Final Report

Deliverable 10

Project Title: Reclaimed water for irrigation of container grown plants

Sponsoring Agency: Southwest Florida Water Management District

Project No. 35979

Investigating Agency: University of Florida (UF), Institute of Food and Agricultural Sciences (IFAS)

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Introduction

About 60% of Florida's fresh water supply comes from wells (Marella, 2000) and the demand for this resource continues to increase. Inadequate amount and distribution of rainfall have resulted in the need for water conservation. Irrigation water used by commercial nurseries in most areas of Florida is restricted both in quantity and the time periods during which it can be applied. Alternative water sources such as reclaimed water offer some relief from the limitations of inadequate water resources. Reclaimed water may serve as the sole source of irrigation water or may supplement amount of water permitted because Water Management Districts can permit the lowest quality water that is economical, technologically, and environmentally feasible to use. In some locales, reclaimed water may be the only water available for irrigation. Fortunately, reclaimed water costs about one half that of potable water, although additional connection and service fees may apply.

Reclaimed water is processed from municipal sewage wastewater and should not be confused with black water or gray water. In Florida, the operation of a processing facility is outlined in Chapter 62-600 F.A.C. (see Application Rules website below). Part III of Chapter 62-610 F.A.C. (see Application Rules website below) outlines the criteria that result in high quality reclaimed water for land application. In addition to filtration, reclaimed water processed according to guidelines for Part III must have a high-level of disinfection so it can be used in public areas. The suitability of reclaimed water (Part III) for overhead sprinkler irrigation of container-grown plants has been the subject of an evaluation at University of Florida, IFAS. As part of this evaluation reclaimed water users and non-users were surveyed to gain insight with regards to their attitudes and perceptions about reclaimed water use, and to obtain specific information with regards to reclaimed water application in the wholesale container nursery.

Survey of Reclaimed Water Users and Non-users

Survey Work Performed Year 1

A list of container nurseries that used reclaimed water was not available so the information had to be complied. From the Florida Department of Environmental Protection (FDEP) website, (http://www.dep.state.fl.us/water/reuse/docs/inventory/AppD.pdf) a list (Appendix D 2003) of reclaimed water treatment facilities was obtained for reuse type Public Access Areas & Landscape Irrigation (PAA&LI) and reuse subtype Other Public Access Areas (OPAA) for Part III (Chapter 62-610, F. A. C.) reuse water as suggested by Lauren Walker-Coleman, Reuse Specialists, FDEP. She also provided a list of contact phone numbers for the reclaimed water treatment facilities in the state. From these two lists, a list of water treatment facilities producing Part III water that could possibly supply container nurseries was compiled. Each of the approximately 95 treatment facilities was contacted by phone and queried to determine if they supplied reclaimed water to wholesale nurseries producing plants in containers. If so, the nursery name was obtained. This resulted in a list of 22 potential users of reclaimed water statewide. Each nursery was then contacted to verify that they sold plants wholesale and used reclaimed water for irrigation. If these conditions existed, then an appointment for a site visit to complete the survey was established.

Seven nurseries were viable reclaimed water user candidates and completed the survey. Some nurseries on the list of 22 users were out of business, grew plants in native soil, or no longer used reclaimed water.

A nursery not using reclaimed water in close proximity to a nursery using reclaimed water was also surveyed. Average distance between nurseries was 6.2 miles for six of the users and non-users, and 37 miles for another user and non-user nursery.

Reclaimed water users were located in the following counties:
Brevard, Manatee, Orange, Pinellas, Seminole

Non-users were located in the following counties:
Brevard, Manatee, Orange, Osceola, Pinellas

Results Summary: Survey of Nurseries Using Reclaimed Water Year 1

Seven nurseries were surveyed that were currently using municipal reclaimed water for the irrigation of container plants. The nurseries surveyed had been in business an average of 36 years and reported using municipal reclaimed water for an average of 8 years (range: 2 to 15 years). Nurseries were located an average of 0.6 miles from the water treatment facility from which they were receiving the reclaimed water. Fifty-seven percent of respondents (N=7) reported having a contract with their reclaimed water supplier, of those 50% reported maximum water received as 20 and 100 thousand gallons per day. One respondent reported minimum water received of 15 thousand gallons per day. Fifty-seven percent of respondents (N=7) purchased the reclaimed water for irrigation.

Respondents were then asked to rate the consistency of quality and quantity of reclaimed water delivered to them using a five-point Likert (Likert, 1932) scale, with one indicating strong agreement that quality or quantity of reclaimed water was consistent and five indicating strong disagreement that quality or quantity of reclaimed water was consistent. To assess the data collected, responses of one or two were labeled as agreement to the consistency in quality or quantity of reclaimed water, a response of three was labeled neutral, and responses of four or five were labeled as disagreement to the consistency in quality or quantity of reclaimed water. Sixty-seven percent of respondents (N=6) reported that reclaimed water quality was consistent over time, 17% gave a neutral response (N=6), and 17% reported inconsistency of quality (N=6). Fifty percent of respondents (N=6) reported that reclaimed water quantity was consistent over time, 33% gave a neutral response (N=6), and 17% reported inconsistency of quantity (N=6).

Survey participants were asked what plants they were currently producing. Plants grown in the greatest and least quantities are given in Table 1.

Table 1. Ornamental plants grown with municipal reclaimed water ranked from greatest to least quantity (1= Greatest, 5= Least).

1.	All plants in nursery; Schefflers arbicola 'Trinette'- 3gal; Gardenia spp.; Ixora spp.; Ligustrum spp. and Jasminum spp. (Jasmine); Phoenix roebeleni; Quercus virginiana (Live Oak)- 15gal; Rhaphiolepsis indica- 3gal
2.	Codiaeum spp. (Croton); Gardenia spp.- 1 to 10 gal; Loropetalum chinensis- 3gal; Quercus virginiana (Live Oak)- 25gal; Rhaphiolepsis alba- 3gal; Syagrus romanzoffiana (Queen Palm), Schefflera arbicola and Hibiscus spp.
3.	Ixora spp., Viburnum spp., and Philodendron selloum; Jasminum spp.; Juniperus chinensis 'Parsonii'- 3gal; Rosa spp.-3gal; Syagrus romanzoffiana (Queen Palm)- 15gal; Viburnum odoratissimum- 3gal
4.	Juniperus chinensis 'Shore'- 3gal; Pittosporum spp., Nerium oleander, and Philodendron 'Xanadu'; Quercus (Oak)- 10gal; Quercus laurifolia (Laurel Oak)- 15gal; Viburnum suspensum- 3gal
5.	Ligustrum japonica- 3gal; Ilex spp. (Holly) and Rhododendron spp. (Azalea); Viburnum odoratissimum- 3gal; Quercus laurifolia (Laurel Oak)- 25gal

Percentages of municipal reclaimed water used for container plant irrigation ranged from 95-100% for seven respondents. One of seven respondents indicated that reclaimed irrigation water was collected in a pond or basin after use and used in later irrigation. Thirty percent of the water applied (reclaimed or reclaimed and non-reclaimed) was collected for reuse from outdoor or shade production areas.

Survey responses with regards to use of reclaimed water (Part III) for irrigation of container ornamental plants are given in Tables 2 and 3.

Table 2. A survey was conducted in Florida of seven users of municipal reclaimed water (Part III). Survey participants were asked to indicate which statements applied to their container nursery because of reclaimed water use.

Survey question	Percent responding yes
Need for filtration	43
Very high pressure	43
Fluctuating pressure	29
Health or safety concerns	29
Emitter or nozzle clogging	29
Need for acidification	14
Pipes or valves breaking due to pressure	14
Lack of reliable supply	14
Irrigation system down time	14
Loss of plant sales	14
Disgruntled employees	14
Water treatment because of emitter or nozzle clogging	14
Forced to take more water than needed	0
Toxic reaction with fertilizer or chemicals	0
Water treatment because of pathogens	0
Increased pesticide use	0

Table 3. A survey was conducted in Florida of seven users of municipal reclaimed water (Part III). Survey participants were asked to indicate if they were strongly satisfied with reclaimed water use.

Survey question	Percent strongly satisfied
How satisfied are you with reclaimed water?	100
How satisfied are you with your current arrangement with the reclaimed water supplier regarding water quality?	86
How satisfied are you with your current arrangement with the reclaimed water supplier regarding water quantity?	86

Seventy-one percent of respondents reported that they had received incentives to use municipal reclaimed water for irrigation. Some of incentives listed included; low costs, more water, low salinity, and connection to consumptive use permit renewal.

The next series of questions presented to participants focused on fertilizer use. Participants were asked to report the types of fertilizer they currently use. Controlled-release fertilizer was reported as the most commonly used, with each of the seven respondents reporting its use. Granular fertilizer applied in combination with controlled-release fertilizer and granular soluble fertilizer were the second most commonly used, with 71% of respondents (N=7). The third most reported fertilizers used were solution and natural organic fertilizers; each used by two of five respondents. The least commonly used fertilizer was controlled-released fertilizer combined with solution fertilizer that was used by two of six respondents. Twenty-nine percent of respondents (N=7) reported that it was necessary to change their fertilizer program since using reclaimed water for irrigation of container plants. Respondents reported that it had been necessary to alter fertilizer programs to adjust to new growth habits, to decrease nitrogen in fertilizer, and to eliminate boron from the micronutrients applied.

Total area irrigated outdoors or under shade averaged 8.7 acres (range: 5.0-23.5 acres) for seven respondents and the average amount of reclaimed water applied per day during peak demand was 69 thousand gallons (20-125 thousand gallons) for three respondents. Six respondents reported using overhead sprinkler irrigation on an average of 8.6 acres (2-23 acres) and the average amount of water applied per day was 67.3 thousand gallons (20-120 thousand gallons) for three respondents. Two respondents reported irrigating using microirrigation on an average of 2.3 acres (0.5-4 acres) and the amount of water applied per day was 5 thousand gallons for one respondent. Respondents using only reclaimed water outdoors or under shade reported no other methods of irrigation.

Reclaimed water was applied in greenhouses to an average of 100 thousand square feet (16-280 thousand square feet) for five respondents and the average amount of reclaimed water applied per day during peak demand was 4.75 thousand gallons (4.5-5.0 thousand gallons) for two respondents. Five respondents reported using overhead sprinkler irrigation for an average of 116 thousand square feet (16-260 thousand square feet) and the amount of water applied per day during peak demand was 5 thousand gallons for one respondent. One respondent reported using microirrigation on 20 thousand square feet of greenhouse space and water volume applied was not reported. Respondents using only reclaimed water in greenhouses reported no other methods of irrigation.

Results Summary: Survey of Nurseries Not Using Reclaimed Water Year 1

Nurseries were surveyed that were currently not using municipal reclaimed water for the irrigation of container plants. A listing of plants grown in greatest and least quantities is given in Table 4. The nurseries surveyed had been in business an average of 32 years (range: 27 to 45 years).

Table 4. Ornamental plants grown with non-reclaimed water ranked from greatest to least quantity (1= Greatest, 5= Least).

1.	Euphorbia spp.-4,6,6-1/2,8,10"; Hibiscus spp.-1&3gal; Rhaphiolepis spp.-3&7gal; Rhaphiolepsis indica-3gal; Veitchia merrillii (Adonidia Palm)-15gal, 25gal, BB; Moraea iridoides-1gal
2.	Rosa spp.- 3gal; Ixora spp.-1&3gal; Viburnum spp.- 3, 7, 15, 30gal; Viburnum odoratissimum- 3gal; Wodyetia bifurcata (Foxtail Palm)- 15gal, 25gal, BB; Philodendron selloum- 3gal
3.	Flowering hanging baskets -10&12"; Codiaeum spp. (Croton)-1&3gal; Loropetalum spp.-3&7gal; Schefflera arbicola 'Trinette' -3gal; Phoenix canariensis (Canary Palm)-15gal, 25gal, BB; Liriope spp. (Aztec grass)-1gal
4.	Cordyline terminalis (Ti)- 1&3gal; Lantana camara -1gal; Codiaeum variegatum 'Mammey'-3gal; Syagrus romanzoffiana (Queen Palm)- 15gal, 25gal, BB; Ophiopogon japonica-1gal
5.	Allamanda spp.-1&3gal; Spartina bakerii- 1&3gal; Pentas lanceolata- 1gal; Phoenix roebelenii (Pygmy Palm)- 15gal, 25gal, BB; Trachycarpus fortuneii- 1gal

Survey participants were also questioned regarding their source of water for irrigation, their water monitoring practices, and locations providing runoff. Wells were the most common source of irrigation water for 83% of respondents (N=6) and their well water comprised 93% (N=5) of the total water applied. Surface water was the second most used source of water for two of three respondents and municipal or potable water was used by one of two respondents.

Controlled-release fertilizer was reported as the most commonly used for 71% of respondents (N=7). Granular fertilizer applied alone or in combination with controlled-release fertilizer was the second most commonly used for 57% of respondents (N=7). Solution and natural organic fertilizers were the third most used for 50% of respondents (N=6). Controlled-released fertilizer combined with solution fertilizer was the least used for 17% of respondents (N=6).

Total area irrigated outdoors or under shade averaged 8.2 acres (1.2-23.0 acres) for seven respondents and water applied each day during peak demand averaged 62.1 thousand gallons (1.0-162.9 thousand gallons) for five respondents. Overhead sprinkler irrigation averaged 10 acres for five respondents and water applied each day during peak demand averaged 59.9 thousand gallons (0.5 -162.9 thousand gallons) for five respondents. Microirrigation, flood irrigation, and hand watering were each reported by one respondent as 0.1, 4.0, and 0.5 acres, respectively, with 10 and 0.5 thousand gallons applied each day during peak demand for flood and hand watering, respectively. Gallons applied with microirrigation were not reported. Eighty-six percent of respondents (N=7) reported that they would use reclaimed water for irrigation outdoors or under shade if it were available to them.

Total area irrigated in greenhouses averaged 110.7 thousand square feet (1.2-354 thousand square feet) for five respondents and water applied each day during peak demand averaged 17 thousand gallons (4.5-26.5 thousand gallons) for three respondents. Overhead sprinkler irrigation averaged 110.7 square feet (1.2-354 thousand square feet) for five respondents and water applied each day during peak demand averaged 18.2 thousand gallons (10-26.5 thousand gallons) for two respondents. One respondent reported interchangeable use of flood or overhead sprinkler irrigation on 354 thousand square feet and water applied each day during peak demand averaged 10 thousand gallons for flood irrigation. Respondents did not use microirrigation, ebb and flow bench irrigation, or any other type of irrigation in a greenhouse. Eighty percent of respondents (N=5) reported they would use reclaimed water for irrigation in their greenhouses if it were available.

The next section of the survey addressed participants' attitudes and perceptions regarding the use of reclaimed water for irrigation of container-grown plants. Respondents rated their level of agreement to several statements using a five-point Likert (Likert, 1932) scale, with one indicating they strongly agree and five indicating they strongly disagree. To assess the data collected from the seven respondents, responses of one or two were labeled as agreement to the statement, a response of three was labeled neutral, and responses of four or five were labeled as disagreement to the statement. Responses are summarized in Table 5.

Table 5. A survey was conducted in Florida of seven non-reclaimed water users. Survey participants indicated their agreement with limitations regarding use of reclaimed water for container plant irrigation.

Limitations of reclaimed water	**Percent responding**		
	Agree	**Neutral**	**Disagree**
Expense of connection to reclaimed	71		
Unknown water quality	57		
Health or safety concerns	57		
Need for water treatment		57	
Reliability of supply			43
Expense of water			43
Restrictions on existing water supply	43		
Need for plumbing repairs or retrofitting	43		
Regulations	29		
Forced to take more water than needed	29		
Limited research on reclaimed water	14		

When asked what other limitations to the use of reclaimed water for container plant irrigation, the responses given were reclaimed water for irrigation may not be available in a given locale and political issues surrounding the distribution of reclaimed water may be limitations. Respondents also listed reasons for not using reclaimed water that included: not available, no pipe under road, and politics.

Participants were asked to rank eleven reasons for not using reclaimed water that were provided as a list. A summary of the results for the three respondents is presented below.

Greatest importance
Concerns for disease/plant quality, variation in the quality or quantity of reclaimed water
Intermediate importance
Health or safety concerns, regulations
Lowest importance
Expense of connection and piping, limited research and restrictions on use
Widest spread of importance
Forced to take more than needed, need for water treatment and/or filtration

A reclaimed water sample was collected at each nursery surveyed. Samples were analyzed by standard procedures at the Analytical Research Laboratory, University of Florida Gainesville. The results are given in Table 6.

Table 6 . Average values for analyses of municipal reclaimed water from nurseries participating in survey (N=7).

Elec. Cond.	**pH**	**Aluminum**	**Ammonium**	**Barium**	**Boron**	**Cadmium**
dS/m		mg/l	mg/l	mg/l	mg/l	mg/l
0.96	7.91	0.78	2.69	0.00	0.34	0.00

Calcium	**Chloride**	**Copper**	**Iron**	**Lead**	**Magnesium**	**Manganese**	**Molybdenum**
mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
65.32	135.96	0.00	0.00	0.01	13.59	0.00	0.02

Nickel	**Nitrate Nitrogen**	**Phosphorus (ortho)**	**Phosphorus (total)**	**Potassium**	**Silicon**	**Sodium**	**Zinc**
mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
0.00	2.86	1.80	1.60	16.97	8.23	122.02	0.00

Chloride, pH, and electrical conductivity (EC) of the reclaimed water should be monitored weekly to ensure consistency with time and that the desired levels for irrigation water given in *Best Management Practices Guide for Producing Container Grown Plants* (Yeager et al., 2007) are achieved. Chloride and pH exceeded the desired levels for irrigation water (less than 100 ppm and less than 7, respectively). Calcium concentrations in the reclaimed water surpassed the 20-40 ppm desirable range for the container substrate, while potassium in the reclaimed water was within the desirable range of concentrations (10-20 ppm) for the substrate (Yeager et al., 2007). Another noteworthy concern is that phosphorus in the reclaimed water might contribute excessively to runoff phosphorus, particularly in watersheds where total phosphorus discharged to the Everglades is targeted for 10 ppb (http://www.sfwmd.gov/org/wrp/wrp_evg/projects/efa.html).

Conclusions from Surveys Year 1

Reclaimed water seems to be suitable for irrigation of container-grown nursery plants; however, elemental analyses should be conducted frequently or reports of analyses obtained from the supplier to ensure elemental constitutes of the reclaimed water are consistent and not excessive. The need to filter the water and excessive water pressure should be investigated by nursery operators considering the use of reclaimed water. Reclaimed water was used on an array of container plant types with azaleas noted as receiving only non-reclaimed water by one respondent. Azaleas were reported by one reclaimed water user as receiving only non-reclaimed water because elevated salt levels in the reclaimed water would burn leaves; however, azaleas were also listed as grown with reclaimed water by another user, but in the least quantity Table 1. The reclaimed irrigation water for the azaleas was not recycled reclaimed water. The fact that azaleas and ten other of the same genera were grown with reclaimed and non-reclaimed water may indicate that respondents had determined they could irrigate many genera with reclaimed water if managed diligently. Thus, from the surveys it was not evident that certain plants needed to be irrigated with non-reclaimed water.

More than 79% of nurseries not using reclaimed water, but within 3-37 miles of nurseries using municipal reclaimed water, indicated they would use reclaimed water if available. Concerns for disease/plant quality and variation in quality and quantity of water were very important considerations when deciding not to use reclaimed water. Seventy-one percent of respondents agreed that expense of connection to a reclaimed system was a limitation, but expense of connection was ranked low in importance among reasons for not using reclaimed water.

Research Evaluating Plant Responses

In addition to the plants grown by survey respondents, researchers at University of Florida, IFAS in Gainesville have used municipal reclaimed water (Part III) for overhead irrigation of the following plants: Taiwan Dwarf Ixora (*Ixora coccinea*), Maui Ixora (*Ixora coccinea*), Croton 'Petra' (*Codiaeum variegatum*), Seminole Pink Hibiscus (*Hibiscus rosa-sinensis*), Loropetalum (*Loropetalum chinensis*) 'Ruby' and 'Plum', Imperial Blue Plumbago (*Plumbago ericulata*), azalea (*Rhododendron japonica*) 'Mrs. G. G. Gerbing', Poinsettia (*Euphorbia pulcherrima*) 'Prestige', Chrysanthemum (*Dendranthema x morifolium*) 'Beth' and 'Covington', and holly (*Ilex crenata*) 'Helleri'. Experiments have been conducted to evaluate the impact of reclaimed and recycled reclaimed irrigation water on plant growth. In addition, the nutritive value of reclaimed water has been investigated with a reduction in either potassium or nitrogen, phosphorus, and potassium applied as controlled-release fertilizer. Results for these evaluations are presented below.

Recycled Reclaim Work Performed Year 2 Objective 1

In the first experiment (2004), plants selected for evaluation were either grown by survey respondents or suggested by industry personnel to be included in the experiment. In June 2004, plugs of Taiwan Dwarf Ixora (*Ixora coccinea*), Maui Ixora, Croton 'Petra' (*Codiaeum variegatum*) , Seminole Pink Hibiscus (*Hibiscus rosa-sinensis*), Loropetalum `Ruby' (*Loropetalum chinensis*) and Imperial Blue Plumbago (*Plumbago ericulata*) were potted in trade 1-gallon containers with a 2:1:1 (Pine bark: Canadian peat: sand substrate by volume) common nursery substrate amended with 7 pounds per cubic yard dolomitic limestone and 3 pounds per cubic yard Perk micronutrients. The substrate surface of each plant received 15 g Osmocote 18-6-12.

Four replicate plants of each species were placed on one of eight 4 x 6 foot plastic outdoor platforms designed to catch irrigation water. Each platform was lined with standard black polypropylene with 0.75 inch polyethylene tube connected to each of the platforms for drainage into a 40-gallon container that was buried to ground level. Secondary valves were installed to allow rainwater to be diverted from the collection container. Trade one-gallon dwarf yaupon holly plants were used as border plants around each platform.

Plants were watered as needed with either City of Gainesville municipal tap water (two platforms #2, #8) or fresh municipal reclaimed water (Part III) from Gainesville Regional Utilities Kanapaha Wastewater Treatment Facility (three platforms #3, #4, #6), or reclaimed water that was captured by gravity flow and stored in buried container and reapplied or recycled (three platforms #1, #5, #7). Plant species were randomly placed on the platforms and the watering treatments were randomly assigned to the platforms.

Reclaimed and recycled reclaimed water was pumped from a storage container and applied overhead to plants by personnel with Dramm hose breaker nozzle that was attached to 0.75 inch hose. Municipal water was applied similarly. Approximately 15 – 20 gallons of water was applied as needed to each irrigation treatment.

Recycled reclaimed application did not start until collection containers were full. Collection of recycled reclaimed water was not able to keep up with the demand by plants, so the recycled reclaim treatment received recycled reclaimed water beginning the third week and about once a week in July and August. In September, there was an interruption of collection due to hurricanes, but recycled reclaimed water treatment resumed beginning mid-October. Out of 20 weeks, recycled reclaimed water was applied for ten weeks and reclaimed water for the other ten weeks.

Plants were moved twice in September to a building to provide protection from hurricanes. Plants received municipal water for irrigation from September 3-15 (12 days) and September 25-27 (3 days).

A calendar was kept to record actual watering days versus rain events. Plants were irrigated ten times in July, 20 times in August, seven times in September, 16 times in October, 16 times in November, and not watered in December.

Data collected included the following.

- Visual observations
- Plant growth indexes and dry weights
- Substrate electrical conductivity (salt) of one container plant species per block
- Electrical conductivity of water in collection containers
- Reclaimed water analyses
- Photos

Recycled Reclaim Results Summary Year 2 Objective 1

At 20 weeks (November 2004), most of the plumbago was chlorotic in all treatments with wilted appearance after flowers faded and both ixora species exhibited leaf scorching that was not related to water treatments. These aberrances were possibly heat or sun damage.

There was no visible difference in irrigation treatments for the Taiwan dwarf ixora or hibiscus (Table 7). Croton irrigated with recycled reclaimed water was rated better than plants irrigated with municipal tap water, while Maui ixora irrigated with municipal tap water or recycled reclaimed water were rated better than plants irrigated with reclaimed water. Loropetalum and plumbago irrigated with municipal tap water were rated better than plants irrigated with recycled reclaimed water (Table 7).

Table 7. Summary of visual observations determined after 20 weeks (November 2004).

Water Type	Plumbago	Croton	Tw. D. Ixora	Maui Ixora	Hibiscus	Loropetalum
Municipal tap	2.50	2.25	2.00	2.13	2.00	2.00
Reclaim	3.00	2.17	2.00	2.42	2.00	2.08
Recy/rec	3.00	2.00	2.00	2.17	2.08	2.17
	m>rr=r	rr>r>m	same	m>rr>r	same	m=r>rr

1= Good, excellent structure, color and leaf appearance
2 = Medium, average structure, lighter green color, some leaf damage
3 = Poor, dead or poor leaf structure, inadequate color, advanced leaf damage

Changes in growth index and plant dry weights were similar regardless of the irrigation water type (Table 8). But, it might be worthy to note that Loropetalum tended to decline in shoot weight when irrigated with recycled reclaimed water compared to municipal tap or municipal reclaimed water. There has been some concern by producers in Hillsborough County that Loropetalum might be sensitive to reclaimed water.

Table 8. Dry weights and growth indexes for plants grown in trade 1-gallon containers with a 2:1:1 (pine bark: Canadian peat: sand by volume) substrate and irrigated for 20 weeks with different types of irrigation water. Plant dry weight and final growth index data were recorded in December 2004 and initial growth index determined in July 2004.

Plant selection	**Irrigation type**	**Shoot dry wt. (g) ± std.**	**Root dry wt. (g) ± std.**	**Initial GI***	**Final GI***	**GI** change ± std.**
Plumbago	Municipal tap	18± 4.5	-	37	69	32± 8.8
	Reclaimed	19± 3.6	-	38	65	27± 5.3
	Recy/rec	21± 3.3	-	37	70	33± 8.9
Croton	Municipal tap	10± 3.1	-	34	57	23± 3.6
	Reclaimed	13± 3.4	-	36	59	23± 4.7
	Recy/rec	12± 4.5	-	35	57	24± 6.7
Maui Ixora	Municipal tap	17± 5.8	-	20	67	47± 13.5
	Reclaimed	19± 10.4	-	20	75	55± 13.9
	Recy/rec	17± 8.3	-	20	75	55± 19.0
Tw. D. Ixora	Municipal tap	20± 5.3	5.1 ± 1.2	22	46	24± 6.6
	Reclaimed	22± 4.7	5.8 ± 1.3	22	53	31± 4.0
	Recy/rec	22± 6.3	6.2 ± 2.5	21	51	30± 9.6
Hibiscus	Municipal tap	33± 4.7	-	42	80	38± 7.7
	Reclaimed	32± 5.2	-	40	81	41± 6.9
	Recy/rec	32± 4.3	-	42	85	43± 9.1
Loropetalum	Municipal tap	32± 6.2	-	46	90	44± 12.7
	Reclaimed	29± 4.9	-	41	91	50± 9.5
	Recy/rec	25± 6.2	-	43	80	37± 16.2

*GI= Ht + ((W1 + W2)/2) ** Final growth index – initial growth index = Growth index change
Municipal tap water N=8, Reclaimed and Recycled Reclaimed N=12

EC values were used to indicate a change in the nutrient concentration of solutions. Reclaimed water from the supply tank and the recycled reclaimed water in collection containers were tested every other week for EC. Monthly averaged EC values are listed in Table 9.

Table 9. Electrical conductivity values (dS/m) for reclaimed and recycled reclaimed water used for irrigation of Taiwan Dwarf Ixora (*Ixora coccinea*), Maui Ixora, Croton

‘Petra’ (*Codiaeum variegatum*) , Seminole Pink Hibiscus (*Hibiscus rosa-sinensis*), Loropetalum ‘Ruby’ (*Loropetalum chinensis*) and Imperial Blue Plumbago (*Plumbago ericulata*) grown in trade 1-gallon containers with a 2:1:1 (pine bark: Canadian peat: sand by volume) substrate. The substrate surface of each plant received 15 g Osmocote 18-6-12.

2004	**Reclaimed**	**Recycled Reclaim**
July	0.75	0.62
August	0.59	0.66
September	0.52	0.58
October	0.52	0.63
November	0.53	0.65
December	0.58	0.64
Average	0.58	0.63

EC values in the recycled reclaimed were slightly higher than the reclaimed water applied throughout the experiment, except the first month. However, this difference only reached a maximum of 0.13 and this is considered normal variation in the readings. Therefore, no significant change in the EC occurred by recycling the reclaimed water and recycled reclaimed water EC was within acceptable levels for irrigation water (Yeager, et al., 2007). So recycling should not have altered significantly the nutrient composition of the water; thus, the recycled reclaimed water should not harm the environment if discharged. In a production nursery recycling water, there are many infrastructure components such as acreage irrigated relative to acreage of runoff collection, irrigation delivery rate and acres irrigated at once, environmental factors, and many other factors that impact the volume of water available to be recycled. Thus, from this limited experimental approach it is impractical to surmise that recycling reclaimed water would never damage container plants, but from these data it seems plausible to recycle reclaimed water if needed. In addition, the EC of the container substrate (Table 10) was within acceptable ranges for plants in which fertilizer was applied in the irrigation water and controlled-release fertilizer applied to substrate (Yeager, et al. 2007).

Table 10. Substrate electrical conductivity (dS/m) for Twain Dwarf Ixora grown in trade 1-gallon containers with a 2:1:1 (pine bark: Canadian peat: sand by volume) substrate. The substrate surface of each plant received 15 g Osmocote 18-6-12.

Date	Week	Municipal tap N=2	Reclaimed N=3	Recy/reclaimed N=3
07/01/2004	1	0.76	0.89	0.82
07/15/2004	3	0.45	0.58	0.62
07/27/2004	5	0.38	0.73	0.76
08/10/2004	7	0.48	0.63	0.65
08/24/2004	9	0.42	0.47	0.41
09/08/2004	11	0.64	0.75	0.53
09/21/2004	13	0.64	0.78	0.79
10/05/2004	15	0.46	0.80	0.57
10/19/2004	17	0.38	0.80	0.80
11/02/2004	19	0.57	0.83	0.85
11/09/2004	21	0.69	0.45	0.49
11/23/2004	23	0.54	0.60	0.47
12/09/2004	25	0.38	0.42	0.52
Average		0.52	0.67	0.64

An analysis of the reclaimed water available for irrigation is important regardless if recycling or not. The reclaimed water for this experiment was sampled and an analysis conducted about every other week when reclaimed water was obtained from the wastewater treatment facility. Three reclaimed water samples were collected each time a new supply of municipal reclaimed water was obtained (Table 11). Samples were analyzed by standard procedures at the Analytical Research Laboratory, University of Florida Gainesville.

Table 11. Average values for analyses of reclaimed water from Kanapha Wastewater Treatment Facility (N=3).

Date	EC dS/m	pH	NO3-N mg/l	NH4-N mg/l	TP mg/l	OrthoP mg/l	K mg/l	Ca mg/l	Mg mg/l	Na mg/l	Cl mg/l
06/22/04	0.45	7.9	1.52	0.01	2.23	1.45	11.73	33.07	19.59	58.73	73.17
07/16/04	0.49	8.1	0.29	0.05	0.23	0.23	10.81	41.57	13.45	69.00	95.05
08/03/04	0.72	7.7	1.99	0.02	1.88	1.59	12.11	36.49	19.85	113.20	187.30
08/19/04	0.53	8.0	2.29	0.07	3.17	1.21	26.42	34.02	17.39	62.03	70.72
08/31/04	0.54	9.0	1.04	0.04	1.07	0.81	12.86	36.07	17.15	58.53	71.85
09/14/04	0.45	8.9	0.68	0.03	0.44	0.55	09.18	40.67	12.90	41.38	55.90
09/23/04	0.50	8.7	1.68	0.03	0.62	0.77	10.64	38.78	14.91	50.30	66.45
10/07/04	0.52	8.1	4.28	0.11	0.94	1.02	11.15	42.61	14.51	50.40	68.05
10/08/04	0.62	7.9	3.72	0.42	1.37	5.84	13.53	45.96	16.17	56.50	N/A
10/22/04	0.58	8.0	9.19	0.45	1.36	1.10	12.49	44.67	17.98	206.03	N/A
11/03/04	0.56	7.9	3.73	0.36	0.98	0.80	12.12	38.41	17.09	52.93	N/A
11/12/04	0.58	8.0	2.88	0.55	0.70	0.57	16.12	39.47	17.55	53.20	N/A
11/22/04	0.59	7.9	2.71	0.90	1.33	1.08	12.36	41.04	19.54	54.37	N/A

Date	Mn mg/l	Cu mg/l	Zn mg/l	Fe mg/l	Al mg/l	B mg/l	Ba mg/l	Cd mg/l	Mo mg/l	Ni mg/l	Pb mg/l	Si mg/l
06/22/04	0	0	0.04	0	0.07	0.47	0	0	0.03	0	0.02	14.36
07/16/04	0	0	0.03	0	0.10	0.80	0	0	0.03	0	0.02	9.69
08/03/04	0	0	0.03	0	0.11	0.49	0	0	0.03	0	0.02	13.99
08/19/04	0.03	0	0.03	0	0	0.39	0	0	0	0	0.02	13.24
08/31/04	0.03	0	0.03	0	0	0.44	0	0	0	0	0.01	12.94
09/14/04	0.03	0	0.02	0	0	0.32	0	0	0	0	0.01	9.50
09/2304	0.03	0	0.02	0	0	0.35	0	0	0	0	0.01	10.85
10/07/04	0.03	0.01	0.04	0	0	0.39	0	0	0	0	0.01	10.78
10/08/04	0.03	0.01	0.00	0	0	0.78	0	0	0	0.04	0.01	10.59
10/22/04	0.08	0.02	0.00	0	0	0.48	0	0	0	0.01	0.00	11.26
11/03/04	0.08	0.01	0.00	0	0	0.46	0	0	0	0.01	0.00	12.32
11/12/04	0.08	0.02	0.00	0	0	0.48	0	0	0	0.01	0.00	12.95
11/22/04	0.08	0.02	0.00	0	0	0.53	0	0	0	0.01	0.00	13.50

Recycled Reclaim Conclusions Year 2 Objective 1

Reclaimed water or recycled reclaimed water resulted in plants of similar size after 20 weeks to plants that were irrigated with municipal tap water even though the visual appearance varied with water source. Taiwan Dwarf Ixora (*Ixora coccinea*) and Seminole Pink Hibiscus (*Hibiscus rosa-sinensis*) visual ratings were similar regardless of irrigation water type while Loropetalum `Ruby' (*Loropetalum chinensis*) and Imperial Blue Plumbago (*Plumbago ericulata*) irrigated with municipal tap water were rated superior to plants irrigated with recycled reclaimed water. Croton 'Petra' (*Codiaeum variegatum*) watered with recycled reclaimed was rated better than plants receiving municipal tap water and the Maui Ixora plants irrigated with municipal tap or recycled reclaimed water were rated better than plants irrigated with reclaimed water. Rather these difference would impact plants sales is unknown.

Reclaimed water or recycled reclaimed water seems to be suitable for irrigation of container-grown nursery plants based on growth. A container plant producer should sample weekly the reclaimed water used for irrigation to ensure the EC is within desirable ranges. Also, elemental analyses should be conducted at least monthly or reports of analyses obtained from the supplier to ensure elemental constitutes of the reclaimed water are not excessive.

One of the treatments in this experiment was recycled reclaimed water, facilitated by capturing and reapplying (recycling) the runoff from irrigation with reclaimed water. This experiment verified that recycling was a viable option; however, the survey revealed that most reclaimed water users were not recycling probably because of lack of costly infrastructure within the nursery. Recycling was done by one survey respondent that only recycled 30% of the reclaimed water applied.

Controlled-Release Fertilizer Without Potassium Work Performed Year 2 Obj. 2

A significant finding from the surveys was that 71 % of respondents had not modified the fertilization program in response to reclaimed water use even though nutrients commonly found in fertilizers are present in the reclaimed water. So the focus of subsequent experiments was to modify or determine the fertilization program to use with reclaimed water. For example, one respondent indicated they had reduced the amount of nitrogen applied when reclaimed water was used. Modifying the fertilization program is something all reclaimed water users could do without changing the nursery infrastructure, once it was identified through research the best options for modifying the fertilization program. All survey respondents noted using controlled-release fertilizers. From reclaimed water analyses in 2004, it was evident that calcium concentrations in the reclaimed water surpassed the 20-40 ppm desirable range for the container substrate, while potassium and magnesium in the reclaimed water were generally within the desirable range of concentrations (10-20 and 15-20 ppm, respectively) for the substrate (Yeager et al., 2007). Well water in Florida often contains ample calcium and magnesium for nursery plants, so the subsequent experiment focused on reclaimed water as a source of potassium for nursery plants.

In August 2005, small plants of Taiwan Dwarf Ixora (*Ixora coccinea*), Azalea (*Rhododendron japonica 'G. G. Gerbing'*), Loropetalum 'Plum' (*Loropetalum chinensis*), Poinsettia (*Euphorbia pulcherrima*) 'Prestige', and Chrysanthemum (*Dendranthema x morifolium* 'Covington' and 'Beth')were potted in trade 1-gallon containers with a 2:1:1 (Pine bark: Canadian peat: sand substrate by volume) common nursery substrate amended with 7 pounds per cubic yard dolomitic limestone and 3 pounds per cubic yard Perk micronutrients.

Four replicate plants of each species or cultivar were placed on one of eight 4 x 6 foot plastic outdoor platforms designed to catch irrigation water. Each platform was lined with standard black polypropylene with 0.75-inch polyethylene tube connected to each of the platforms for drainage. Each plant was randomly placed on four platforms and received 5g 40-0-0, 2g 0-40-0, and 3g 0-0-43 (Meister Fertilizer) applied to the container substrate surface. Each plant on the four other platforms received the same surface-applied fertilizer without the potassium. Platforms were positioned randomly. Trade one-gallon dwarf yaupon holly plants were used as border plants around each platform. Plants were covered with 30% light exclusion shade resulting in 750-800 micromoles m^{-2} sec^{-1} (May) at plant canopy.

Plants were watered as needed with municipal reclaimed water (Part III) from Gainesville Regional Utilities Kanapaha Wastewater Treatment Facility. Reclaimed water was pumped from a storage container and applied overhead to plants by personnel with Dramm hose breaker nozzle that was attached to 0.75-inch hose.

Data collected included the following.

- Visual observations
- Plant growth indexes and dry weights
- Substrate electrical conductivity (salt) of one container plant species per block
- Reclaimed water analyses
- Photos

Controlled-Release Fertilizer Without Potassium Results Summary Year 2 Obj. 2

None of the plants exhibited leaf toxicity or growth stunting from use of reclaimed water when fertilized with a rate of N-P-K common for producing container-grown plants. Reclaimed water did not provide adequate potassium for mums, poinsettias and loropetalum grown without potassium fertilizer. Potassium deficiency symptoms of mums and poinsettia were exhibited as leaf marginal necrosis while loropetalum had chlorotic interveinal newer leaves (Table 12).

Table 12. Visual observations for Taiwan Dwarf Ixora (*Ixora coccinea*), Azalea (*Rhododendron japonica 'G. G. Gerbing'*), Loropetalum 'Plum' (*Loropetalum chinensis*), Poinsettia (*Euphorbia pulcherrima*) 'Prestige', and Chrysanthemum (*Dendranthema x morifolium* 'Covington' and 'Beth') potted August 2005 in trade 1-gallon containers with a 2:1:1 (pine bark: Canadian peat: sand by volume) substrate and irrigated with municipal reclaimed water.

Plant	Time after potting	N-P-K Fertilizer	N-P-0 Fertilizer
Azalea	3 weeks	**1**	**1**
Rhododendron japonica	9 weeks	**1**	**1**
	16 weeks	**1**	**1**
Chrysanthemum 'Covington'	2 weeks	**1**	**1**
	7 weeks	**2**	**3**
	14 weeks	**3**	**4**
Chrysanthemum 'Beth'	2 weeks	**1**	**1**
	7 weeks	**1**	**3**
	14 weeks	**2**	**4**
Pointsettia 'Prestige'	3 weeks	**1**	**1**
	9weeks	**1**	**1**
	15 weeks	**1**	**3**
Ixora Taiwan Dwarf	4 weeks	**2**	**2**
	19 weeks	**2**	**2**
	38 weeks	**2**	**2**
Loropetalum 'Plum'	4 weeks	**1**	**1**
	19 weeks	**1**	**1**
	38 weeks	**2**	**3**

1= best quality plants with no toxicity or growth damage
2 = average plants with aberrances at acceptable level for nursery standards
3 = below averages plant with aberrances at unacceptable level for nursery standards
4 = plant with over 85-90% leaf damage or growth stunting

The difference between initial and final growth index was used to evaluate response to fertilization in combination with municipal reclaimed water. Growth indexes were not different regardless of whether plants were fertilized with or without potassium (Table 13).

Table 13. Growth indexes for plants potted in August 2005 and grown in trade 1-gallon containers with a 2:1:1 (pine bark: Canadian peat: sand by volume) substrate and irrigated with municipal reclaimed water.

Plant selection	Fertilizer	Date GI*	Date GI*	Date GI*	Date GI*	Date GI*	GI** Change ± std.
		8/22/05		**11/04/05**	**2/15/06**	**6/7/06**	
Tw. D. Ixora	N-P-K	41		53	52	56	15± 3.6
	N-P-0	41		54	52	57	16± 4.1
		8/22/05		**11/04/05**	**2/15/06**		
Azalea	N-P-K	47		64	77		30± 6.9
	N-P-0	50		63	75		25± 6.9
		8/22/05		**11/04/05**	**2/15/06**	**6/7/06**	
Loropetalum	N-P-K	22		54	53	79	57± 4.9
	N-P-0	23		56	59	79	56± 5.7
		8/22/05	**10/26/05**	**11/04/05**			
Poinsettia	N-P-K	29	52	57			28± 3.7
	N-P-0	31	56	57			26± 5.8
		8/22/05		**11/04/05**			
'Covington' Mum	N-P-K	22		59			37± 3.9
	N-P-0	23		56			33± 3.3
		8/22/05		**11/04/05**			
'Beth' Mum	N-P-K	11		47			36± 3.5
	N-P-0	11		43			32± 3.3

*GI= Ht + ((W1 + W2)/2) ** Final growth index – initial growth index = Growth index change
N=16

By weight, plant sizes were similar regardless of fertilization except for 'Covington' mums. 'Covington' mums grown without potassium in the fertilizer and irrigated with reclaimed water had a smaller shoot dry mass (Table 14) than plants that received the same reclaimed irrigation water but with potassium in the fertilizer. Shoot tissue potassium percentages are indicative of the reduced dry weight; however, plant growth indexes were similar (Table 13) regardless of fertilizer treatment. A similar response for shoot tissue potassium percentages was observed for 'Beth' mums and poinsettia. The total milligrams of potassium in the tissue were less for plants fertilized with N-P-0 that N-P-K (Table 14).

Even though the shoot dry weights for loropetalum were not different considering the standard deviation of the data, it might be worthy to note that loropetalum shoot dry weights tended to decline when fertilized without potassium and irrigated with reclaimed water. These plants exhibited some interveinal chlorosis on 80-90% of newer leaves. Seven loropetalum plants fertilized with N-P-K exhibited minor chlorosis on newer leaves and leaves appeared larger than for plants without potassium fertilizer. This aberrance might be indicative of the fact that there has been some concern by producers in Hillsborough County that loropetalum may be sensitive to reclaimed water. Thus, this plant was the subject of additional investigation.

Table 14. Dry weights and shoot tissue potassium percentages for plants potted in August 2005 and grown in trade 1-gallon containers with a 2:1:1 (pine bark: Canadian peat: sand by volume) substrate and irrigated with municipal reclaimed water.

Plant selection	Fertilizer	Harvest Date	Shoot dry wt. (g) ± std.	Shoot tissue K (%)	Shoot tissue K (mg)±std.
Tw. D. Ixora	N-P-K	June 2006	36± 7.2		
	N-P-0		40± 6.3		
Azalea	N-P-K	Feb. 2006	37± 3.7		
	N-P-0		40± 4.6		
Loropetalum	N-P-K	June 2006	37± 5.4		
	N-P-0		29± 4.4		
Poinsettia	N-P-K	Dec. 2005	16± 2.3	2.07	323± 31
	N-P-0		15± 2.7	0.75	109± 21
'Covington' Mum	N-P-K	Nov. 2005	28± 4.4	1.21	330± 73
	N-P-0		17± 2.5	0.29	50± 26
'Beth' Mum	N-P-K	Nov. 2005	7.0± 1.5	2.78	193± 38
	N-P-0		4.8± 1.3	0.81	38± 11
			N=16	N=16	N=16

Substrate EC and potassium levels (Table 15) were generally less for the ixora fertilized without potassium and irrigated with reclaimed water (N-P-0). Additionally, all but one substrate potassium value was less than the 30-50 mg/liter concentration acceptable for container substrates in which fertilizer was applied in the irrigation water and controlled-release fertilizer applied to substrate (Yeager, et al. 2007). The substrate EC levels were adequate for plants fertilized with controlled-release fertilizer except when lower than 0.5 d/S/m (Yeager, et al. 2007).

Table 15. Substrate electrical conductivity and potassium for Twain Dwarf Ixora grown in trade 1-gallon containers with a 2:1:1 (pine bark: Canadian peat: sand by volume) substrate.

Fert		K	EC
N-P-K		mg/liter	dS/m
8/29/05		30.50	0.80
9/26/05		18.84	0.84
10/26/05		17.96	0.71
11/21/05		43.42	1.04
12/19/05		53.23	0.14
1/19/06		41.90	0.67
2/14/06		33.63	0.40
3/14/06		33.26	0.59
4/11/06		13.48	0.43
5/16/06		13.25	0.74

Fert		K	EC
N-P-0		mg/liter	dS/m
8/29/05		25.86	0.75
9/26/05		16.18	0.84
10/26/05		5.35	0.68
11/21/05		22.48	0.94
12/19/05		37.87	0.11
1/19/06		6.81	0.51
2/14/06		4.77	0.33
3/14/06		1.46	0.50
4/11/06		0.10	0.36
5/16/06		3.05	0.68

An analysis of the reclaimed water available for irrigation is important regardless of fertilization program. The reclaimed water for this evaluation was sampled and an analysis conducted about every other week when reclaimed water was obtained from the wastewater treatment facility. Three reclaimed water samples were collected each time a new supply of reclaimed was obtained (Table 16). Samples were analyzed by standard methods at the Analytical Research Laboratory, University of Florida Gainesville.

Table 16. Average values for analyses of municipal reclaimed water from Kanapha Wastewater Treatment Facility (N=3).

Date	EC dS/m	pH	NO_3-N mg/l	NH_4-N mg/l	TP mg/l	OrthoP mg/l	K mg/l	Ca Mg/l	Mg mg/l	Na mg/l	Cl mg/l
08/19/05	0.61	8.02	3.72	0.12	1.23	1.077	13.52	49.01	18.35	53.80	80.80
09/02/05	0.63	7.93	3.60	0.35	2.25	2.001	13.90	41.92	17.94	52.37	78.68
09/14/05	0.65	7.94	3.37	0.12	2.10	1.765	14.36	40.35	19.09	57.50	89.90
09/19/05	0.64	7.97	3.79	0.11	2.92	2.453	14.58	39.86	20.90	56.43	81.86
09/28/05	0.62	8.17	3.55	0.09	1.71	1.222	14.68	34.97	18.94	64.40	70.23
10/11/05	0.56	7.87	1.63	0.10	1.09	0.844	13.45	35.48	17.77	60.27	63.04
10/19/05	0.50	7.77	2.93	0.14	1.51	0.706	12.19	34.67	17.23	53.53	57.56
11/04/05	0.61	7.70	3.14	0.14	2.08	1.656	15.33	35.40	19.85	61.40	68.64
11/11/05	0.62	7.83	3.59	0.15	2.94	2.270	15.71	40.60	20.79	61.30	67.64
11/23/05	0.65	7.90	3.79	0.11	1.15	0.885	14.58	42.42	20.04	63.57	75.95
12/09/05	0.66	7.90	4.63	0.17	1.26	1.162	35.92	47.92	22.97	68.23	87.80
12/20/05	0.58	7.83	3.29	0.15	1.18	1.673	37.36	46.66	19.47	50.66	83.53
01/07/06	0.49	7.87	2.50	0.14	1.37	1.287	22.66	38.31	15.81	42.55	63.64
01/12/06	0.56	7.50	2.54	0.18	1.69	1.512	36.73	35.37	18.62	55.68	81.25
01/31/06	0.60	8.03	1.83	0.10	0.49	0.583	10.37	55.97	18.12	42.39	64.39
02/08/06	0.50	7.97	1.63	0.13	0.79	0.844	10.20	39.09	15.62	43.80	50.72
02/24/06	0.58	8.30	0.76	0.16	0.17	0.322	11.75	43.94	18.30	46.00	67.38
03/15/06	0.58	7.93	1.57	0.10	0.42	0.508	11.92	42.49	18.37	49.74	71.55
03/30/06	0.62	8.03	1.75	0.13	1.01	1.012	14.46	45.58	20.77	52.47	75.21
04/10/06	0.62	7.90	2.25	0.10	0.22	0.366	13.35	43.26	20.09	56.40	74.83
04/25/06	0.63	7.73	0.75	0.11	0.41	0.492	15.05	43.56	21.49	54.59	80.04
05/05/06	0.59	7.60	0.98	0.21	1.07	1.059	14.38	36.36	20.11	59.77	78.59

Date	Mn mg/l	Cu Mg/l	Zn mg/l	Fe mg/l	Al mg/l	B mg/l	Ba mg/l	Cd Mg/l	Mo mg/l	Ni mg/l	Pb mg/l	Si mg/l
08/19/05	0.11	0.02	0.00	0.00	0.00	0.41	0.00	0.00	0.00	0.00	0.00	12.86
09/02/05	0.11	0.01	0.00	0.00	0.00	0.56	0.00	0.00	0.00	0.00	0.00	12.58
09/14/05	0.10	0.00	0.00	0.00	0.00	0.49	0.00	0.00	0.00	0.00	0.00	12.75
09/19/05	0.10	0.00	0.00	0.00	0.00	0.52	0.00	0.00	0.00	0.00	0.00	14.16
09/28/05	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.00	14.90
10/11/05	0.00	0.00	0.00	0.00	0.00	0.25	0.00	0.00	0.00	0.00	0.00	14.08
10/19/05	0.00	0.00	0.00	0.00	0.00	0.21	0.00	0.00	0.00	0.00	0.00	14.65
11/04/05	0.00	0.00	0.00	0.00	0.00	0.21	0.00	0.00	0.00	0.00	0.00	14.84
11/11/05	0.00	0.00	0.00	0.00	0.00	0.24	0.00	0.00	0.00	0.00	0.00	15.15
11/23/05	0.00	0.00	0.00	0.00	1.51	0.25	0.00	0.00	0.00	0.00	0.00	14.27
12/09/05	0.00	0.00	0.00	0.00	2.02	0.22	0.00	0.00	0.00	0.00	0.00	13.44
12/20/05	0.00	0.00	0.00	0.00	2.00	0.19	0.00	0.00	0.00	0.00	0.00	11.98
01/07/06	0.00	0.00	0.00	0.00	2.00	0.17	0.00	0.00	0.00	0.00	0.00	12.47
01/12/06	0.00	0.00	0.00	0.00	2.01	0.20	0.00	0.00	0.00	0.00	0.00	13.56
01/31/06	0.00	0.02	0.00	0.00	2.19	0.17	0.00	0.00	0.00	0.00	0.00	12.70
02/08/06	0.00	0.02	0.00	0.00	2.19	0.13	0.00	0.00	0.00	0.00	0.00	11.57
02/24/06	0.00	0.02	0.00	0.00	2.18	0.15	0.00	0.00	0.00	0.00	0.00	12.68
03/15/06	0.00	0.02	0.00	0.00	2.18	0.16	0.00	0.00	0.00	0.00	0.00	12.66
03/30/06	0.00	0.02	0.00	0.00	2.18	0.16	0.00	0.00	0.00	0.00	0.00	12.65
04/10/06	0.00	0.02	0.00	0.00	2.18	0.19	0.00	0.00	0.00	0.00	0.00	11.95
04/25/06	0.00	0.02	0.00	0.00	2.18	0.22	0.00	0.00	0.00	0.00	0.00	12.58
05/05/06	0.00	0.02	0.00	0.00	2.18	0.19	0.00	0.00	0.00	0.00	0.00	14.24

Controlled-Release Fertilizer Without Potassium Conclusions Year 2 Objective 2

Taiwan Dwarf Ixora (*Ixora coccinea*), Azalea (*Rhododendron japonica 'G. G. Gerbing'*), Loropetalum 'Plum' (*Loropetalum chinensis*), Poinsettia (*Euphorbia pulcherrima*) 'Prestige', and Chrysanthemum (*Dendranthema x morifolium* 'Covington' and 'Beth') that were potted in trade 1-gallon containers with a 2:1:1 (Pine bark: Canadian peat: sand substrate by volume) common nursery substrate and grown for one production season with reclaimed water irrigation had similar growth indexes regardless if fertilized with N-P-K or N-P-0. However, 'Covington' and 'Beth' mums, and poinsettia 'Prestige' fertilized with N-P-0 exhibited necrotic leaves because of potassium deficiency that would impact sales of these plants. Plant dry weights for 'Covington' mums were less for plants fertilized with N-P-0 than N-P-K. Loropetalum new leaves exhibited interveinal chlorosis on plants without potassium fertilizer. Reclaimed water seems to be suitable for irrigation of these plants provided a controlled release fertilizer supplying N-P-K is used.

Azalea and ixora plants grown without potassium fertilization (N-P-0) were similar size to plants fertilized with potassium. Thus, it seems that potassium in the reclaimed water was adequate for these plants so there is the potential for nursery operators to minimize potassium fertilizer applications for some crops and possibly reduce potassium loading on the environment. However, elemental analyses of the reclaimed water should be conducted at least monthly and EC determined weekly or reports of analyses obtained from the supplier to ensure elemental constitutes of the reclaimed water are not excessive.

Controlled-Release Fertilizer Rate Reduction Work Performed Year 3

It was not evident from the surveys that certain plants had to be irrigated with non-reclaimed water. So for the third experiment (2006), the plants evaluated were either grown by survey respondents, suggested by industry personnel, or previous experiments indicated possible sensitivity to reclaimed water.

A significant finding from the surveys was that 71 % of respondents had not modified the fertilization program in response to reclaimed water use even though nutrients commonly found in fertilizers are present in the reclaimed water. So the focus of this experiment was on modifying or determining the fertilization program to use with reclaimed water. For example, one respondent indicated they had reduced the amount of nitrogen applied when reclaimed water was used. Modifying the fertilization program is something <u>all</u> reclaimed water users could do without changing the nursery infrastructure, once it is identified through research the best options for modifying the fertilization program. All survey respondents noted using controlled-release fertilizers.

As indicated in the survey, another consideration regarding reclaimed water use is to reduce the amount of fertilizer applied. From the reclaimed water analyses of the nurseries surveyed (Table 6), it is evident that nitrate nitrogen and phosphorus concentrations in municipal reclaimed water are less than desirable (Yeager et al. 2007), but might supply a portion of the nutrition. So experimentation in 2006 focused on reducing the controlled-release fertilizer (N-P-K) applied when using reclaimed water. A reduction in N and P applied would be particularly beneficial in environmentally sensitive locations.

In May 2006, small plants of Loropetalum 'Plum' and 'Ruby' (*Loropetalum chinensis*) and 'Helleri'holly (*Ilex crenata*) were potted in trade 1-gallon containers with a 2:1:1 (Pine bark: Canadian peat: sand substrate by volume) common nursery substrate amended with 7 pounds per cubic yard dolomitic limestone and 1.5 pounds per cubic yard Micromax micronutrients.

Eight replicate plants of each species or cultivar were placed on one of eight 4 x 6 foot plastic outdoor platforms designed to catch irrigation water. Each platform was lined with standard black polypropylene with 0.75-inch polyethylene tube connected to each of the platforms for drainage. Four plants per species per platform received 5g of 40-0-0, 2g of 0-40-0, and 3g of 0-0-43 (Meister Controlled-Release Fertilizer, 1.0N-0.4P_2O - 0.6K_2O) applied to the container substrate surface. Four additional plants per species per platform received the same surface-applied fertilizer but at one half the N-P-K rate. Platforms were positioned randomly. Trade one-gallon dwarf yaupon holly plants were used as border plants around each platform. Plants were covered with 30% light exclusion shade resulting in 750-800 micromoles m^{-2} sec^{-1} (May) at plant canopy.

Plants on four platforms were watered as needed with municipal tap water (Gainesville municipal) or municipal reclaimed water (Part III) from Gainesville Regional Utilities Kanapaha Wastewater Treatment Facility. Reclaimed water was pumped from a storage container and applied overhead to plants by personnel with Dramm hose breaker nozzle that was attached to 0.75-inch hose. Tap water was applied similarly.

Data collected included the following.

- Visual observations

- Plant growth indexes and dry weights
- Substrate electrical conductivity (salt) readings
- Reclaimed water analyses
- Photos

Controlled-Release Fertilizer Rate Reduction Results Summary Year 3

Visual ratings for *Loropetalum* 'Plum' and 'Ruby' and 'Helleri' holly 9 months after fertilizing tended to be lower for plants that received reclaimed water or tap water when the 0.5N-0.2P_2O-0.3K_2O fertilizer was applied compared to plants that received tap water and the 1.0N-0.4P_2O-0.6K_2O fertilizer (Table 17). 'Plum' and 'Helleri' plant ratings were similar regardless of water source for the 1.0N-0.4P_2O-0.6K_2O fertilizer. Visual rating for 'Ruby' decreased for plants that received reclaimed water and the 1.0N-0.4P_2O-0.6K_2O fertilizer although most plants were salable.

Table 17. Visual ratings for *Loropetalum* 'Plum' and 'Ruby' (*Loropetalum chinensis*) and 'Helleri' holly (*Ilex crenata*) potted May 2006 in trade 1-gallon containers with a 2:1:1 (pine bark: Canadian peat: sand substrate by volume) substrate fertilized with 5g of 40-0-0, 2g of 0-40-0, and 3g of 0-0-43 (Meister Fertilizer) applied in July to the container substrate surface or one half this amount of fertilizer applied and plants watered with municipal tap water or municipal reclaimed water (N=16).

Visual Ratings					
Plant	**Time after fertilization**	**1.0N-0.4P_2O-0.6K_2O Fertilizer**		**0.5N-0.2P_2O-0.3K_2O Fertilizer**	
		Tap Water	Reclaimed	Tap Water	Reclaimed
Loropetalum 'Plum'	0 months	2.0	2.0	2.0	2.0
	5 months	1.2	1.1	2.1	2.1
	9 months	1.4	1.6	3.0	3.2
Loropetalum 'Ruby'	0 months	2.5	2.5	2.5	2.5
	5 months	1.1	2.3	2.3	2.4
	9 months	1.4	2.6	2.9	3.6
'Helleri' holly	0 months	1.0	1.0	1.0	1.0
	5 months	1.3	1.2	1.9	1.8
	9 months	2.0	2.0	2.7	2.9
1 = large plants with normal foliage 2 = smaller plants with minor nutritional or toxicity damage 3 = smallest plants with moderate to major nutritional or toxicity damage 4 = very poor plant not up to nursery standards for resale					

Growth indexes were not different whether plants were irrigated with municipal reclaimed or municipal tap water and fertilized with either1.0N-0.4P_2O -0.6K_2O or 0.5N-0.2P_2O-0.3K_2O (Table 18). Growth indexes were not different due to fertilization.

Table 18. Growth indexes (±standard deviations) for plants potted in May 2006 and grown in trade 1-gallon containers with a 2:1:1 (pine bark: Canadian peat: sand by volume) substrate fertilized with 5g of 40-0-0, 2g of 0-40-0, and 3g of 0-0-43 (Meister Fertilizer) applied in July to the container substrate surface or one half this amount of fertilizer applied and plants watered with municipal tap water or municipal reclaimed water.

Plant Growth Indexes					
Plant	**Time after fertilizing**	**1.0N-0.4P_2O-0.6K_2O Fertilizer**		**0.5N-0.2P_2O-0.3K_2O Fertilizer**	
		Tap Water	Reclaimed	Tap Water	Reclaimed
Loropetalum 'Plum'	0 months	45± 8	45± 6	44± 7	44± 9
	5 months	82± 12	81± 10	72± 10	68± 20
	9 months	84± 12	84± 8	75± 8	75± 12
Loropetalum 'Ruby'	0 months	53± 11	58± 10	56± 6	54± 11
	5 months	88± 14	85± 12	77± 11	80± 10
	9 months	98± 12	101± 12	90± 10	95± 11
'Helleri' holly	0 months	39± 6	38± 6	39± 5	40± 5
	5 months	51± 6	49± 6	49± 7	50± 4
	9 months	55± 5	53± 5	51± 8	54± 6

GI= Ht + ((W1 + W2)/2) N=16

Shoot dry weights for 'Plum', and 'Helleri' shoot and root dry weights, were different due to fertilization (averaged over irrigation) with means of 40g and 28g for 'Plum' shoots and 36g and 29g for 'Helleri' shoots and 30g and 36g for 'Helleri' roots when fertilized with1.0N-0.4P_2O-0.6K_2O or 0.5N-0.2P_2O-0.3K_2O, respectively (Table 19). Plum shoot dry weights were different for irrigation water (averaged over fertilizer) with a tap water mean of 37g and a reclaimed water mean of 31g. The irrigation water response (tap or reclaimed) was not different for 'Helleri' shoot or root dry weights. 'Ruby' shoots dry weights exhibited an interaction between irrigation water and fertilizer. The greatest growth was achieved with municipal tap water and the 1.0N-0.4P_2O-0.6K_2O fertilizer. 'Ruby', 'Plum', and 'Helleri' visual ratings 9 months after fertilization corresponded to the shoot dry weights.

Table 19. Dry weights for plants potted in May 2006 and grown in trade 1-gallon containers with a 2:1:1 (pine bark: Canadian peat: sand by volume) substrate fertilized with 5g of 40-0-0, 2g of 0-40-0, and 3g of 0-0-43 (Meister Fertilizer) applied in July to the container substrate surface or one half this amount of fertilizer applied and plants watered with municipal tap water or municipal reclaimed water (N=16).

Plant Dry Weight					
Plant		**$1.0N-0.4P_2O-0.6K_2O$ Fertilizer**		**$0.5N-0.2P_2O-0.3K_2O$ Fertilizer**	
		Tap Water	Reclaimed	Tap Water	Reclaimed
Loropetalum 'Plum'	Shoot Weight	44	37	30	25
	Water = *				
	Fertilizer = *				
Loropetalum 'Ruby'	Shoot Weight	57	39	39	31
Water x Fertilizer LSD = 12					
'Helleri' holly	Shoot Weight	37	36	30	27
	Water = NS				
	Fertilizer = *				
N=4	Root Weight	29	30	40	33
	Water = NS				
	Fertilizer = *				

* = $P \leq 0.05$, NS = Non-significant, LSD = Least significant difference

Substrate EC levels 9 months after fertilization were less for 'Helleri' holly fertilized with $0.5N-0.2P_2O-0.3K_2O$ compared to $1.0N-0.4P_2O-0.6K_2O$ when plants were irrigated with reclaimed water and were less for plants irrigated with municipal tap water than reclaimed water regardless of fertilization (Table 20). The substrate EC levels were adequate for plants fertilized with controlled-release fertilizer except when lower than 0.5 dS/m (Yeager, et al. 2007); however, plant dry weights were similar for each irrigation regime.

Table 20. Electrical conductivity (±standard deviations) for 'Helleri' holly potted in May 2006 and grown in trade 1-gallon containers in a 2:1:1 (pine bark: Canadian peat: sand by volume) substrate fertilized with 5g of 40-0-0, 2g of 0-40-0, and 3g of 0-0-43 (Meister Fertilizer) applied in July to the container substrate surface or one half this amount of fertilizer applied and plants watered with municipal tap water or municipal reclaimed water (N=4).

Fertilzer	**EC (dS/m)**		**Fertilizer**	**EC (dS/m)**	
1.0N-0.4P_2O-0.6K_2O	**Tap**	**Reclaimed**	**0.5N-0.2P_2O-0.3K_2O**	**Tap**	**Reclaimed**
0 months	**0.3**	**0.3**	0 months	**0.3**	**0.3**
5 months	**0.4**± 0.09	**0.7**± 0.09	5 months	**0.4**± 0.06	**0.7**± 0.07
9 months	**0.7**± 0.07	**1.1**± 0.10	9 months	**0.6**± 0.04	**0.8**± 0.05

An analysis of the reclaimed water available for irrigation is important regardless of fertilization program. The reclaimed water for this evaluation was sampled and an analysis conducted about every other week when reclaimed water was obtained from the wastewater treatment facility. Three reclaimed water samples were collected each time a new supply of reclaimed water was obtained (Table 21). Samples were analyzed by standard methods at the Analytical Research Laboratory, University of Florida Gainesville.

Table 21. Average values for analyses of municipal reclaimed water from Kanapha Wastewater Treatment Facility (N=3).

Date	**EC dS/m**	**pH**	**NO_3-N mg/l**	**NH_4-N mg/l**	**TP mg/l**	**OrthoP mg/l**	**K mg/l**	**Ca mg/l**	**Mg mg/l**	**Na mg/l**	**Cl mg/l**
5/5/06	0.59	7.60	0.98	0.21	1.07	1.059	14.38	36.36	20.11	59.77	78.59
5/16/06	0.64	8.10	1.91	0.25	3.82	3.265	18.42	40.23	23.21	67.33	84.51
5/25/06	0.66	7.77	3.11	0.31	7.45	6.365	20.29	40.57	24.47	65.70	82.54
5/30/06	0.67	8.30	1.19	0.20	5.49	4.672	18.54	46.45	25.01	67.53	81.43
6/7/06	0.67	8.00	4.28	0.13	5.07	4.362	18.25	48.41	25.09	66.17	79.80
6/27/06	0.70	8.63	3.01	0.12	1.42	1.343	16.23	56.33	24.86	66.37	82.43
7/13/06	0.66	7.40	3.51	0.12	5.92	5.147	18.02	39.59	23.22	64.90	87.73
9/26/06	0.66	8.10	1.83	0.13	2.68	2.399	18.33	41.54	23.36	53.83	0.00
10/24/06	0.64	7.77	4.03	0.13	1.53	1.562	14.56	39.34	21.27	47.28	0.00
11/21/06	0.57	7.90	2.73	0.12	1.07	1.190	10.34	37.87	22.59	37.04	0.00
12/21/06	0.66	8.10	1.02	0.12	2.85	2.645	16.29	39.55	23.08	50.47	0.00
2/2/07	0.62	7.73	2.73	0.10	2.91	2.755	16.12	35.35	20.51	47.08	0.00
2/27/07	0.65	7.63	2.60	0.12	1.49	1.482	15.47	43.66	22.38	48.90	0.00
3/14/07	0.64	7.63	5.06	0.15	5.93	4.764	16.71	41.73	22.23	52.30	80.04
4/7/07	0.63	8.07	1.85	0.15	1.51	1.683	14.13	41.01	22.25	49.47	74.34
5/9/07	0.56	8.03	1.81	0.17	2.00	2.897	12.72	38.05	19.40	43.29	63.42

Date	Mn mg/l	Cu mg/l	Zn mg/l	Fe mg/l	Al mg/l	B mg/l	Ba mg/l	Cd mg/l	Mo mg/l	Ni mg/l	Pb mg/l	Si mg/l
5/5/06	0.00	0.02	0.00	0.00	2.18	0.19	0.00	0.00	0.00	0.00	0.00	14.24
5/16/06	0.00	0.00	0.00	0.00	0.00	0.27	0.00	0.00	0.00	0.00	0.00	14.51
5/25/06	0.00	0.00	0.00	0.00	0.00	0.23	0.00	0.00	0.00	0.00	0.00	14.27
5/30/06	0.00	0.00	0.00	0.00	0.00	0.27	0.00	0.00	0.00	0.00	0.00	13.78
6/7/06	0.00	0.00	0.00	0.00	0.00	0.23	0.00	0.00	0.00	0.00	0.00	14.24
6/27/06	0.00	0.00	0.00	0.00	0.00	0.24	0.00	0.00	0.00	0.00	0.00	14.03
7/13/06	0.00	0.00	0.00	0.00	0.00	0.22	0.00	0.00	0.00	0.00	0.00	14.01
9/26/06	0.00	0.01	0.00	0.00	0.79	0.28	0.00	0.00	0.00	0.00	0.00	14.55
10/24/06	0.00	0.00	0.00	0.00	0.70	0.27	0.00	0.00	0.00	0.00	0.00	14.15
11/21/06	0.00	0.00	0.00	0.00	0.70	0.18	0.00	0.00	0.00	0.00	0.00	14.29
12/21/06	0.00	0.00	0.00	0.00	0.70	0.25	0.00	0.00	0.00	0.00	0.00	14.85
2/2/07	0.00	0.00	0.00	0.00	0.71	0.22	0.00	0.00	0.00	0.00	0.00	13.47
2/27/07	0.00	0.00	0.00	0.00	0.70	0.26	0.00	0.00	0.00	0.00	0.00	13.39
3/14/07	0.00	0.03	0.07	0.01	0.00	0.29	0.04	0.00	0.00	0.00	0.02	13.45
4/7/07	0.00	0.02	0.05	0.00	0.00	0.27	0.03	0.00	0.00	0.00	0.01	14.09
5/9/07	0.00	0.03	0.08	0.00	0.00	0.24	0.03	0.00	0.00	0.00	0.01	14.48

Municipal tap water analyses are presented below in Table 22.

Table 22. Average values for analyses of municipal tap water (N=3).

Date	EC dS/m	pH	NO_3-N mg/l	NH_4-N mg/l	TP mg/l	OrthoP µg/l	K mg/l	Ca Mg/l	Mg mg/l	Na mg/l	Cl mg/l
12/06/05	0.4	7.6	0	0.1	0	2.4	1.3	42.4	24.1	13	31.8
3/20/07	0.7	8.0	0	0.1	0	6.4	2.9	37.2	23.5	0	28.8

Controlled-Release Fertilizer Rate Reduction Conclusions Year 3

Loropetalum ‘Plum’ and ‘Ruby’ (*Loropetalum chinensis*) and ‘Helleri’ holly (*Ilex crenata*) that were potted in trade 1-gallon containers with a 2:1:1 (Pine bark: Canadian peat: sand substrate by volume) common nursery substrate were fertilized with 5g of 40-0-0, 2g of 0-40-0, and 3g of 0-0-43 (Meister Fertilizer) or one half this amount of fertilizer and irrigated with municipal tap water or municipal reclaimed water. Growth indexes were similar 9 months after fertilization regardless if fertilized with1.0N-0.4P_2O -0.6K_2O or 0.5N-0.2P_2O -0.3K_2O, or irrigated with municipal tap or municipal reclaimed water.

Visual ratings for ‘Plum’ and ‘Ruby’ and ‘Helleri’ 9 months after fertilizing tended to be lower for plants receiving reclaimed water or tap water when the 0.5N-0.2P_2O -0.3K_2O fertilizer was applied compared to plants receiving tap water and the1.0N-0.4P_2O -0.6K_2O fertilizer. ‘Plum’ and ‘Helleri’ plant ratings were similar regardless of water source for each fertilizer. Visual rating for ‘Ruby’ decreased for plants receiving reclaimed water and the1.0N-0.4P_2O -0.6K_2O or the 0.5N-0.2P_2O -0.3K_2O fertilizer. Visual ratings 9 months after fertilization corresponded to the shoot dry weights.

Shoot dry weight data indicate the reclaimed water did not compensate for the reduced amount of fertilizer applied, and that reclaim water did not result in a growth reduction for ‘Helleri’. However, this was not the case for ‘Plum’ or ‘Ruby’. This might be indicative of the fact that there has been some concern by producers in Hillsborough County that loropetalum may be sensitive to reclaimed water. Elemental analyses of the reclaimed water should be conducted at least monthly and EC determined weekly or reports of analyses obtained from the supplier to ensure elemental constitutes of the reclaimed water are not excessive.

Overall Conclusions Years 1-3

Municipal reclaimed water was used for overhead sprinkler irrigation in seven nurseries producing container plants. Survey results from those nurseries indicated that many different types of plants were irrigated with reclaimed water and it was inconclusive that specific plants could not be irrigated with reclaimed water. From experimental evaluations, it was determined that irrigation with reclaimed water (Part III) resulted in comparable plants to those irrigated with recycled reclaimed or municipal tap water. Loropetalum ‘Plum’ and ‘Ruby’ seemed to be exceptions; however, a limited plant palette was investigated. The nitrogen, phosphorus, and potassium in the reclaimed water were an insufficient substitute for nutrients in controlled-release fertilizer for several of the plants evaluated. Elemental analyses of the reclaimed water should be conducted at least monthly and EC determined weekly or reports of analyses obtained from the supplier to ensure elemental constitutes of the reclaimed water are not excessive.

Literature cited

Application Rules for Reuse Projects – Florida Dept. of Environmental Protection http://www.dep.state.fl.us/water/reuse/apprules.htm

Likert, R. 1932. A technique for measurement of attitudes. Archives of Psychology. 140: 1- 55.

Marella, R. L. 2004. Water withdrawals, use, discharge, and trends in Florida, 2000. United States Geological Survey, SIR 2004-5151. In cooperation with Florida Department of Environmental Protection, Tallahassee, Florida.

Yeager, T. T. Bilderback, D. Fare, C. Gilliam, J. Lea-Cox, A. Niemiera, J. Ruter, K. Tilt, S. Warren, T. Whitwell, and R. Wright. 2007. Best management practices: Guide for producing nursery crops. 2nd Edition. Southern Nursery Association, Atlanta, Georgia.

This report contains information that has not been subjected to scientific peer review nor incorporated into recommendations. Mention of trade names does not constitute a recommendation or endorsement.