionized water; 2) 25% reclaimed water:75% deionized water; 3) 50% reclaimed water:50% deionized water; 4) 75% reclaimed water:25% deionized water; and 5) 100% reclaimed water. Each irrigation treatment was 460 mL applied to the substrate surface of each container. Treatments 6 to 10 were the same as Treatments 1 to 5, respectively, except that 50 to 70 mL of the corresponding substrate-applied irrigation water was applied by overhead spray to each plant with a handheld sprayer that delivered a fan pattern for 10 s. Irrigation treatments were applied every other day and then daily when

needed as determined by visually observing substrate. Reclaimed water (Part III) was obtained from Gainesville Regional Utilities Kanapaha Wastewater Treatment Facility. Elemental composition of reclaimed water at initiation of each experiment is given in Table 1. The plants were on benches in a randomized complete block design containing eight blocks with one plant per treatment per block. Measurements from the substrate surface to the top of each plant (plant height), the plant width at the widest point, and the plant width perpendicular to the widest point were recorded for all plants and growth indices (height + average width) were determined. Additionally, the leachate resulting from pouring 100 mL of deionized water onto the surface of the substrate was collected, and EC and nutrient concentrations ($\text{NO}_3\text{-N}$, P, and K) were determined according to standard procedures (Analytical Research Laboratory, 2008) for Blocks 1 to 4. At experiment termination, visual appearances were observed and roots were washed of substrate and stems cut above the uppermost root. Shoots and roots were dried in a forced-air oven at 70 °C. Shoot and root dry weights were recorded for all plants.

Expt. 1. Vinca plugs were potted with Metro Mix® 500 (SunGro Horticulture, Bellevue, WA) in 2.3-L containers on 10 Aug. 2001. Each container substrate was surface-applied with 9 g of Osmocote® 14N-6P-12K (The Scotts Company, Marysville, OH). Data were recorded after 1, 4, and 8 weeks of irrigation.

Expt. 2. Salvia plugs were potted 26 Oct. 2001 and fertilized like in Expt. 1. Data were recorded after 1, 4, and 8 weeks of irrigation except for EC data on Weeks 4 and 8.

Expt. 3. Dwarf Yaupon holly liners were potted in 2.3-L containers on 30 Apr. 2002 with a 2:1:1 by volume (pine bark/peat/sand) substrate amended with 4.2 $\text{kg}\cdot\text{m}^{-3}$ dolomitic limestone and 0.9 $\text{kg}\cdot\text{m}^{-3}$ Micromax® micro-nutrients (The Scotts Company). Each container was top-dressed with 14 g Osmocote® 18N-2.6P-10K (The Scotts Company). Irrigation treatments began 10 May 2002. Data were recorded after 0.5, 2.5, 4, 6, and 8 months of irrigation.

Expt. 4. 'Helleri' holly liners were potted 11 Nov. 2002 and fertilized like in Expt. 3. Irrigation treatments began 25 Nov. 2002. Data were recorded after 0.5, 4.5, and 8.5 months of irrigation.

Statistical analyses. Shoot and root dry weights were analyzed using two-way factorials and regression analyses. Waller-Duncan

Table 1. Reclaimed water analyses for a sample taken at beginning of each experiment conducted in greenhouse from 2001 to 2003 to evaluate the growth response of *C. roseus* (vinca), *S. splendens*, *I. vomitoria* 'Nana', and *I. crenata* 'Helleri' to various percentages of reclaimed:deionized water (0:100, 25:75, 50:50, 75:25, and 100:0) applied at each irrigation.²

Plant	$\text{NO}_3\text{-N}$ ($\text{mg}\cdot\text{L}^{-1}$)	Phosphorus ($\text{mg}\cdot\text{L}^{-1}$)	Potassium ($\text{mg}\cdot\text{L}^{-1}$)	Calcium ($\text{mg}\cdot\text{L}^{-1}$)	Magnesium ($\text{mg}\cdot\text{L}^{-1}$)	Zinc ($\text{mg}\cdot\text{L}^{-1}$)	Manganese ($\text{mg}\cdot\text{L}^{-1}$)	Copper ($\text{mg}\cdot\text{L}^{-1}$)	Iron ($\text{mg}\cdot\text{L}^{-1}$)	Sodium ($\text{mg}\cdot\text{L}^{-1}$)	Chloride ($\text{mg}\cdot\text{L}^{-1}$)	pH	Electrical conductivity ($\text{dS}\cdot\text{m}^{-1}$)
<i>C. roseus</i>	3.8	0.2	20	39	20	0.05	0.02	0.01	0	72	88	7.8	0.7
<i>S. splendens</i>	3.8	0.1	16	52	26	0.05	0.02	0.01	0	81	83	8.3	0.7
<i>I. vomitoria</i>	3.1	0.1	12	31	16	0.06	0	0	0	52	90	7.9	0.5
<i>I. crenata</i>	1.0	0.3	15	36	21	0.06	0	0	0	75	95	7.8	0.7

²Reclaimed water was obtained from Gainesville Regional Utilities Kanapaha Wastewater Treatment Facility, Gainesville, FL.

k-ratio *t* tests were used to determine the presence of significant differences between treatment means.

RESULTS AND DISCUSSION

Expt. 1. There were no interactions between the main effects of irrigation method and percentage of reclaimed municipal water applied for vinca shoot and root dry weights. Shoot dry weights were not different for irrigation method ($P \leq 0.086$) (averaged over percentage reclaimed applied), but shoots exhibited a positive linear response to increased percentage of reclaimed water applied (Fig. 1). Shoot growth indices were not different 4 or 8 weeks after experiment initiation for irrigation method or percentage of reclaimed water applied, and visual observations did not reveal foliar aberrances at 8 weeks (data not shown).

Root dry weights were different (surface-applied = 3.0 g, surface-applied plus overhead = 3.3 g) for each irrigation method ($P \leq 0.008$) and percentage of reclaimed water applied ($P \leq 0.039$). Root dry weight for surface irrigation method increased as percentage of reclaimed water increased (Fig. 2).

Leachate $\text{NO}_3\text{-N}$, P, and K concentrations declined throughout the experiment regardless of irrigation method (Fig. 3A–C). However, K leachate concentrations were above the 10 to 20 $\text{mg}\cdot\text{L}^{-1}$ optimum for container plants (Yeager et al., 2007) at 8 weeks. Leachate EC ranged from 0.6 to 1.9 $\text{dS}\cdot\text{m}^{-1}$ during the experiment (Fig. 3D). The highest ECs, although not excessive, were observed at 8 weeks for plants that received the surface-applied plus overhead application of reclaimed water. Reclaimed water $\text{NO}_3\text{-N}$, P, and K concentrations at the beginning of the experiment were 3.8, 0.2, and 20 $\text{mg}\cdot\text{L}^{-1}$, respectively, and EC was 0.7 $\text{dS}\cdot\text{m}^{-1}$ (Table 1).

Data from this experiment indicated that reclaimed water can be used for irrigation of vinca. These results concur with the findings of Maurer and Davies (1993). They found in a study with reclaimed water irrigation of ‘Redblush’ grapefruit trees (*C. paradisi* Macf.) on a Swingle citrumelo rootstock [*C. paradisi* (L.) Osb. $\times$ *Poncirus trifoliata* (L.) Raf.] that tree heights were enhanced by irrigation with simulated reclaimed water compared with well water for trees that received fertilization. A possible explanation for the increased shoot biomass with increased percentages of reclaimed water in our experiment is the contribution of nutrients in the reclaimed water, although this was not investigated. This is further substantiated by the larger root biomass at higher percentages of reclaimed water when plants received a substrate surface application of reclaimed water.

Expt. 2. *Salvia* exhibited no interactions between the main effects of irrigation method and percentage of reclaimed water applied for shoot or root dry weights. Root dry weights of plants irrigated with surface-applied (5.0 g) irrigation were larger than plants that received surface-applied plus overhead (4.3 g) irrigation ($P \leq 0.020$); additionally, root dry weights

Fig. 1. Shoot dry weights of *C. roseus* grown for 8 weeks in 2.3-L containers with Metro Mix® 500 substrate and irrigated with various percentage combinations of reclaimed and deionized water either applied to the substrate surface or applied to substrate surface plus overhead to the plant canopy. Shoot dry weight = $0.032 (\%) + 22.8$ ($P \leq 0.001$).

Fig. 2. Root dry weights of *C. roseus* grown for 8 weeks in 2.3-L containers with Metro Mix® 500 substrate and irrigated with various percentage combinations of reclaimed and deionized water applied to substrate surface plus applied overhead to the plant canopy (●) or applied to the substrate surface (▲). Surface + overhead irrigation = $0.003 (\%) + 3.15$ ($P \leq 0.143$); surface-applied irrigation = $0.005 (\%) + 2.77$ ($P \leq 0.011$).

Fig. 3. (A–D) Leachate $\text{NO}_3\text{-N}$, phosphorus (P), potassium (K), and electrical conductivity (EC) for *C. roseus* grown for 8 weeks in 2.3-L containers with Metro Mix® 500 substrate and irrigated with 0:100% (●), 25:75% (□), 50:50% (△), 75:25% (x), or 100:0% (*) reclaimed:deionized water applied to the substrate surface (S) or applied to substrate surface plus applied overhead (SO) to the plant canopy.

decreased as percentage of reclaimed water applied increased (Fig. 4).

Shoot dry weights were not different for irrigation method ($P \leq 0.489$) or percentage of reclaimed water applied ($P \leq 0.433$); however, the first growth index determination (Week 1) was larger ($P \leq 0.006$) for surface-applied (47) compared with overhead plus surface-applied irrigation (44) (data not shown). The second growth index determination (Week 4) was not different and visual observations at 8 weeks did not reveal any foliar aberrance (data not shown).

Leachate $\text{NO}_3\text{-N}$, P, and K concentrations declined from Weeks 1 to 4 regardless of irrigation method and then increased at 8 weeks to about the concentrations determined at 1 week (Fig. 5A–C). Potassium concentrations at 8 weeks were high to excessive, ranging from 130 to 190 $\text{mg}\cdot\text{L}^{-1}$ (Eakes et al., 1991). Leachate EC ranged from 0.4 to 1.6 $\text{dS}\cdot\text{m}^{-1}$ during the experiment and EC tended to be higher with higher percentages of reclaimed water applied (Fig. 5D). Reclaimed water $\text{NO}_3\text{-N}$, P, and K concentrations at the beginning of the experiment were 3.8, 0.1, and

16 $\text{mg}\cdot\text{L}^{-1}$, respectively, and EC was 0.7 $\text{dS}\cdot\text{m}^{-1}$ (Table 1).

Salvia shoot dry weights were not different as a result of irrigation application method or percentage of reclaimed water applied; however, the differences in root dry weights could be indicative of salvia's salt sensitivity (Black, 1994) and attributable to increased EC levels associated with increased percentages of reclaimed water applied. Despite the reduction in root dry weight, these data indicate that reclaimed water can be used for irrigation of salvia based on shoot growth response.

Expt. 3. Dwarf Yaupon holly did not have an interaction for root dry weight ($P \leq 0.098$) but there was an interaction between the main effects of irrigation method and percentage of reclaimed municipal water applied for shoot dry weight ($P \leq 0.039$). Waller-Duncan K-ratio t test for shoot dry weights (Table 2) revealed that surface-applied plus overhead irrigation without reclaimed water (46 g) resulted in greater shoot dry weights than 0%, 50%, or 100% reclaimed water surface-applied only (36, 38, and 34 g, respectively). Shoot dry weights were not different as a result of irrigation application method for each treatment that contained reclaimed water. Growth indices were not different at each determination for irrigation application method or percentage of reclaimed water applied, and visual observation at 8 months did not reveal foliar aberrances (data not shown). Root dry weights were larger for plants with surface-applied plus overhead irrigation (41 g) than root dry weights (37 g) for surface-applied irrigation only ($P \leq 0.042$). Percentage reclaimed water applied did not result in different root dry weights.

Leachate $\text{NO}_3\text{-N}$, P, and K (Fig. 6A–C) concentrations were high regardless of irrigation application method at 2.5 months and then tended to decline until end of the experiment at 8 months when it appeared that nutrients supplied by the fertilizer were limited. Leachate $\text{NO}_3\text{-N}$, P, and K concentrations at 2.5 and 4 months exceeded optimal substrate concentrations (Yeager et al., 2007). Leachate EC (Fig. 6D) followed a similar pattern except for the surface-applied plus overhead application of 100% reclaimed water at 8 months, in which an excessive EC of 2.9 $\text{dS}\cdot\text{m}^{-1}$ was recorded (Yeager et al., 2007).

Fig. 4. Root dry weights of *S. splendens* grown in 2.3-L containers with Metro Mix® 500 substrate and irrigated for 8 weeks with various percentage combinations of reclaimed and deionized water applied to substrate surface plus applied overhead to the plant canopy (●) or applied to the substrate surface (▲). Surface + overhead irrigation = -0.025 (%) + 5.56 ($P \leq 0.001$); surface-applied irrigation = -0.029 (%) + 6.44 ($P \leq 0.001$).

Fig. 5. (A–D) Leachate $\text{NO}_3\text{-N}$, phosphorus (P), potassium (K), and electrical conductivity (EC) for *S. splendens* grown in 2.3-L containers with Metro Mix® 500 substrate and irrigated for 8 weeks with 0:100% (●), 25:75% (□), 50:50% (△), 75:25% (x), or 100:0% (*) reclaimed:deionized water applied to the substrate surface (S) or applied to substrate surface plus applied overhead (SO) to the plant canopy.

Table 2. Mean shoot dry weights for *I. vomitoria* grown in a 2 pine bark:1 Canadian peat:1 sand (by volume) substrate in 2.3-L containers and irrigated for 8 months with various percentage combinations of reclaimed and deionized water applied to the substrate surface or applied to substrate surface and applied overhead to the plant canopy.

Reclaimed: deionized (%)	Surface (g)	Surface + overhead (g)
0:100	36	46
25:75	39	43
50:50	38	43
75:25	44	39
100:0	34	39

Means separated by Waller-Duncan K-ratio t test. Minimum significant difference = 7 g.

Fig. 6. (A–D) Leachate $\text{NO}_3\text{-N}$, phosphorus (P), potassium (K), and electrical conductivity (EC) for *I. vomitoria* grown in a 2 pine bark:1 Canadian peat:1 sand (by volume) substrate in 2.3-L containers and irrigated for 8 months with 0:100% (◆), 25:75% (□), 50:50% (△), 75:25% (x), or 100:0% (*) reclaimed:deionized applied to the substrate surface (S) or applied to substrate surface plus applied overhead (SO) to the plant canopy.

Reclaimed water $\text{NO}_3\text{-N}$, P, and K concentrations at the beginning of the experiment were 3.1, 0.1, and 12 $\text{mg}\cdot\text{L}^{-1}$, respectively, and EC was 0.5 $\text{dS}\cdot\text{m}^{-1}$ (Table 1).

Dwarf Yaupon holly was selected as a result of its perceived salt tolerance (Black, 2003; Watkins and Sheehan, 1988). However, shoot dry weights of plants that received 100% reclaimed water applied to the substrate surface were smaller than when 0% reclaimed water was surface-applied plus surface irrigation. This may be related to the fact that 100% reclaimed, regardless of application method, resulted in the highest EC at 6 and 8 months. Root dry weights were not different in relation to percent of reclaimed water applied but were larger for overhead plus surface irrigation than for surface irrigation alone. There does not seem to be a logical explanation for this based on substrate nutrition. However, these data indicate that reclaimed water can be successfully used for the irrigation of Dwarf Yaupon holly.

Expt. 4. ‘Helleri’ holly exhibited an interaction between the main effects of irrigation method and percentage of reclaimed water applied for shoot dry weights ($P \leq 0.012$) and root dry weights ($P \leq 0.040$). The Waller-Duncan K-ratio t test for shoot dry weights and root dry weights revealed no differences between treatments (Tables 3 and 4). The mean shoot and root dry weights for all treatments were 68 g ($\text{SD} \pm 10$) and 30 g ($\text{SD} \pm 10$), respectively.

Growth indices were not different for the first (0.5 months) and second (4.5 months) determination (data not shown). The third determination (8.5 months) revealed a significant interaction ($P \leq 0.026$) of irrigation method and percentage reclaimed water applied with growth indices exhibiting a similar response to shoot dry weights. Plants that received 100% reclaimed water applied to substrate surface plus overhead exhibited the greatest growth index (91) and 0% reclaimed applied similarly and 100% reclaimed surface-applied resulted in the smallest growth indices (78 and 76, respectively). Visual observation of foliage at 8.5 months did not reveal aberrances of foliage (data not shown).

Leachate $\text{NO}_3\text{-N}$, P, and K concentrations were excessive at 4.5 months (Yeager et al., 2007), but decreased at 8.5 months to approximately initial concentrations regardless of irrigation method (Fig. 7A–C). However, P and K concentrations were approximately two to five times, respectively, optimal concentrations (Yeager et al., 2007), possibly as a result of P and K in the reclaimed water. Leachate EC exhibited a similar pattern and ranged from 0.7 to 2.4 $\text{dS}\cdot\text{m}^{-1}$ during the experiment (Fig. 7D). Reclaimed water $\text{NO}_3\text{-N}$, P, and K concentrations at the beginning of the experiment were 1.0, 0.3, and 15 $\text{mg}\cdot\text{L}^{-1}$, respectively, and EC was 0.7 $\text{dS}\cdot\text{m}^{-1}$ (Table 1).

‘Helleri’ holly was selected as a result of its nontolerance of salt (Watkins and Sheehan, 1988). The salt sensitivity was reflected in the

Table 3. Mean shoot dry weights for *I. crenata* ‘Helleri’ grown in a 2 pine bark:1 Canadian peat:1 sand (by volume) substrate in 2.3-L containers and irrigated for 8.5 months with various percentage combinations of reclaimed and deionized water applied to the substrate surface or applied to substrate surface and applied overhead to the plant canopy.

Reclaimed: deionized (%)	Surface (g)	Surface + overhead (g)
0:100	72	62
25:75	74	64
50:50	66	71
75:25	70	65
100:0	64	74

Means separated by Waller-Duncan K-ratio t test. Minimum significant difference = 14 g.

Table 4. Mean root dry weights for *I. crenata* ‘Helleri’ grown in a 2 pine bark:1 Canadian peat:1 sand (by volume) substrate in 2.3-L containers and irrigated for 8.5 months with various percentage combinations of reclaimed and deionized water applied to the substrate surface or applied to substrate surface and applied overhead to the plant canopy.

Reclaimed: deionized (%)	Surface (g)	Surface + overhead (g)
0:100	31	29
25:75	29	27
50:50	30	35
75:25	33	26
100:0	27	36

Means separated by Waller-Duncan K-ratio t test. Minimum significant difference = 17 g.

growth index and, although not statistically different, also in root growth of plants that received 100% reclaimed water surface-applied. EC peaked at 2.4 $\text{dS}\cdot\text{m}^{-1}$ at the experimental midpoint (4.5 months) for 100% reclaimed water surface-applied and growth index was a low of 76 at 8.5 months. One hundred percent reclaimed water surface-applied plus overhead irrigation resulted in the highest growth index (91) at 8.5 months and the lowest EC (1.93 $\text{dS}\cdot\text{m}^{-1}$) at the experimental midpoint (4.5 months). Previous experimentation with ‘Helleri’ holly (unpublished observation) indicated that an EC above 2.0 $\text{dS}\cdot\text{m}^{-1}$ was detrimental to root growth. These findings suggest that monitoring and control of EC are important during production of ‘Helleri’ holly when reclaimed water is used.

CONCLUSIONS

Reclaimed water was a viable source of irrigation for the container plants grown in these experiments, either when applied to substrate surface or applied to the plant canopy and substrate surface. A key component of crop management when using reclaimed water irrigation is the monitoring and regulation of EC levels of the substrate within a range most appropriate for the plant species grown. Additionally, producers should monitor EC of irrigation water. Routine monitoring of substrate and irrigation water EC are best management practices (Yeager et al., 2007) and

Fig. 7. (A–D) Leachate NO₃-N, phosphorus (P), potassium (K), and electrical conductivity (EC) for *I. crenata* ‘Helleri’ grown in a 2 pine bark:1 Canadian peat:1 sand (by volume) substrate in 2.3-L containers and irrigated for 8.5 months with 0:100% (◆), 25:75% (□), 50:50% (△), 75:25% (×), or 100:0% (*) reclaimed:deionized water applied to the substrate surface (S) or applied to substrate surface plus applied overhead (SO) to the plant canopy.

thus should not be new production strategies for growers changing from ground or surface water to reclaimed water sources. In other plant evaluations we have conducted, the EC of reclaimed water processed according to Part III guidelines ranged from 0.5 to 0.7 dS·m⁻¹ during 2004 to 2007 (unpublished data). Furthermore, survey responses of container plant growers and owners (unpublished data) indicated a willingness to use reclaimed water for irrigation with a few notable contingencies. Primary concerns were costs, availability, water quality, and politics. Thus, results of these experiments suggest that if low-cost/high-quality reclaimed water was consistently available with freedom from political barriers, container plant producers should embrace the opportunity to use this valuable irrigation resource.

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