Landscape

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Effect of Mulch Type on Post-Transplant Root Growth on *Myrica cerifera*

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Index Words: Horhizotron™, Establishment, Landscape, Wax Myrtle, Shrub

Significance to Industry: Wax myrtle (*Myrica cerifera*) was transplanted with the lower half of the root ball in field soil (sandy loam) and the upper half in 100% pine bark, peat moss, cotton gin compost, or more field soil. Results suggest that when planting wax myrtle slightly above grade and mounding mulch around the top of the rootball, more post-transplant root growth occurs in cotton gin compost and peat compared to pine bark or soil. This practice can improve survival of transplanted container-grown plants in the landscape.

Nature of Work: The key to survival of transplanted container-grown plants is development of a root system into the surrounding soil. Until this occurs, a plant must rely on the water and nutrient supplies in the transplanted container substrate. This may be especially difficult for nursery-grown plants that have been heavily fertilized to encourage a large canopy that is attractive for purchase. Since newly planted landscapes often struggle with poor soils, competition for space with infrastructure, pollution, excessive heat, high foot traffic, and overall neglect, all of which may inhibit root growth, many plants do not survive (2). The need for more reliable planting techniques that encourage root growth in adverse conditions has prompted research into planting above grade. In this planting practice, the plant is planted with the upper portion of the root ball exposed, mulch is mounded up around this part of the root ball, and the surrounding soil covered in a shallow mulch application. These studies have proven successful both with trees (1) and woody shrubs (7).

Pine bark and peat are common container substrates in horticultural production and are often recommended as a source of organic matter for incorporation into the soil at planting (2). The above grade planting technique may also be effective since it simulates the upper organic layer found in natural environments. Plants grown with this natural organic layer present can have nearly double the root: shoot ratio of those grown in cultivated landscapes (4). Composted cotton gin trash has also been shown to be a good horticultural production substrate (3) and therefore may have potential for use in the landscape as a mulch. Finding the mulch type that encourages post-transplant root growth most effectively may improve survival of transplanted landscape species.

The objective of this study was to utilize the Horhizotron™ to determine the effect of mulch type on root growth of wax myrtle (*Myrica cerifera*) when grown with the lower half of the root ball in field soil and the upper half in mulches of 100% pine bark (PB), 100% peat (P), 100% cotton gin compost (CGC), or more field soil (unmulched). The Horhizotron provides a nondestructive method for measuring root growth over time and observing the development of roots from the same plant into different rhizosphere conditions (9).

On 1 March 2006, wax myrtle plants were removed from 11.3 L (3 gal) containers, and one plant was placed in each of five Horhizotrons on greenhouse benches at the Paterson Horticulture Greenhouse Complex, Auburn University, Auburn, AL [day/night temperatures of 79/70°F (26/21°C)]. Each Horhizotron had four quadrants made from two glass panes that extended away from the root ball and could be filled with a different substrate (treatment). Root balls of all plants were positioned in the center of each Horhizotron, and each of the Horhizotron's four quadrants was filled with field soil (Marvyn sandy loam) in the lower 10 cm (3.9 in). The upper 10 cm (3.9 in) of the quadrants in each Horhizotron were randomly filled with either: 1) PB, 2) P, 3) CGC (sifted through a 15mm screen for debris removal), or 4) more field soil. This study was a randomized complete block design with each Horhizotron representing an individual block and five blocks total. Horhizotrons were hand watered as needed, and pH and EC measurements were performed on six samples of each substrate on the first and last day of the study. Once per week, the horizontal root lengths (length measured parallel to the ground, (HRL) of the five longest roots visible along each glass pane (two panes per quadrant) were recorded. When all roots of one treatment had reached maximum length at the end of the quadrant [26 cm (10.2 in)], the experiment was terminated. Roots in each quadrant were cut from the original root ball, washed to remove substrate, dried for 48 hours at 66°C (150°F), and weighed. Data were analyzed using GLM procedures, regression analysis, and means separation using PDIFF at $P = 0.05$ (6).

Results and Discussion: Horizontal root length (HRL) increased quadratically over time in all mulches and soil (Figure 1). From the first measurement date, 21 days after planting (DAP), CGC and P had the longest roots, and this trend continued for every measurement following. With the exception of the first date when CGC and P were similar, CGC had significantly longer roots than the other treatments. P had significantly longer roots than field soil and PB on all measurement dates. Roots in CGC were first to reach the end of the quadrant 37 DAP, and roots in all other treatments first reached the end of quadrants 44 DAP. Though roots grew into the soil portion of each quadrant, in most quadrants the majority of roots, particularly in the first few weeks, were in the mulch layer (visual observation). Additionally, the fact that more root growth occurred in the CGC and P treatments than in 100% soil suggests that more root growth could be expected in organic matter than in soil. Results indicate that PB is not the best organic material to use when transplanting wax myrtle. Root dry weights were similar in all treatments, illustrating the importance of measuring root length over time to determine not only the rate of root growth over time but also the extent of root development laterally into the surrounding substrate or backfill. In solutions extracted from substrates, EC was highest in CGC (Table 1). This may explain why more root growth occurred in CGC since no fertilizer was added at planting. Root growth did not seem to be correlated with pH, however, since the pH of solutions extracted from CGC and PB were similar but yielded different HRL measurements. Also, CGC and P had different pH but had similar HRL. Although our results show that CGC and P had similar HRL throughout the study, we recommend CGC since P is a non-renewable resource. Additionally, CGC is readily available, in need of disposal, and may increase fertility (Table 1)(3). This experiment provides strong evidence that utilizing the above-grade planting practice with mulch will encourage root growth most effectively, yielding high transplant survival rates and attractive, low-maintenance landscapes.

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Figure 1. Effect of mulch type on horizontal root length (length measured parallel to the ground, HRL) of wax myrtle measured 21 to 44 days after planting (DAP). Plants were planted on March 1, 2006 in a greenhouse at Auburn University in Auburn, AL.

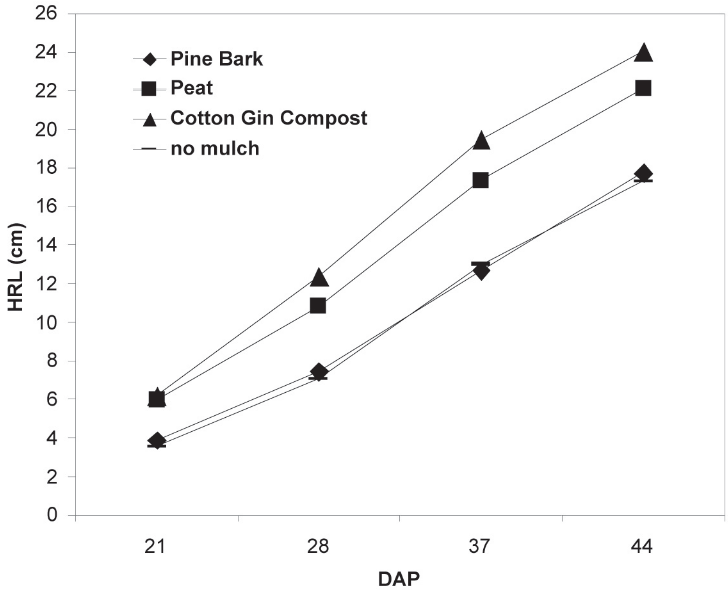

Table 1. Initial and final pH and EC of soil and substrate solutions[z].

	pH		EC (mmho/cm)	
	Initial	Final	Initial	Final
Pine Bark	6.4b[y]	6.3b	0.1b	0.2b
Peat	3.9d	3.9c	0.2b	0.2b
Cotton Gin Compost	5.8c	6.5b	2.7a	0.6a
Field Soil	7.1a	6.8a	0.1b	0.2b

[z]Solutions extracted using pour-through nutrient extraction procedure (6).

[y]Means separated by Fisher's Protected LSD at P = 0.05.

The Effect of Drought on Root Growth of Native Shrub Species

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Index Words: Horhizotron™, *Myrica cerifera*, Establishment, Landscape

Significance to the Industry: Understanding plant response to drought can provide insight into irrigation requirements and relative drought tolerance of landscape shrub species. Wax myrtle (*Myrica cerifera* L.) plants were grown such that root zones of each plant experienced four different soil moisture conditions, ranging from well-watered to unwatered. Although the least amount of root growth occurred in areas that received no irrigation, results suggest that roots of wax myrtle will continue to grow in drought conditions as long as some portion of the root ball is receiving relatively small amounts of moisture.

Nature of Work: Research into plant responses to water stress is becoming increasingly important, as most climate-change scenarios suggest an increase in aridity in many areas of the globe (2). On a global basis, drought, in addition to coincident high temperature and radiation, pose the most important environmental constraint to plant survival and to crop productivity (1). A better understanding of the effects of drought on plants is vital for improved management practices and breeding efforts in horticulture and for predicting the fate of vegetation under climate change (2).

Studies in the past have suggested that root growth decreases as soil water decreases (5). Of the factors affecting landscape establishment of container-grown ornamental plants, root growth following transplanting is one of the most important (4). Growth of roots into the surrounding landscape soil is critical for a plant to obtain the necessary elements needed for survival, most notably water and mineral nutrients. Time to initiation of new root growth is important in predicting or describing transplant success, since initiation of new root growth shortly after transplanting has been correlated with successful transplant establishment (5).

The objective of this study was to utilize the Horhizotron™ to evaluate root growth of wax myrtle (*Myrica cerifera* L.) when portions of the root system are exposed to different levels of soil moisture. The Horhizotron™ is a simple and inexpensive type of split root technique used for non-destructively evaluating root growth over time under a variety of rhizosphere conditions (6).

On 9 February 2006 (Day 1), five wax myrtle plants were removed from 11.3 L (3 gal) containers and placed in the center of five separate Horhizotrons (6). Horhizotrons were placed on greenhouse benches at the Patterson Horticulture Greenhouse Complex, Auburn University [day/night temperatures of 79/70°F (26/21°C)]. Each Horhizotron had four quadrants extending away from the root ball of each plant. Quadrants were filled with Profile™ (Profile Products, Buffalo

Grove, IL.), a calcined clay material, that had been amended with 9.48 kg/yd^3 (16 lbs/yd^3) 17N-5P_2O_5-11K_2O (Pursell Industries, Sylacauga, AL), 1.18 kg/m^3 (2 lbs/yd^3) dolomitic limestone, and 0.89 kg/m^3 (1.5 lbs/yd^3) Micromax™ (The Scotts Co., Marysville, OH). Profile's physical and chemical properties are similar to those of soil, and it is easily removed from roots at harvest. Treatments were four different irrigation frequencies randomly assigned to quadrants within each Horhizotron. Treatments included: substrate watered daily (~20% moisture), substrate rewatered once dried to 15% moisture, substrate rewatered once dried to 10% moisture, and substrate that remained unwatered throughout the study. Treatments were applied 8 March 2006 (Day 28). Substrate percent moisture (by volume) was measured daily using a Theta probe (Delta-T Devices Ltd., Cambridge, England). When watered, quadrants received 400 mL water. Daily, 400 mL water was also applied directly to the original container root ball. The experimental design was a randomized complete block design, with five blocks and one Horhizotron equaling one block. Weekly root growth measurements were taken by measuring the horizontal root length (measured parallel to ground) of the five longest roots visible along the glass panes forming each side of a quadrant (two sides per quadrant). At the end of the study roots that had grown into each quadrant were removed from the original root ball and substrate was gently rinsed from roots. Roots were dried for 48 hours at 150°F (66°C), and dry weights were recorded. Data were analyzed using GLM procedures and regression analysis, and means were separated using Least Significant Difference (P<0.05).

Results and Discussion: Horizontal root length (HRL) increased quadratically over time in all treatments (Fig. 1). Fifty-eight days after planting (DAP) was the first date significant differences were noticed for the driest treatment; on this day the HRL in the unwatered treatment was lower than the well watered substrate and substrate rewatered at 15% moisture. Seventy DAP, HRL in the driest treatment was significantly lower than that in all other treatments and followed this trend until the end of the experiment. Final HRL (79 DAP) was similar in the well watered substrate, the rewatered at 15% moisture, and the rewatered at 10% moisture. Since root growth in the well watered substrate, and that in substrates rewatered at 15% and 10% moisture did not differ, it could be suggested that a substrate or soil containing at least 10% moisture would not restrict root growth. Even though root length was less in the unwatered substrate, roots still managed to extend about 21cm (8.3 in) into that quadrant, suggesting that plants were allocating water from areas of higher moisture content to areas of lower moisture content. Less root growth in the unwatered substrate, agrees with the results of work by other researchers (3). Dry weight (Fig. 2) of roots in the unwatered substrate was significantly lower than that in the well watered substrate, similar to results herein for root length (Fig. 2). This experiment provides information that wax myrtle roots are drought tolerant, and root growth will persist, as long as some portion of the root ball is receiving some water.

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Figure 1. Effect of irrigation frequency on horizontal root length (measured parallel to ground, HRL) of wax myrtle grown from Feb 9-Apr 28 in Horhizotrons in a greenhouse. Treatments began 28 days after planting (DAP). Treatments included: substrate watered (400mL) daily (~20% moisture), substrate rewatered (400mL) once dried to 15%, substrate rewatered (400mL) once dried to10% moisture, and substrate that remained unwatered throughout the study.

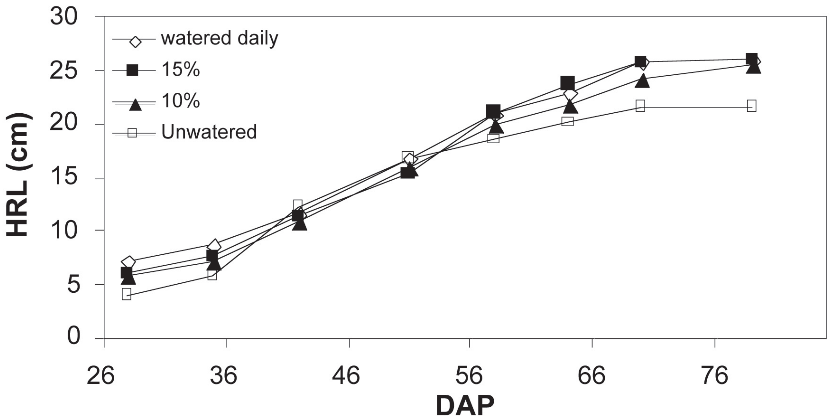
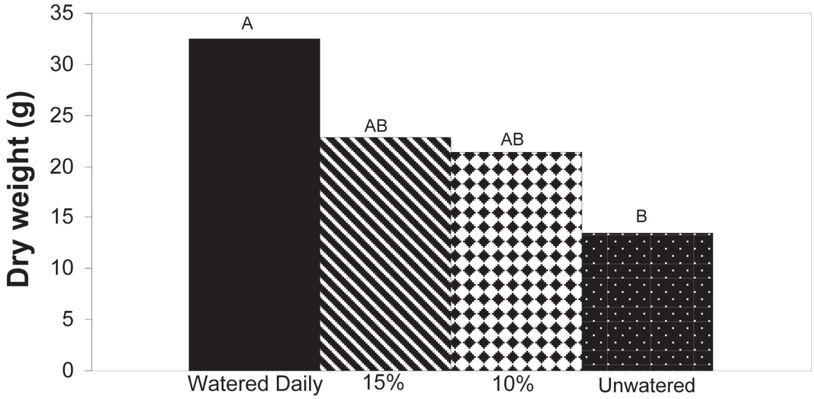


Figure 2. Effect of irrigation frequency on root dry weight of wax myrtle grown from Feb 9-Apr 28 in Horhizotrons in a greenhouse. Treatment began 28 days after planting (DAP). Treatments included: substrate watered (400mL) daily (~20% moisture), substrate rewatered (400mL) once dried to 15%, substrate rewatered (400mL) once dried to10% moisture, and substrate that remained unwatered throughout the study. Means separated using LSD (P < 0.05). Means followed by the same letter are not significantly different.



Effect of Planting Technique on Establishment of *Kalmia latifolia*

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Index Words: Landscape, Root Growth, Transplant, Mulch, Native

Significance to Industry: Increasing post-transplant root growth of container-grown shrubs can improve their chances of survival following transplanting into the landscape. In this research planting mountain laurel (*Kalmia latifolia* 'Olympic Wedding') such that the root ball was planted 7.6 cm (3 in) above grade and pine bark was mounded up around the exposed root ball resulted in substantially more post-transplant root growth than planting at grade. While amending the backfill with 50% (by volume) pine bark when planting at grade resulted in more post-transplant root growth than planting without amendments, this still did not produce as much root growth as the above-grade plantings.

Nature of Work: Mountain laurel is an attractive, evergreen shrub native to the eastern United States. In previous research conducted to improve transplant survival of this species, field grown mountain laurel had more shoot growth and higher survival when the soil was amended with peat or pine bark compared to when grown in unamended soil (2). Other research has indicated that mountain laurel may produce more post-transplant root growth when the backfill is amended with pine bark (6). Another technique that is sometimes suggested for improved landscape survival involves transplanting with the root ball above grade and applying mulch to the exposed root ball. Of the recent work that has investigated the benefits of this practice, much of the evaluation criteria was limited to above-ground performance (1, 3). Information regarding the effects of this planting practice on root growth are also needed. In its native habitat, mountain laurel roots tend to proliferate horizontally in the upper organic layer (pers. obs.). The potential benefit of planting mountain laurel above grade and mounding mulch up around the root ball has been suggested by results from studies done in Horhizotrons™ (5) in a greenhouse in which increased root growth occurred in treatments mimicking this practice (6). Therefore, the objective of this research was to compare the effect of three planting practices on root and shoot growth of mountain laurel transplanted into the landscape.

Plants of mountain laurel (*Kalmia latifolia* 'Olympic Wedding') were removed from 19 L (5 gal) containers in the fall of 2002 and planted into field plots at the Old Rotation Field Laboratory, Auburn University, Auburn, AL and the Urban Horticulture Center, Virginia Tech, Blacksburg, VA. Soil types at these locations were Marvyn sandy loam and Groseclose silt loam, respectively. Treatments and experimental design were the same in each location. Treatments were three different planting techniques: planting with top of root ball even with grade and planting hole backfilled with unamended soil (standard); planting with top of root ball at grade and planting hole backfilled with soil amended with 50% (by volume) composted pine bark (amended backfill); and planting with the top of the root ball 7.6 cm (3 in) above grade with composted pine bark mounded up around the exposed portion of the root ball, and planting hole backfilled with unamended soil (above grade). Regardless of planting technique 2.5 cm (1 in) pine bark mulch was applied to the soil surrounding each plant. In no situation was mulch mounded up around the plant stem. Experimental design was a randomized complete block design with five blocks. In the fall of 2005, plants were destructively harvested to determine root system diameter and either above ground growth index [(average canopy width + canopy height)/2] (Auburn) or shoot dry weight (Blacksburg). The uppermost layer of mulch was removed to indicate the horizontal spread of roots into the soil and/or mulch. Based on this observation, plants were dug, and the diameter of the root system was measured in two directions and then averaged. Data were analyzed using general linear models procedures and means were separated using LSD ($P<0.05$) (4).

Results and Discussion: In both Auburn and Blacksburg, the diameter of the root system was largest when plants were planted above grade and mulch was applied to the root ball (Fig. 1). Additionally, root system diameter was larger when the backfill was amended with 50% (by volume) pine bark as compared to planting with unamended backfill (Fig. 1). This agrees with previous work evaluating the effect of backfill composition on root growth of mountain laurel (6). The original diameter of the root balls at planting was 24 cm (9.4 in), indicating that those plants receiving the standard planting technique exhibited very little post-transplant root growth (Fig. 1), with roots penetrating only a few centimeters into the surrounding soil even after three years. Final shoot dry weight of plants in Blacksburg was higher in the above grade plantings (897 g) than in the amended backfill or standard plantings (734 g and 691 g, respectively). Final above ground growth index of plants in Auburn was higher for the standard and above grade plantings (104 and 106, respectively) than for the amended backfill plantings (83). The higher shoot growth in Auburn associated with the standard planting technique was not accompanied by increased root growth, a situation that negatively impacted plant appearance (visual observation). A favorable root:shoot ratio can improve landscape establishment and survival following transplanting (7). Current and previous results demonstrate the importance of quantifying root growth in addition to shoot growth responses. Finally, planting techniques that more closely resemble a plant’s natural environment can increase post-transplant root growth and improve establishment of landscape shrubs considered difficult-to-transplant.

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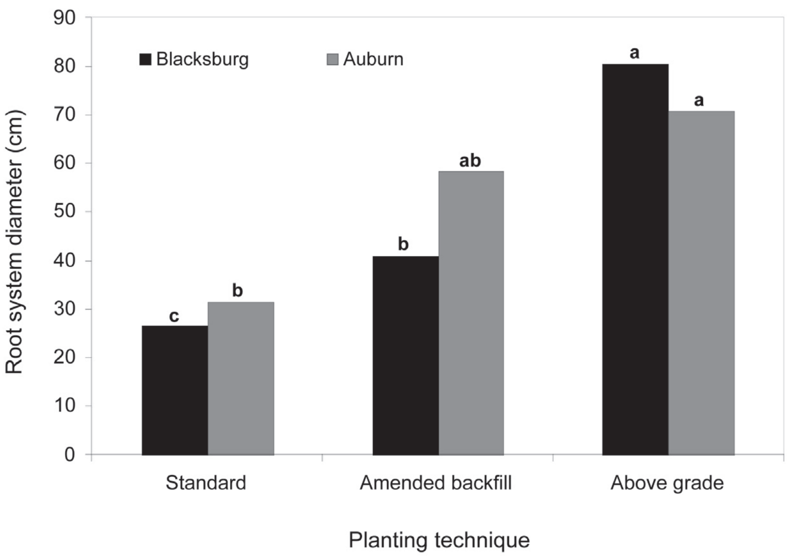
Figure 1. Effect of planting technique on root system diameter three years after transplanting 19 L (5 gal) plants of mountain laurel (*Kalmia latifolia* 'Olympic Wedding') into field plots in Auburn, AL and Blacksburg, VA. Planting techniques included planting with top of root ball at grade and planting hole backfilled with unamended soil (standard); planting with top of root ball at grade and planting hole backfilled with soil amended with 50% by volume composted pine bark (amended backfill); and planting with the top of the root ball 7.6 cm (3 in) above grade with composted pine bark mounded up around the exposed portion of the root ball, and planting hole backfilled with unamended soil (above grade). Letters represent mean separation among planting techniques within species (LSD, $P<0.05$).



Impact of Hurricane Katrina on New Orleans Landscape Soils

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Index Words: Inundation, waterlogging, sodic soils, urban landscapes, hypoxia, flooding

Nature of Work: The Gulf Coast region suffered severe devastation due to Hurricane Katrina flood waters and high winds on 29 August 2005. A team of LSU AgCenter horticulturist were assembled to evaluate the impact of flood waters on soil contamination and damage to urban landscapes. Soil samples were taken across the Louisiana Gulf Coast region impacted by the hurricane. Soil sample sites included: Slidell, Erath, Pecan Island, Grand Chenier, South Cameron, Kenner, Metairie, and several sites in the New Orleans Metropolitan area (Lakeview, Mid City, Chalmette, New Orleans East, St. Bernard, New Orleans City Park, and the 9th Ward). Only the New Orleans metropolitan area soil samples will be discussed in this paper.

Flooding was caused by levee breaks in the London Street Canal and 17th Street Canal in New Orleans. Levee topping and failure, along with storm surge were the primary cause of flooding in the Southern parishes on the Louisiana coast. The flood water inundated some areas of New Orleans with over 20' of water for up to 3 weeks. Existing soils were inundated and in many cases covered with varying depths of residue from the floodwater. Soil inundation has been shown to cause plant nutritional deficiencies and toxicities, hypoxia (decreased soil oxygen), pH changes, and creating an imbalance in the SAR value (1, 2, 3, 4).

Soil samples were taken at pre-determined sites to allow for accessability and to assure appropriate distribution of the affected areas. Soil analysis sites were collected in the same locations (GPS) the Department of Civil and Environmental Engineering sampled flood water (5). Soil samples were taken at a depth of 6 inches from multiple sub-samples and mixed and placed in soil boxes. Samples were dried, ground and analyzed by the LSU Soil Testing Lab in the Department of Agronomy. Soil samples were analyzed for N, P, K, Ca, Mg, S, Zn, Fe, B, Na, Cl, Mn, Mo, Na, Al, Cd, Co, Cr, As, Ni, Hg, Pb, SAR, and oil.

Results and Discussion: Pre-Katrina soil results were used to evaluate changes in the native soils, as well as repeated soil testing over a 6 month period. Flooded soil samples revealed sodium and chloride above pre-existing levels in inundated soils (Table 1). Soil samples in the downtown area had elevated Pb and As levels, but these soils have historically measured higher than most New Orleans soil samples before inundation (data not shown). Most soil samples were within acceptable pH and fertility levels. Calcareous soils seemed to balance the sodium impact keeping the soil SAR within acceptable balance. Residue concentrations were greater than most soil samples, especially where long term inundation occurred. EC and sodium levels were greatest in the residue levels. Soil salt levels, Na, and EC dropped by at least 30% in samples taken 6 months after Katrina compared to those collected 2 months after the storm with the exception of N. O. East. Limited rainfall has slowed soil leaching of sodium and chlorides. Overall, New Orleans Metropolitan soils are suitable for planting in most cases. Soil residues have been leached or removed in many situations. Precipitation has to some extent started leaching salts through the soil profile. New Orleans soils are suitable for re-planting with recommended adjustments based on soil test results. There were no toxic substances measured above EPA standards. Future soil testing will continue to monitor sites impacted by Hurricane Katrina for a 2 year period.

Significance to Industry: The green industry is valued as a 2.2 billion dollar annual contribution to Louisiana's economy. Remediation and reconstruction of neighborhoods have begun to restore affected landscapes in New Orleans. Our results indicate that soils should be tested prior to landscaping to determine if Na and Cl levels are not elevated before planting. No samples exceeded EPA established limits. Soil testing is recommended before replanting in inundated areas prior to planting.

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Table 1. Soil salt levels sampled from flooded areas within Metropolitan New Orleans urban landscapes before and after Hurricane Katrina.

Sample Location Date	Soil Salt (ppm)	Soil Na (ppm)	Soil EC (mmoh/cm)	Soil SAR	Residue Salt (ppm)
10/4/2005 Chalmette	5,299	845	8.3	8.7	12,888
3/14/2006 Chalmette	1.413	317	2.2	9.2	---
10/4/2005 City Park	2,063	388	3.2	7.7	---
3/14/2006 City Park	673	96	1.1	2.7	---
10/4/2005 Downtown	1,743	261	2.7	4.8	---
3/14/2006 Downtown	684	134	1.1	5.0	---
10/4/2005 Lakeview	2,611	489	4.1	8.4	10,253
3/14/2006 Lakeview	1,874	186	2.9	2.6	---
10/4/2005 9 th Ward	1,497	255	2.3	5.1	9,062
3/14/2006 9 th Ward	410	100	0.6	4.4	---
10/4/2005 N. O. East	1,297	333	2.0	6.6	2,426
3/14/2006 N. O. East	1,370	384	2.1	10.4	---
10/4/2005 Old Metairie	986	166	1.5	4.4	---
3/14/2006 Old Metairie	392	87	0.6	4.1	---

Nutrient Requirements of Herbaceous Perennials in Newly Established Landscape Plantings

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Significance to the Industry: Seven herbaceous perennials were studied for their growth, flowering, and overwintering survival in response to a variety of fertilization regimes in landscape plantings. No nutrient deficiency was observed in fertilized plants regardless of fertilization regimes. All species except daylily responded positively to increasing fertilizer rates. Two OsmocotePlus tablets per plant and the 2 lb N/1000 ft^2 resulted in higher growth and overall plant quality. Although highest numbers of flowers were obtained with daylily, *Rudbeckia hirta*, and *Echinacea purpurea* fertilized with 4 lb N/1000 ft^2, 2 tablets CRF per plant (= 1.32 lb N/1000 ft^2 at 2 feet plant spacing) resulted in acceptable flower display. Large plants resulted from 4 lb N/1000 ft^2 led to less compactness and flower performance. Overwintering survival varied significantly among species.

Nature of Work: Herbaceous perennials are continuously gaining popularity in landscape plantings. The wholesale value of this group increased 8 percent from 2003 to 2004 with a total crop value of $687 million (NASS, 2005). The business goal of lawn and garden care companies emphasizes aesthetic value of the urban landscape (1). Improper nutrient management, such as overapplication of fertilizer, is inefficient and may result in increased pest problems and risks of contaminating ground and surface waters by nutrient leaching and runoff (2). However, nutrient requirement of many species in the herbaceous perennial group during their first year establishment in the landscape is still unknown. Fertilization recommendations for herbaceous perennials vary dramatically from source to source and nutrient requirement among species can be very different (3). Generally, two applications of controlled release fertilizer (CRF), one incorporated at transplant and one top dressed in the middle of a growing season, is recommended for herbaceous perennials. Tablet-type CRF may provide season-long nutrients and reduce total amount of fertilizer used per unit area. The objective of this study was to determine effects of fertilizer type (tablet vs. granular), application rate (0 to 20 g $N \cdot m^{-2}$) and application method (single or split application) on the first year growth and flowering of seven flowering herbaceous perennials in full sun landscapes.

The experiment was conducted in a newly established landscape research area that had not been fertilized for several years. Soil in this area is a sandy loam with 1% organic matters, 38 $mg \cdot l^{-1}$ P, 53 $mg \cdot l^{-1}$ K, 499 $mg \cdot l^{-1}$ Ca, and 123 $mg \cdot l^{-1}$ Mg with soil pH at 5.3 (Soil Testing and Plant Analysis Laboratory, LSU). About 2 inches pine bark was incorporated into the top 6 inches soil, and dolomitic limestone was incorporated at 70-lb/1000 ft^2 to adjust pH. Raised plots (10' x 12') were made with a 2 ft alley way in between every two plots to avoid plant roots and fertilizer intruding into other plots. Experimental design was a split-plot design. Whole plots were arranged as a completely randomized block design with seven fertilizer treatments and 4 blocks. Seven perennial species: cigar plant (*Cuphea ignea*), daylily (*Hemerocallis spp*.) 'Stella d' Oro', Guara (*Guara linfheimeri*) 'Siskiyou Pink', Mexican heather (*Cuphea hyssopifola*), lantana (*L. camara*) 'New Gold', Purple coneflower (*Echinacea purpurea*), and blackeyed Susan (*Rudbeckia hirta*) 'Goldstrum' were randomly arranged in each fertilizer treatment as sub-plots. Two plants of each species (3 plants of daylily) were planted next to each other as sub-samples.

Fertilizer types: OsmocotePlus 16-8-12 tablet (7.5 g, 3 - 4 month) or OsmocotePlus 15-9-12 (5 - 6 month) and application methods: single application at transplant (22 April 2005) or split application with one applied at transplant plus a topdressing on 20 July were studied. Treatment combinations were: 1) unfertilized, 2) two tablets per plant (= 1.32 lb N/1000 ft^2 at 2 feet plant spacing), 3) OsmocotePlus 15-9-12 at 1 lb N/1000 ft^2, 4) OsmocotePlus 15-9-12 at 2 lb N/1000 ft^2, 5) split application of treatment 4 with half incorporated at transplant and half as topdressing in July, 6) OsmocotePlus 15-9-12 at 4 lb N/1000 ft^2; 7) one tablet per plant (= 0.66 lb N/1000 ft^2 at 2 feet plant spacing) at transplant and topdressing of OsmocotePlus 15-9-12 at 1 lb N/1000 ft^2 in July. At transplant, CRF treatments were incorporated into the top 4" soil and CRF tablets were dropped next to the root ball of a plant. All plots were mulched with pine straw (4 inches). Topdressing in July was applied as broadcast to the whole plot. Plots were irrigated by overhead micro sprinklers controlled by a timer to supply about 1½ inch of water per week before May 15 and 2½" inch of water per week thereafter. Irrigation was automatically postponed at ½" rainfall events by a rain sensor.

Plant growth in the first year was measured as growth index (GI) during first week of every month after planting. GI = plant height (including flowers)+1/2(maximum plant width + perpendicular width). Numbers of flowers were counted weekly for daylily from April to June, and monthly for *R. hirta* and *E. purpurea* from May to August. Flowers were removed from plants after each counting and the total number over the data collection periods was calculated. A daylily flower was counted as open if the outer 3 petals were partially reflexed. A *rudbeckia* or *enchinacea* flower was counted as open when all ray flowers were completely unfurled and the disk exposed. Considering plant size, greenness, and flowering display, an overall quality rating in a scale of 1 to 10 was assigned to individual plants to assess aesthetic quality of the plants. A plant is considered having premium quality when receiving a rating of 9 or 10, less ideal quality when receiving a rating of 7 or 8, and should be discarded if <7. Quality ratings were conducted by two individuals separately and averaged before data analysis. Survival rate [(number of plants emerged in 2006)/(number of plants transplanted in 2005) x 100%] was calculated for each species. Tissue samples collected from the youngest-fully-expanded leaves were analyzed for nutrient content of N, P, K, Mg, Ca, and Fe.

Results and Discussion: Nitrogen deficiency symptoms including lower leaf chlorosis and poor plant growth were observed in all species except daylily when plants were unfertilized. No nutrient deficiency was observed in fertilized plants regardless of fertilizer regimes. Tissue N content in non-deficient plants of *C. ignea*, *C. hyssopifola*, guara, lantana, *E. purpurea*, and rudbeckia were in the range of 2.6–2.8%, 1.6–2%, 2.1–2.8%, 2.1–2.6%, 2.9–3.2%, 2.4–3.0%, respectively. These ranges represent the sub-optimum nutrient status (no deficiency symptom yet) at the low rate (1 lb N/1000 ft^2) and over-consumption of nutrients at the high rate (4 lb N/1000 ft^2) when these species were fertilized. Tissue N content in unfertilized daylily plants was 1.8% and was in the range of 1.9 to 2.4 in fertilized plants. Compared with unfertilized plants, all species except daylily responded positively to fertilization with higher growth index (GI) under increasing fertilizer rates and 4 lb N/1000 ft^2 resulted in the highest GI in August. Two tablets per plant and the 2 lb N/1000 ft^2 resulted in GI that was usually higher than the rest of treatments in *C. ignea*, lantana, and *C. hyssopifola* (only data of *C. ignea* are shown in Figure 1). The lack of response in daylily was unexpected, and similar to the lack of response found in iris (3). Total number of flowers per plant from April to June suggests that when fertilized with 4 lb N/1000 ft^2 or 1 or 2 tablets CRF per plant, daylilies had higher number of flowers than unfertilized (50, 49, 48, vs. 31, Table 1). The 2 lb N/1000 ft^2 or the split application of the 2 lb N/1000 ft^2 or the 1 tablet plus 1 lb N/1000 ft^2 resulted in significantly fewer flowers than the above three treatments but still more than unfertilized.

Total number of flowers in *R. hirta* and *E. purpurea* from May to August were significantly different under different fertilization regimes (Table 1) with 4 lb N/1000ft^2 resulting in the highest numbers of flowers. Two tablets per plant and 2 lb N/1000 ft^2 resulted in acceptable flower display in *E. purpurea*. Two tablets per plants and 1 or 2 lb N/1000 ft^2 resulted in acceptable flower display in *R. hirta*. Overall quality ratings of plants in the 4 lb N treatment, however, were not significantly different from that of plants in some other treatments because large plant size led to less compactness and flower performance. Two tablets per plant and the OsmocotePlus 2 lb N/1000 ft^2 resulted in optimum quality of many species in May (Table 2). Split application of tablet and CRF at low rate resulted in good flower display in daylily but lower plant quality than single application of two tablets at transplant.

Survival rate was significantly different among species (data not shown). All daylily and lantana had 100% survival. Two tablets CRF per plant resulted in higher survival rates in *R. hirta*, *C. ignea*, and *C. hyssopifola*. Four lb N/1000 ft^2 resulted in similar results in *Cuphea* plants but not *R. hirta*. Split applications resulted in similar results as single application of two tablets only in guara but lower survival in other species.

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Figure 1. Plant growth index of *C. ignea* fertilized with two types of CRFs at different rates from May to August, 2005. Treatment 1 to 7 corresponding to the treatments described in the materials and methods section.

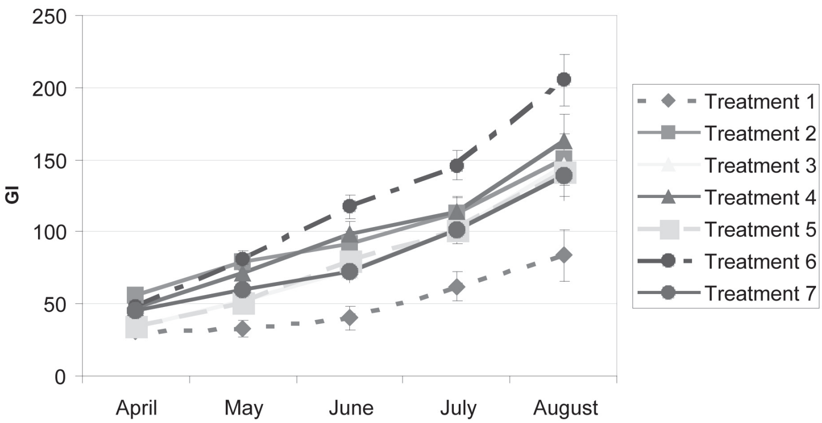

Table 1. Total number of flowers in daylily, *R. hirta*, and *E. purpurea* fertilized under different fertilization regimes. Flower numbers were recorded weekly from April to June for daylily, and monthly from May to August for rudbeckia, and *E. purpurea*.

Fertilizer Treatment	Daylily	*E. purpurea*	*R. hirta*
1	31.7 c	1.7 d	16.6 d
2	48.3 a	7.4 bc	59 bc
3	39.8 ab	4.5 cd	70.4 b
4	36 bc	8.4 b	48.6 bc
5	41.8 ab	3.5 cd	36.9 cd
6	49.5 a	13.3 a	147.6 a
7	49.2 a	4.2 cd	44.8 bcd

Table 2. Overall Plant quality of seven herbaceous perennials fertilized with two types of CRFs at different rates by May and August, 2005.

Species	*C. ignea*	Daylily	Guara	*C. hyssopifola*	Lantana	*E. purpurea*	*R. hirta*
Treatment	May	May	May	May	May	May	May
1	3.8e	7.6cd	4.1c	4.0d	3.1d	4.0d	4.6d
2	8.6c	8.3b	9.3a	9.6ab	9.4ab	8.5ab	9.3ab
3	8.9bc	8.0bc	8.9ab	8.3c	7.9c	7.0c	8.6b
4	9.6ab	7.9cd	9.1a	9.2ab	9.6a	8.5ab	9.3ab
5	8.4c	7.4d	8.9ab	8.1c	8.1c	7.1c	7.6c
6	10a	9.1a	9.8a	9.8a	9.4ab	9.3a	9.6a
7	7.2d	8.3bc	8.0b	8.9bc	8.6bc	7.3bc	8.7b

The Effect of Mid-season Pruning on the Cold Hardiness of Six Abelia Hybrids

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Index Words: Freeze injury, cold tolerance

Significance to the Nursery Industry: Curtailing freeze damage is of economic importance to the nursery industry in the southern United States. Because abelia suffers freeze damage north of USDA zone 7B (1, 5), cultural practices that increase cold hardiness should be identified so that losses can be avoided. This study identified the effect of mid-season pruning on cold hardiness of six abelia taxa. Over the 2003-04 winter, all but one taxa were more cold hardy in unpruned versus pruned treatments. Many southeastern homeowners, landscape professionals, and production companies tailor pruning activities around time and labor constraints, yet in the case of abelia, we have shown that mid-season pruning can lead to significant freeze damage the following winter. We recommend that pruning be carried out in early spring to allow for hardening off of new abelia tissues prior to winter.

Nature of Work: For a century or more, abelia have been utilized in landscapes of the southeastern United States (4). Many abelia taxa suffer significant leaf drop and stem dieback during winter months and no taxa have survived temperatures below -26°C (-14.8°F) in laboratory testing (5). To reduce size and improve form and flowering, abelia are often severely pruned (2). The recommended time to prune abelia in the southeastern U.S. is before spring growth initiates (6), yet the actual pruning time is variable and dependant upon labor availability and plant appearance. This study was conducted to examine the effect of mid-season pruning (3 and 4 July 2003) on cold hardiness of six abelia taxa.

Six abelia genotypes were evaluated in this study. Five of six genotypes originated as open pollinated seedlings of *Abelia chinensis* and two of these are named cultivars: ‘Rose Creek’ and ‘Canyon Creek’. The remaining genotype, ‘Sherwoodii’, is an *A.* x *grandiflora* selection. All plant material was collected as cuttings from stock plants in Athens, GA and planted into a field plot in Griffin, GA in a completely randomized design in October 2001. On 3-4 July 2003, half of the ten to sixteen individuals of each taxa in the study were selected and severely pruned (75% of growth removed). The remaining plants were left unpruned. Eighty stem sections per combination were randomly collected monthly from October 2003 to April 2004. Twenty bundles per taxa-treatment combination were made by wrapping four stem sections together in moist cheesecloth. As described by Lindstrom and Dirr (3), bundles were inserted into test tubes and eighteen tubes per taxa-treatment combination were submerged in a temperature bath with the remaining two tubes kept at 21°C (70°F). Temperatures of the samples were held constant at -2°C (28.4°F) for 14 hrs and subsequently cooled to -27°C (-16.6°F). Two tubes of each taxa-treatment combination (two reps of four stems each) were removed at -3°C (5.4°F) increments. Following removal from the temperature bath, samples were thawed and placed onto moistened filter paper inside petri dishes for five days at room temperature. At five days, stems exhibiting more than 50% discoloration of cambium and phloem as a result of tissue death were rated as dead. The data set was analyzed as a whole to compare the performance of taxa across months and to determine the effect of pruning on the cold hardiness of abelia. The data set was also broken down into individual months to compare the performance of each taxa-treatment combination.

Results and Discussion: Analysis of data revealed that the cold hardiness of each taxa varied significantly from October to April, as was expected, with maximum cold hardiness in central Georgia occurring in the December to February time period (5). In addition, it was determined that with the exception of 'Canyon Creek', unpruned treatments were more cold hardy than pruned treatments. This effect of increased cold tolerance in unpruned individuals was evident throughout the season, showing that the effect of pruning is long lasting.

When assessing the results of each month separately, there were significant differences in taxa-treatment combinations for the months of December 2003 (Table 1) and January and Feburary 2004 (data not shown). In the month of December, unpruned 'Rose Creek' and 'Canyon Creek' were significantly more cold hardy than their pruned counterparts or either of the 'Sherwoodii' treatments. Results for the months of October and November 2003 and March and April 2004 were not significant. The lack of significance in these months was due to an absence of cold acclimation in all individuals regardless of the treatment, leading to severe damage of all stems in those months. When comparing minimum survival temperatures of stems between treatments yet within a taxa (Table 2), the trend also indicates that unpruned individuals are able to withstand lower temperatures with minimal damage to stems.

All taxa that received mid-season pruning exhibited rapid growth from approximately two weeks after pruning until the first freeze, often returning to their pre-pruned size. This rapid growth was in contrast to unpruned entries that demonstrated a typical growth pattern for abelia, including slow growth rates in mid-summer with a small burst of growth as temperatures cooled and soil moisture increased in late summer. Such rapid growth of the pruned entries, lasting until the first freeze, reduced the cold acclimation of plant tissue because tissues were primarily non-woody at the time of the first freeze. These results point toward a need to closely follow the recommended pruning procedures for abelia (6).

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Table 1. Mean freeze damage ratings for all taxa-treatment pairs, grouped in ascending order.

15 December 2003		
Cultivar	**Treatment**	**Damage**
'Rose Creek'	Unpruned	1.60[z] a[Y]
98-8	Unpruned	1.75 ab
98-13	Unpruned	1.85 ab
98-11	Unpruned	1.95 ab
'Canyon Creek'	Unpruned	2.20 abc
'Rose Creek'	Pruned	2.30 bcd
98-13	Pruned	2.65 cde
'Canyon Creek'	Pruned	2.65 cde
98-8	Pruned	2.90 de
'Sherwoodii'	Unpruned	3.00 e
'Sherwoodii'	Pruned	3.15 e
98-11	Pruned	3.20 e

[z]Mean damage rating over two replications of four stems each, with 0 representing no dead stems and 4 representing all stems dead.

[y]Mean separation based on least significant difference (LSD) at P>0.05. Means followed by the same letters are statistically similar.

Table 2. Mean minimum survival temperatures, in degrees Celsius, for each taxa-treatment combination, recorded monthly, from October 2003 to April 2004.

Taxa	Treatment	December	January	February
'Canyon Creek'	Pruned	18.5	6.3	2.3
'Canyon Creek'	Unpruned	14.4	-0.4	2.3
'Rose Creek'	Pruned	13.1	7.7	6.3
'Rose Creek'	Unpruned	3.56	-1.8	-1.8
'Sherwoodii'	Pruned	25.2	15.8	14.4
'Sherwoodii'	Unpruned	23.0	19.0	17.1

Status of Mississippi Gulf Coast Live Oak Trees after Hurricane Katrina

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Significance to Nursery industry: Live oak trees, *Quercus virginiana*, have long been considered to be the symbol of the Old South. Part of the attraction of the Atlantic and Gulf Coasts is the stately live oaks. These majestic live oaks have weathered many hurricanes in their >200 yr life span. Most recently, on 29 August 2005 Hurricane Katrina, with sustained winds exceeding 160 miles per hour and a storm surge of 30 feet in some areas challenged the fortitude of the live oaks on the Mississippi Gulf Coast (17). In the aftermath, the Mississippi Forestry Commission reported an estimated $2.4 billion in timber damage including estimated urban tree damage at $1.1 billion (6). With an individual tree valued at >$31,300, arguably the economic impact of conserving existing trees and replacing severely damaged stands is an essential part of the recovery effort along the Mississippi–Louisiana Gulf Coast. Also, recovery efforts following major disturbances such as hurricanes are essential. A part of the recovery effort is to determine how trees are impacted by such events and what factors are important to aid the recovery of these native stands.

Nature of Work: Several studies are under way to determine the impact of Hurricane Katrina on the health of the aging population of live oaks, *Quercus virginiana*, in coastal Mississippi . A total of six research sites have been established in Harrison County with each site containing twelve study trees (n=72). All trees in the study are victims of wind stress and all are located in urban areas. The first site is located at Mississippi Gulf Coast Community College – Jefferson Davis Campus (JD) in Gulfport. The second site is the Veteran's Administration facility (VA) located on Pass Road in Biloxi. The third site is a recreational area on the west side of Keesler Air Force Base (wKAFB) in Biloxi.

Another variable being investigated is saltwater inundation. Soils that have been saltwater inundated have been determined to alter a variety of physical, chemical and biological processes in plant growth (10). For instance, it eliminates soil oxygen, decreases cambial growth and has been shown to inhibit formation of new leaves (13, 1, 16). The remaining three sites were saltwater inundated and include: site four, the University of Southern Mississippi (USM) Coastal Campus in Long Beach. The fifth site is Beauvoir, the historical home of Jefferson Davis in Biloxi. The sixth and final site is located on the east side of Keesler Air Force Base (eKAFB) also in Biloxi.

Different treatment regimens have been implemented in order to determine the best way to treat these mature trees after a catastrophic event, such as a hurricane. Control trees are monitored yet receive no treatment. A low maintenance, or homeowner regime, includes a one-meter ring of mulch and irrigation. A high maintenance, or professional regime, includes soil aeration, a three-meter ring of mulch, irrigation and insecticides, if deemed appropriate.

Results and Discussion: *Value of Trees.* Since the trees within the scope of the study cannot be replaced by transplanting a tree of like size, the Trunk Formula Method was used in calculating their values (3). The International Society of Arboriculture in their 9th edition of Guide for Plant Appraisal defines the Trunk Formula Method as:

$$\text{Basic value} = RC + [BP * (TA_A - TA_R)] * SR$$

Where:

RC is the replacement cost of the largest normally locally available tree
BP is the basic price (i.e. cost per square inch of trunk area of replacement tree)
TA_A is the area of the trunk of the appraised tree
TA_R is the area of the trunk of the replacement tree
SR is the species rating for the appraised tree

The second step is to determine the appraised value using the following formula.

Appraised Value = Basic Value * Condition Rating * Location Rating (7)

The value of live oak trees at the JD site is $327,000. Values for the VA and wKAFB are $357,100 and $385,200, respectively. Saltwater inundated sites elicited values of $522,300, $310,500 and $349,300 for USM, Beauvoir and eKAFB respectively. The 72 trees in this study have an estimated appraisal value over $2.3 million. These estimates express financially the irreplaceable value of the live oaks in the Mississippi Gulf Coast landscape.

Canopy Cover. Canopy cover is an important aspect of measurement when looking at tree health. Prior studies have determined that repeated and severe defoliation effects on tree physiology are expected to cascade through an entire ecosystem by altering carbon, nitrogen, and water fluxes, and subsequently affecting nitrogen cycling and plant-herbivore interactions (15, 9).

In our study, a spherical densiometer was used to determine percent canopy cover (8). Saltwater inundated sites averaged around an 82% defoliation rate with 65.5%, 89.2%, and 90.2% for eKAFB, Beauvoir, and USM, respectively. The lower percentage in eKAFB could be easily explained by proximity to the Gulf. Where Beauvoir and USM are located directly on the beach, eKAFB is closer to the Back Bay in Biloxi. Non-saltwater inundated sites averaged about 64% defoliation. The JD campus was determined to have a 65.7% defoliation rate while wKAFB and the VA were measured at a 66.3% and 59.8% loss of canopy cover, respectively. Seven months after the storm, 22% (n = 16) of the study trees have yet to put on any new growth. Half of the trees are located at wKAFB, one at USM and the remainder at Beauvoir.

Foliar Nitrogen. Studies have determined that plant foliar chemistry is influenced by nutrient availability, soil conditions, and can influence plant fitness (2, 11, 19). Also, in flooded areas, the leaf nutrient contents of *Quercus* species have been determined to decrease markedly, especially nitrogen (4).

For this study, foliage was collected from branches in the four cardinal directions. Only the ten newest leaves were harvested from each branch. A total wet weight of 50g per tree was collected. Leaves were placed on ice in a cooler and returned to the lab. They were immediately weighed and placed in an oven for 48 hours at 60˚C. Samples were then re-weighed and ground to pass a 20-mesh screen. Like Fridgen and Varco, total foliar nitrogen was determined on 4 to 6 mgs of oven-dried samples using a Carlo Erba N/C 1500 dry combustion analyzer (5). As seen in Figure 1, foliar percent nitrogen was not different for trees when compared by site ($F = 1.64$, $P = 0.16$). However, mean foliar percent nitrogen for all inundated sites was significantly greater than those on non-inundated sites, 1.9582 and 1.8511, respectively (orthogonal contrasts, $t = 2.07$, $P = 0.04$).

It is well known that the amount of nitrogen in plants varies enormously with species, organ, season, and other environmental factors. Some data shows that the growth efficiency of a variety of insects is closely related to plant nitrogen content. As the nitrogen content of their food increases, insects become more efficient in converting plant material into body tissue (14). Even though some conflicting data exists (18, 12), it is agreed upon that a total change in foliar nitrogen content affects insect growth and establishment.

Future Research. The current data combined with on-going research will help to establish baseline information that will be useful in providing the best available care to live oak trees after a hurricane. On-going research includes: soil compaction analysis, stem water potential, root starch analysis, callus formation, and surveys of insects in the canopy and surrounding soil.

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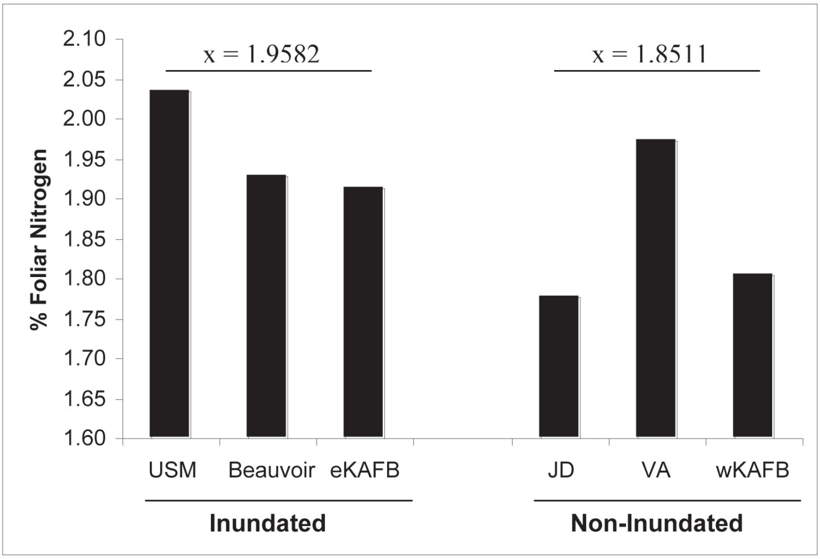
Figure 1. Foliar percent nitrogen was not different for trees when compared by site (F = 1.65, P = 0.1649). Mean foliar percent nitrogen for all inundated sites was significantly greater than those on non-inundated sites (orthogonal contrasts, t = 2.07, P = 0.0442).



Select Ornamental Shrubs and Grasses for Potential Roadside Beautification Applications

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Index Words: *Calamagrostis, Miscanthus, Panicum, Lagerstroemia, Cotoneaster, Hypericum, Spirea, Forsythia, Abelia*

Significance to Industry: Beautification of local and state roadways involves the utilization of plant materials which can withstand low and often severe maintenance practice conditions. Typically most roadways are landscaped using turf type grasses, minimal shrubs, and wildflowers. The use of ornamental shrubs and grasses in roadside application projects is limited and sporadic. This is due to the fact that many ornamental species are utilized in manicured well maintained residential landscapes and have not been evaluated for application to roadside conditions. Many of the grasses that we have on our roadways, especially at critical areas are not effective in runoff control. This leads to frequent, expensive renovation of roadway green spaces. Although turf grasses are inexpensive to install, these areas require constant mowing and weed control. When evaluating the use of plant materials for roadside beautification projects many variables should be considered including establishment, maintenance, aesthetic appeal, safety, road stabilization, runoff, and erosion control. The adaptation and use of ornamental plant materials to accent roadways will provide a safe alternative and/or addition to current roadside projects as well as infuse a unique flare and character representative of each state.

Nature of Work: Eighteen perennial ornamental cultivars were established and then grown under low maintenance, intensive weed competition and severe mowing conditions. These cultivars were evaluated for their potential application for roadside/median beautification. Experimental plots were cleared with Roundup prior to planting. During the first three weeks of establishment, plants were irrigated as needed. Plants were grown for one season then pruned back to simulate bush-hog mowing. Plants were grown under low maintenance and no weed control conditions for two growing seasons. Plants were evaluated each season for simulated bush-hog damage recovery potential, survivability under severe weed competition, height, and spread. Two-way analysis of variance with repeated measurements showed that height and spread variation had a significant interaction between plant cultivar and time of evaluation.

Results and Discussion: Several *Zephyranthes* sp. cultivars performed poorly under severe weed competition and mowing damage resulting in a high mortality rate. Cultivars that did perform well for the two year evaluation period include *Lagerstroemia indica* 'Near East,' 'Centenial,' 'William Toovey,' *Lagerstroemia indica* x *fauriei* 'Zuni,' *Miscanthus sinensis*, *Calamagrostis* 'Karl Foster,' *Panicum virgatum*, *Cotoneaster franchetti*, *Hypericum patulum* 'Sungold,' *Spiraea japonica* 'Shirobana,' and *Forsythia suspense* 'Weeping Forsythia,' *Rosa* x 'Chuckles' and

Rosa x 'Knock Out' cultivars, with their popular showy appearance, performed moderately well and showed high potential for roadside/median beautification applications.

Table 1. Mean height and spread of select perennial ornamental shrubs and grasses grown for two growing seasons under simulated roadside conditions.

Plant	N	Height (inches)	Diameter (inches)
Tonto Crapemyrtle	16	67.62	58.06
Miscanthus sinensis	16	61.69	60.18
Near East Crapemyrtle	16	54.25	61.12
Wintergreen Barberry	16	51.06	51.81
William Toovey Crapemyrtle	16	49.62	51.62
Calamagrostis 'Karl Foster'	16	47.56	17.06
Franchetti Cotoneaster	16	44.93	66.31
Weeping Forsythia	16	41.18	44.31
Zuni crapemyrtle	16	39.31	43.43
Panicum virgatum	16	38.12	26.5
Hopi Crapemyrtle	16	37.37	52.31
Sungold Hypericum	16	36.81	54.25
Shirobana Spirea	16	29.31	33.37
Chinese Abelia	16	29.25	32.0
Pink Shrub Rose	16	27.18	40.56
Mt. Airy Fothergilla	16	25.56	21.25
Centennial Crapemyrtle	16	18.31	18.68
Hummingbird Clethra	16	8.0	5.7
Red Shrub Rose	16	8.0	6.5

Effects of Planting Hole Size and Amendments on Tree Establishment

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Index Words: *Acacia farnesiana*, Planting practices

Significance to Industry: Current planting practices recommend a shallow, wide planting hole and no amendments in the backfill. However, some nurseries and landscape companies still use different sizes of planting holes and organic amendments in the backfill. This study conducted in a semi-arid climate showed that 33% to 50% organic amendment in backfill compared to native soil at transplanting is not beneficial for native trees, but increased the risk of leaning or sinking.

Nature of Work: Current guidelines for transplanting trees and shrubs recommend tilling an area three to five times the diameter of the root ball and no deeper than the root ball. A hole should be dug in the center of the tilled area that is only slightly wider and no deeper than the root ball. Circling roots on the outside of the root ball should be cut. The root ball is then placed on undisturbed soil and unamended soil is used for the backfill. The top of the root ball should be level with or slightly above the soil surface.

Research has shown that the root system of trees and shrubs is relatively shallow and wide because of the availability of oxygen and water close to the surface (1, 2). Many studies conducted on a wide variety of soil types found that in most cases organic amendments in the backfill were not beneficial to plant establishment and growth (1). Reasons for poorer performance of plants amended with organic media in the backfill include: 1. decomposition of organic material followed by settling of the plant and sinking of the root collar below the soil surface; 2. organic amendments create an additional interface between the organic potting media and the mineral soil from which roots may not grow into the native soil, creating a root bound plant within the amended soil, and 3. incompletely decomposed organic material may require nitrogen for further decomposition and may compete with plant roots for minerals, thereby resulting in reduced growth (2). The majority of studies have been conducted in mesic climates.

The objective of the study described here was to determine whether planting hole size and organic material in the backfill would affect plant establishment and growth of a commonly used landscape tree in the semi-arid Southwest during the first three years after planting. *Acacia farnesiana* were transplanted from 15 gal. containers using one of the following four treatments. The planting hole sizes were either a small hole that could accommodate the root ball, dug to a depth of the root ball, and slightly wider at the top, or a planting hole three to five times the width and the same depth of the root ball. Dimensions of the transplanted root balls were 0.36 m in diameter and height. The general size of the small hole was 0.52 m wide and 0.36 m deep. Large holes were 1.37 m to 1.52 m wide and 0.36 m deep. The unamended backfill treatment consisted of soil from the planting hole. Amended backfill treatments consisted of 50% compost (1.9 cm screened) and 50% soil for the small planting hole, and 33% compost and 66% soil for the large planting hole.

The project was installed as part of a streetscape from June to mid July 2001 in Tucson, Arizona. Eight replications of each of the four treatment combinations were installed on two types of soil, sandy silt on the west side, and sandy soil with some rocks on the east side. Drip irrigation with two emitters per tree was installed. Plant height and stem caliper at 20, 70, and 120 cm above the soil line were measured in August 2001, 2002, and October 2004. Taper was calculated by subtracting the upper caliper at 120 cm from the lower caliper at 20 cm and dividing it by the distance between the two measurements. All data were subjected to analysis of variance. Observations at each measurement date also included general health and appearance of trees, for example if foliage was sparse, trees were leaning, or root collars were sunken.

Results and Discussion: Plant height in August 2001 was greater for trees from the west planting with an average height of 2.2 m compared to trees from the east planting at 1.7 m. This difference may be due to trees in the west planting being planted earlier and being provided with irrigation, while plants for the east planting were held six weeks longer in the 15-gal. containers and may have suffered from temporary drought stress during this holding period when evaporative demand was high and daytime temperatures exceeded 38°C. Similarly, calipers at all three levels were greater for trees at the west planting compared to trees at the east planting in August 2001 (Table 1).

Location remained the strongest influence that affected tree growth three years after transplanting. Caliper and taper of trees planted in the west planting were approximately 45% greater than for trees planted in the east planting (Table 1). In October 2004, average plant height in the west planting was 4.3 m, significantly greater than the average tree height of 3.0 m in the east planting. Planting hole size and amendment had no effect on plant growth. Less irrigation delivery, water availability and poorer soil quality likely contributed to significantly less growth of trees in the east planting.

Visual observations in August 2002 recorded that ten trees in the west planting were leaning at angles of 15° to 80° from a vertical position, and on 11 trees the root collar had sunk 6 to 9 cm below the original grade (Table 2). Observations indicate that trees planted in the large planting hole and amended with compost in the backfill had the highest incidence of leaning and sinking. Some of the trees were only sunk, some were only leaning, and some were sunk and leaning at various angles. Seven of those trees needed to be re-staked to remain functional in a public landscape. No leaning trunks and no sinking of the root collar more than 2.5 cm was observed on trees in the east planting, which may in part result from their slower growth during the first year. By October 2004, ten trees were observed leaning at angles of 15° to 40° from a vertical position, nine of which were amended with compost at transplanting (Table 2). One of the trees where the trunk had been almost horizontal in August 2002 was cut back to the ground and had grown into a multi-trunk shrub by October 2004.

Sunken root collars were not as frequently observed three years after transplanting as within one year after transplanting. The root collar of only four trees in the west planting were obviously approximately 10 cm too deep, and according to our records sunken crowns were noted for those same trees in August 2002. Some of the other trees where sunken crowns were observed in 2002 did not show any changes in grade around the base of the tree, but may still be too low. No leaning trees or sunken crowns were observed for trees growing in the east planting. Our observations confirm earlier research across the country that organic amendment in backfill is not beneficial for trees.

Visual observations one and three years after transplanting indicate that trees that were amended with compost in the backfill had the highest incidence of leaning trunks and sinking crowns (20% of trees in study or 37% of those receiving amendments) while of those trees that were not amended only one tree (3%) was leaning three years after transplanting. Hole size at transplanting had no significant effect on leaning or sinking three years after transplanting. These results confirm recommendations that 33% to 50% organic amendment in backfill compared to native soil at transplanting is not beneficial for native trees, but increases the risk of leaning or sinking. Long term health of trees that are affected in this manner may be compromised.

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Table 1. Caliper and taper of *Acacia farnesiana* trees planted in June/ July 2001 in small or large planting holes with or without amendments in two planting locations (n=32).

Planting location	**Caliper (mm) above ground at**			**Taper (mm/cm)**
	20 cm	**70 cm**	**120cm**	
		August 2001		
West	16.9 a*	14.2 a	11.1 a	0.058 b
East	14.8 b	10.8 b	5.8 b	0.090 a
		August 2002		
West	55.2 a	45.9 a	38.8 a	0.16 a
East	39.6 b	32.8 b	22.4 b	0.17 a
		October 2004		
West	103.4 a	88.8 a	70.5 a	0.64 a
East	59.2 b	47.7 b	34.5 b	0.36 b

*Means within a column followed by different letters are significantly different at P<0.05.

Table 2. Number of trees where the plant crown sunk about 2-3” (6-9 cm) below the original grade and number of plants leaning at angles of 10° to 40° from a vertical position.

		August 2002		October 2004	
Plant hole size	Amendment	Crown sunk	Leaning	Crown sunk	Leaning
Large	+	6	4	2	5
Large	-	3	2	0	1
Small	+	2	3	1	4
Small	-	0	1	0	0

Effect of Irrigation Placement on Root Growth of Marigold in the Landscape

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Index Words: Irrigation management, landscape establishment, microirrigation, annual bedding plants

Significance to the Industry: Plant growth, aesthetics, and environmental responsibility must be balanced when selecting irrigation components for landscape plantings. Traditional overhead irrigation provides greater coverage but often waters areas void of plant material, leading to weed growth and increased maintenance. Irrigation with drip or bubbler emitters promotes high quality growth, conserves water, minimizes maintenance and is less expensive than spray stake systems.

Nature of the Work: Microirrigation is commonly recommended for shrub and flower beds to promote water conservation. Emitter types vary widely in both cost and application patterns with models ranging from drip emitters that localize applications to spray stakes that distribute water over a larger area. For sandy soil, spray emitters are advised due to vertical water movement. Emitter choice must also be balanced with effects on root distribution and plant quality as susceptibility to damage and potential disease from spray applications is species dependent (1).

Root growth and distribution in dry soil is controversial. Some authors have found roots proliferate where water and nutrients are readily available (2,3,4,8); however, observational and experimental data (unpublished data) have shown that root growth will occur in trees and shrubs uniformly around root balls in the absence of readily available water. Stevens and Douglas (8) found that under drip irrigation, roots of grapevine were concentrated under the vine row, whereas under microjet irrigation roots were evenly spread across the planting area. Similar results were found for ornamental grasses (unpublished data). Yet, Portas and Taylor (4) found that corn and tomato roots can elongate at a slow rate into soil as dry as -40 bars water potential when the plants are supplied with water from other soil layers. Rapid root development into the surrounding soil profile is essential for establishment and expansion of the soil volume available for water and nutrient uptake. No information is available on the extension of annual bedding plant roots into landscape soils in response to soil moisture. The objective of this study was to evaluate the effect of four microirrigation emitter types on shoot and root development patterns of marigold in the landscape.

Tagetes erecta 'Little Hero Gold' L. obtained from a commercial nursery in 0.72 liter (0.19 gal) containers were transplanted on 12 Oct 2005 into excessively drained fine sand (Apopka fine sand series) in an open-sided clear polyethylene covered shelter. To evaluate the effect of irrigation placement and emitter type on root growth, four emitter types were evaluated: drip emitters, inline spray emitters, spray stakes, and bubblers. Irrigation was applied daily at a rate of 1 L (0.26 gal) per plant. Drip and bubbler emitters represented localized irrigation distribution patterns whereas inline spray and spray stake emitters provided larger, increased distribution patterns. Drip emitters were inserted in a single polyethylene supply line placed in the center of each planting bed. Plants were irrigated with two emitters located on the north and south side of each plant, 15 cm (6 in) from the center. Each emitter distributed water within a 2.5 cm (1 in) radius. Bubbler arrangement was identical to the placement described previously and applied irrigation within a 7.5 cm (3 in) radius. Inline spray emitters were mounted 0.6 m (2ft) apart and 2.5 cm (1in) above the soil grade directly in two polyethylene supply lines parallel to each other within each planting bed. To ensure 100% overlap, emitters were situated in a triangular pattern within the bed area. Microirrigation spray stakes equipped with a full circle flat spreader were situated in a triangular pattern with each emitter 1.2 m (4 ft) apart and mounted 22.9 cm (9 in) above ground level. Beginning one week after transplant and continuing weekly throughout the experiment, one replicate per treatment per block was removed and shoot and new root dry masses collected. To obtain new root dry mass, north and west quadrants of the soil volume outside of the rootball and extending beyond the longest root in each quadrant were removed. For treatments where increased coverage was not the objective (i.e. drip, bubblers), each quadrant represents hydrated and non-hydrated segments of the soil volume, respectively. Longest root length in each quadrant and growth indices were also recorded. Data were analyzed by regression and ANOVA with mean separations performed using Fisher's Protected least significance differences (7). All analysis were conducted using SAS (5).

Results and Discussion: Shoot growth rates were negatively affected by emitter type. Inline spray emitters grew 2.4×, 1.8×, and 1.9× slower ($P < 0.05$, Fig. 1) and produced 2.1-, 1.6-, and 1.7-fold less shoot dry mass ($P < 0.05$, data not shown) than drip, bubbler, or spray stake emitters, respectively. Differences can be partially explained by a severe disease infestation among marigolds receiving irrigation via inline emitters. Plants irrigated with spray stakes were not affected. No differences were found among other treatments. Emitter type had no effect on root growth, canopy size or shoot to root ratios. Despite current recommendations advising spray emitters for sandy soils, root distribution was unaffected by irrigation application patterns and overall growth of marigolds irrigated with drip and bubbler emitters was greater than or equal to treatments receiving increased coverage. Similar results were reported for *Plumbago auriculata* (6) suggesting localized emitter types are effective for flower bed irrigation in sandy soils.

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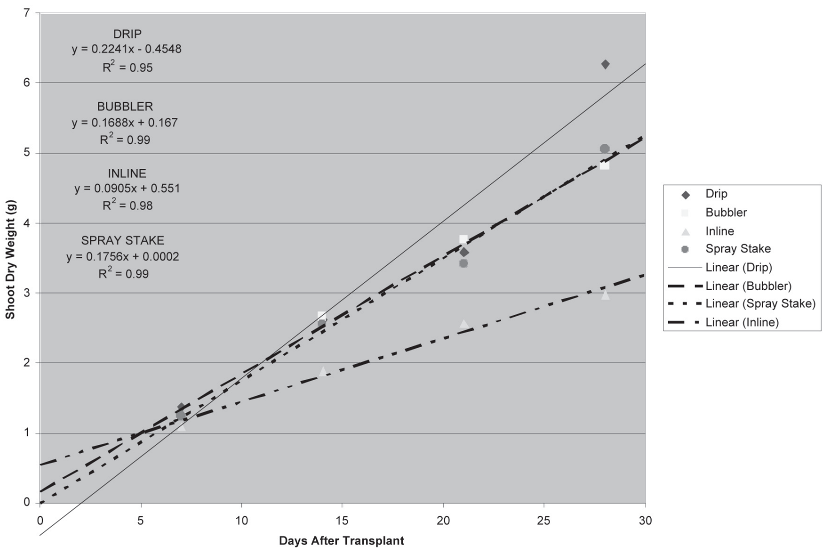
Figure 1. Effect of four microirrigation emitter types on shoot dry weight of marigold in the landscape over a 28 day period.



Hydrangea macrophylla as a Plant for Kentucky Landscapes

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Index Words: hardiness, cultivars

Significance to the Industry: This evaluation will allow Kentucky growers, as well as retail and landscape firms, have a better understanding of which *Hydrangea macrophylla* cultivars will survive across the state.

Nature of Work: During the last decade, *Hydrangea macrophylla* has enjoyed a resurgence as a dominate landscape plant. Selection and hybridization has yielded many new cultivars. During the late 1990's we concluded little was known about the usefulness of the wide range of cultivars for establishment in landscapes in the Ohio River Valley. Starting in 2000, we have established several evaluation plots at three locations (Table 1) across Kentucky as material of landscape size (No. 1 container) became available for use. Cultivars established after 2000 have six replications at each site. Specific cultivars have been established at one, two or three sites. Data is included for cultivars at multiple sites. We have now evaluated over 100 cultivars. Plants have been evaluated for winter hardiness and ability to flower. Quicksand and Lexington sites are on drip irrigation while the Paducah site is hand watered on an as needed basis.

Results and Discussion: Table 1 lists many of the cultivars evaluated. The data lists number of plants which no longer survived from the original planting when evaluated during spring 2006. Plants with no comments are still under review.

Table 1. Number of plants, out of 6, not surviving in the spring of 2006.

Name	Paducah	Quicksand	Lexington	Comments
All Summer Beauty	2	0*	0*	dependable
Alpenglow (Glowing Embers)		3*	2*	difficult to establish, limited bloom
Altona		0	5	
Amy Pasquier		0	1	
Arburg	2	1	0	
Blau Donau	1	2	0	
Blaumiese	0	1		
Blue Billow		1*	3*	no bloom
Blue Deckle		1	0	
Bodensee		0	2	
Böttstein	0	2	0	
Brestenburg		2	1	
Brugg	0	1	0	
Brunegg	4	1	0	

Brunette	1		0	
Burg Königstein	2	2	3	
Burg Rosenburg	2	2	0	
Cardinal Red		3	0	difficult to establish, no bloom
Coerula Lace		0*	0*	blooms extensively with little visual appeal
David Ramsey	0	4	0	blooms evident 1st year
Decatur Blue	1		3	
Domotoi	3		0	iffy bloomer
Dooley		0	0	
Dr. Benard Steinberg	3		0	
Dundalk	1	1	1	
Endless Summer' 'Bailmer'	2	4	0	blooms evident 1st year
Freudenstein	1	0	0	
Fuji Waterfall	3	4	2	questionable hardiness
Générale Vicomtesse de Vibrayé	2		2	
Goffersburg	4		6	questionable hardiness
Goliath	1	2*	3*	iffy bloomer
Habsburg	1	0	0	
Hamburg	2	2		
Harlequin	3	4		questionable hardiness
Hildegard	5	1	6	not hardy
Holstein	3	2	3	questionable hardiness
Horben	3	0	1	
Hörnli		1	l	
Kasteln	1	3	0	
Koralle	4	3	1	
Kuhnert	0	0	0	
Kurohime	0	2	1	
Kyosume		3	5	questionable hardiness
Lenzburg	2	0	2	
Liebegg	5	4	0	questionable hardiness
Lilacina		0	5	
Madame Emily Mouillére	1	0	3	
Madame Fousten Travouillon			0	
Masja		1	1	
Mathilda Gütges	4	6	0	
Merritt Supreme		0	1	
Merveille	5		0	
Monte Forte Perle	6	3	4	very questionable hardiness
Nikko Blue		0*	0*	dependable

Oak Hill	0	4	0	
Oregon Pride	4	1	0	
Parsival		1	3	
Penny Mac	0	2	1	blooms evident 1st year
Raymond Draps	3	3	0	
Red Cap	6	2	4	questionable hardiness
Red Star	0	0	2	
Regula	1	0	0	
Rosarita	0	1	0	
Rose Supreme	4	1	6	questionable hardiness
Rotdrössel		3	0	
Schenkenburg	3	2	0	
Souvenier du President Paul Doumer	2		0	
Stafford	5	2	0	
Tegerfelden	6	1	3	questionable hardiness
Teller White		0*	0*	iffy bloomer
Ticino	5	2	0	
Trotsburg	3	3	5	
Wartburg	2	1	2	
Wildegg	1	1	0	
Wildenstein	2	3	0	

*Cultivars in original plot in Lexington and Quicksand.

Success of Encore Azaleas in the Mid South

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Index Words: winter hardiness

Significance to Industry: Encore Azaleas® are popular in the deep-South because of their repeat blooming. Most Enore Azalea® cultivars performed well in winter hardiness zone 6b. In zone 6a, the best performing cultivars were Autumn Amethyst®, Autumn Cheer®, Autumn Royalty®, Autumn Ruby®, Autumn Sweetheart® and Autumn Twist®.

Nature of Work: Encore Azaleas® are popular in the deep south due to their repeat blooming and are rated for plant hardiness zone 7-9. However, the authors have observed these plants being sold in garden centers in central and eastern Tennessee (zone 6b). The objective of this study is to determine if Encore Azaleas® differed in winter hardiness in zones 6a and 6b at different locations in Tennessee. This paper will present data from year two of a five year study.

Landscape beds were prepared at five locations (Table 1) in Tennessee and twenty-one cultivars of Encore Azaleas® (Table 2) were transplanted into these beds in May to June, 2004. The plants were mulched (2-3 inches) with either softwood or hardwood bark to aid in water retention. Plants were irrigated with drip irrigation during the summer and fall months as needed. In late April to early May of 2005, plants were rated for cold hardiness using the following scale: 0 = no damage, 1= <10% shoots with tip burn or flower bud damage, 2=>10% shoots with tip burn or flower bud damage, no bark splitting, 3= >10% shoots with tip burn or flower bud damage and bark splitting on damaged shoots, 4= <50% shoots with tip burn or flower damage and bark splitting on damaged shoots, 5= >50% shoots with tip burn or flower damage and bark splitting on damaged shoots, and 6 = dead plant.

Results and Discussion: Little damage was observed on any cultivar in winter hardiness zone 6b with the exception of Autumn Coral® which had extensive cold damage (Table 2). In the zone 6a locations, Autumn Amethyst®, Autumn Cheer®, Autumn Royalty®, Autumn Ruby®, Autumn Sweetheart® and Autumn Twist® preformed well. The increase in length of time of flowering that was noted during the second bloom cycle at zone 6b locations was not observed at the zone 6a locations. At the zone 6a locations, eleven of the 21 cultivars did not have a repeat blooming cycle.

Table 1. Locations of Encore Azaleas® plantings in Tennessee (transplanted in 2004).

Location	Type of Landscape	Zone
Claiborne County	Full Sun	6a
Cumberland County	Full Sun	6a
Knox County	Full Shade	6b
Knox County	Partial Shade	6b
White County	Partial Shade	6b

Table 2. Comparison of cold hardiness[z] among cultivars of Encore Azaleas® in winter hardiness zone 6a and 6b.

	Zone 6a			Zone 6b		
	Days Flowering		WH[z]	Days Flowering		WH
Cultivar	Spring	Fall		Spring	Fall	
Autumn Amethyst®	17	12	1	16	74	0
Autumn Angel®	2	9	3	6	0	1
Autumn Bravo®	5	0	5	13	65	2
Autumn Carnation®	15	0	3	11	65	0
Autumn Carnival®	12	0	4	10	54	0
Autumn Cheer®	16	12	1	21	60	0
Autumn Chiffon®	17	7	5	13	86	1
Autumn Coral®	15	0	5	9	79	5
Autumn Debutant®	24	26	2	9	16	0
Autumn Embers®	13	81	1	11	0	3
Autumn Empress®	9	0	3	11	26	2
Autumn Monarch®	17	0	3	10	93	1
Autumn Princess®	25	0	2	8	30	2
Autumn Rouge®	22	0	2	14	86	0
Autumn Royalty®	21	9	1	19	58	1
Autumn Ruby®	23	26	1	19	26	0
Autumn Sangria®	10	14	2	16	54	0
Autumn Starlite®	3	7	4	19	16	0
Autumn Sunset®	17	26	3	14	14	0
Autumn Sweetheart®	10	14	2	18	35	0
Autumn Twist®	15	26	1	17	49	0
Standard Error of the Mean	4	6	1	3	14	1

[z]Winter hardiness was estimated using the following scale: 0 = no damage, 1= <10% shoots with tip burn or flower bud damage, 2=>10% shoots with tip burn or flower bud damage, no bark splitting, 3= >10% shoots with tip burn or flower bud damage and bark splitting on damaged shoots, 4= <50% shoots with tip burn or flower damage and bark splitting on damaged shoots, 5= >50% shoots with tip burn or flower damage and bark splitting on damaged shoots, and 6 = dead plant.

Tree Stabilization at Transplant

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Index Words: Balled and burlapped (B&B), Container-grown, Guying, Staking, Transplanting, Trunk support, Red maple, *Acer rubrum* L. 'Red Sunset', Bradford pear, *Pyrus calleryana* Decne. 'Bradford', Chinese pistache, *Pistacia chinensis* Bunge., Allée® Lacebark elm *Ulmus parvifolia* Jacq. 'Emerald Vase'

Significance to Industry: Methods and products used to stabilize trees at transplant are generally selected based on site conditions and locations, tree sizes and conditions, and planting and maintenance practices, but usually not on the nursery method used to produce the trees. Stabilization method had no effect on growth (as reflected by caliper increase) of container-grown maples, but length of stabilization did. Several products, which caused no negative effect after one year's use, after two years use had caused trunk compression (girdling) or bark damage. These negative effects reinforce the general recommendation to stabilize trees for no longer than one year.

Nature of Work: Tree planting specifications are more frequently developed and drawn assuming that the trees to be transplanted have been produced and harvested B&B. Larger caliper trees are being grown in increasing numbers in containers, and therefore certain aspects of tree transplanting, such as what product or method to use for stabilization, should be tested on trees grown using both production methods.

Appleton and Beatty found significant differences in caliper of Bradford pears (*Pyrus calleryana* Decne. 'Bradford'), but not of Chinese pistache (*Pistacia chinensis* Bunge.) or Allée® lacebark elm (*Ulmus parvifolia* Jacq. 'Emerald Vase' Allée®), one year after stabilization with a variety of above and below ground stabilization products (1). All of these test species were B&B. The purpose of this research was to therefore compare above and below ground stabilization methods using container-grown trees.

In April 2004, two blocks each of 50 approximately 5 cm (2 in) caliper red maples (*Acer rubrum* 'Red Sunset') were planted at the Hampton Roads Agricultural Research and Extension Center, Virginia Beach. Stabilization products applied to one block were to remain in place for one calendar year, and to the other for two calendar years. The 10 treatments used in the one year block were: control (no stabilization); six above-ground methods - two wooden stakes (TWS) with poly chain lock guying, TWS with Tree Support System, one fiberglass pole Reddy Stake, one metal T-post with Tree-MATE-O, three Arbor Guy anchors and guying, three Berkshire anchors and guying; two below-ground methods – two Tomahawks, and four short wooden stakes with cross pieces (2); and one combination above and below-ground method – Arbor Stake.

The 10 treatments used in the two year block were the same as in the one year block with the exception of TWS with TMO Pro replacing the Arbor Stake treatment. Treatments were replicated five times in a randomized complete block design. Trunks were permanently marked at the 15 cm (6 in) and 76 cm (30 in) levels and initial calipers recorded.

Results and Discussion: All stabilization products were removed from the one year block in April 2005 and calipers recorded (data subjected to ANOVA). At removal all products were still intact, and no significant damage was seen on the tree trunks. No significant differences in caliper increase occurred at the 15 cm (6 in) height, but significant differences in caliper did occur at the 76 cm (30 in) height (Table 1).

When the stabilization products were removed from the two year block in April 2006, several products had begun to degrade or come apart. The rubber band guying on both Tree-Mate-O products was missing on several trees, or if present, had begun to imprint a slight pattern into the bark. The guying (Arbor Tie) of the Arbor Guy had frayed and broken on all trees, and the Tree Supports on four of five trees had opened. Significant trunk damage had occurred with three products. The Tree Support had girdled a band the width of the product, and bark tissue below had begun to dry and crack. The guying for the Berkshire Anchor and the Arbor Guy had become embedded into the trunk tissue in several trunk/branch crotches and could either not be removed, or not be removed without further wounding the trees.

As to trunk caliper increases for the two year block, there were no significant differences at either height. Had the products been left for an additional year (total of three years), significant caliper differences would have been expected at the 76 cm (30 in) height, not due to normal tree growth, but due to girdling that was already evident with the Tree Support product. Visible trunk swelling had started on the upper edge of the product due to constriction of the phloem tissue.

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Table 1. Change in red maple trunk caliper at 76 cm (30 in) height in response to tree stabilization methods applied for one year.

Stabilization Product	Caliper change – 76 cm (30 in) above ground[x]
AG[z] – Stakes/poly chain lock	1.9 cm (0.7 in) a
BG[y] – Wooden stakes	1.8 (0.7) ab
AG – Reddy Stake	1.8 (0.7) ab
AG – Tree Support	1.7 (0.7) ab
AG – Tree-Mate-O	1.6 (0.6) b
AG – Arbor Guy	1.6 (0.6) b
AG – Berkshire Anchor	1.6 (0.6) b
Control – no stabilization	1.6 (0.6) b
AG/BG – Arbor Stake	1.5 (0.6) b
BG - Tomahawk	1.5 (0.6) b

[z]AG – Above ground.

[y]BG – Below ground.

[x]Mean separation within column by protected LSD, P=0.05.

Evaluation of Treated Effluent Applied as Drip Irrigation to Landscape Plants

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Index Words: municipal wastewater, non-potable, reclaimed water, reuse water, salt tolerance, sewage effluent, water management, water quality

Significance to the Industry: A potential supplemental or alternative irrigation source for the nursery and landscape industries is treated effluent from municipal wastewater treatment plants. Valuable fresh (potable) water supplies can be conserved by using treated effluent (non-potable water). Treated effluent is also generally less expensive than potable water (2), which can significantly impact an irrigation budget. In addition, using treated effluent for irrigation could significantly impact waste water disposal and water use restrictions. The treated effluent used in this study was too saline to be used for continuous or long term irrigation.

Nature of Work: Water quality is extremely important when deciding whether treated effluent is a viable irrigation water option (7). A particular concern when using treated effluent for irrigation is soluble salt concentrations. Salt tolerances vary between landscape plant species, and can even vary from one cultivar to another (1,4), which can influence plant selection, irrigation method, and frequency. Salt concentrations, mainly from sodium (Na), chloride (Cl), and bicarbonate (HCO_3) ions, should be carefully monitored because treated effluent can have concentrations of these salts that are too high for irrigation without further treatment or dilution (6). Many landscape plants exhibit foliar damage when irrigated with treated effluent due to salty irrigation water or drifting spray repeatedly contacting foliage (3). Long term irrigation with treated effluent can cause salt build up in the soil which can lead to foliar burn or chlorosis and even stunting and plant mortality. Previous studies by Fox et al. showed that overhead irrigation with Hampton Roads Sanitation District Virginia Initiative Plant (HRSD VIP) treated effluent caused significant plant injury and salt buildup in the soil (5).

One method for evaluating the suitability of treated effluent water for irrigation involves testing for electrical conductivity (EC), which is directly related to total salt ion concentration. Water tests should be done regularly because the quality of treated effluent water can vary over time. Though EC levels give a general guide to water quality, individual ion concentrations, especially Na, Cl, and HCO_3 still need to be monitored.

Soil drainage characteristics and composition of soil can influence the severity of plant damage from irrigation water with high salt content. For example, clay soils and soils high in organic matter exhibit faster and higher levels of sodium buildup than sandy soils (4). This is especially important when irrigation water with high soluble salts levels is applied on a long-term basis.

The type of irrigation system used can affect the severity of plant damage from salty irrigation water. More damage gradually occurs with overhead irrigation than drip because saline water coats plants repeatedly, burning and desiccating sensitive species foliage (8).

Finally, microclimate can influence the severity of plant damage. Regions with moderate temperatures and adequate rainfall have fewer problems than regions that regularly experience high temperatures, low precipitation, or drought. Rainfall washes salt from irrigation water off foliage and leaches it through the soil profile, reducing or eliminating potential salt related damage.

The study evaluated the treated effluent produced by the HRSD VIP as an irrigation source for landscape plants common to eastern Virginia. Twenty four species were installed in raised beds and irrigated with one inch of water per week in a split application using a drip system for four months. Soil and water samples and plant aesthetic quality ratings were taken every four weeks. The study was a randomized complete block design with two treatments (potable, non-potable) and three replications.

Results and Discussion: Electrical conductivity (EC) measurements over the four months of the study were consistently higher for the treated effluent than for the potable water (Fig. 1), frequently above the .75 dSm^{-1} considered safe for landscape plants (1). As electrical conductivity is directly related to total salt ion concentrations, sodium (Na) and chloride (Cl) ion concentrations were monitored. Levels of these ions followed the same trend as the EC (Fig. 2). Electrical conductivity and sodium and chloride ion levels were abnormally low for August due to the dilution effect of excessive rainfall, 18.8 cm (7.4 in) over the three days prior to sample collection and analysis. Bicarbonate (HCO_3) ion levels (Fig. 2) were also monitored since large amounts can precipitate calcium, leading to sodium buildup in the soil. Though bicarbonate ion levels were consistently higher in the treated effluent, they remained in the slight to moderate potential hazard range. Factors that contributed to the elevated salt ion concentrations in the treated effluent water include: the number of industries contributing and quantity of contributed effluent, number and length of stay of naval ships docked at the Norfolk Naval Shipyard, and the specific process used to treat the effluent (personal communication with George Kennedy, Environmental Scientist, HRSD). Average water pH was 7.2 +/- .5 for both treatments.

Soil in beds irrigated with treated effluent water had higher sodium and chloride ion levels than soil irrigated with potable water (Fig. 3). While rainfall amounts were average and above during the study (Fig. 4), the soil was not leached sufficiently to prevent the sodium and chloride salts from accumulating over the four months. When salts accumulate to high enough levels in the soil, plants will exhibit characteristic injury symptoms including tip and/or marginal leaf burn, chlorosis, necrosis, deformity, early defoliation, plant stunting, and even death. No significant differences were observed in the aesthetic quality ratings of the plants between the two irrigation treatments (Data not shown).

Use of drip irrigation eliminates the potential injury to plant foliage which can occur from frequent exposure to salty irrigation water as with overhead systems.

Drip irrigation also provides more efficient delivery of irrigation water. While no injury was observed on the plants drip irrigated with HRSD VIP treated effluent in the four months of this study, high salt ion levels in the effluent and subsequent increasing salts levels in the effluent treated soils indicate the potential for problems to occur with long term use of this water source. Though a very modern sewage treatment facility, the current treatment processes at the HRSD VIP do not reduce salt ion concentrations enough to permit use of this treated effluent as the only source of irrigation for landscape plants. Supplemental irrigation from natural rainfall or a potable water source is necessary to prevent salts from accumulating in the soil and the subsequent damage which would make plants aesthetically unacceptable in the landscape. Careful consideration should be given to initial and replacement plant selection when irrigating with treated effluent containing high soluble salts, even when using drip irrigation.

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Figure 1. Electrical conductivity of potable vs. non- potable (treated effluent) water, 2004.

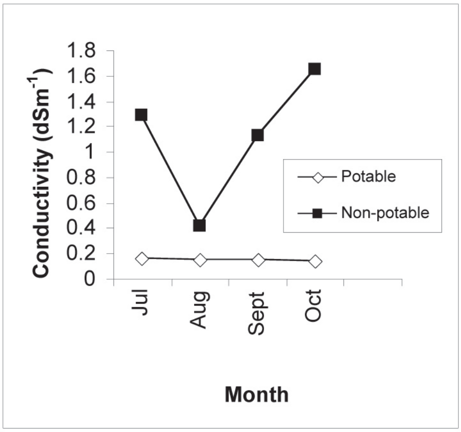

Figure 2. Sodium (Na), chloride (Cl), and bicarbonate (HCO_3) levels July through October, 2004, for potable (P) and non-potable (NP) drip irrigation treatments.

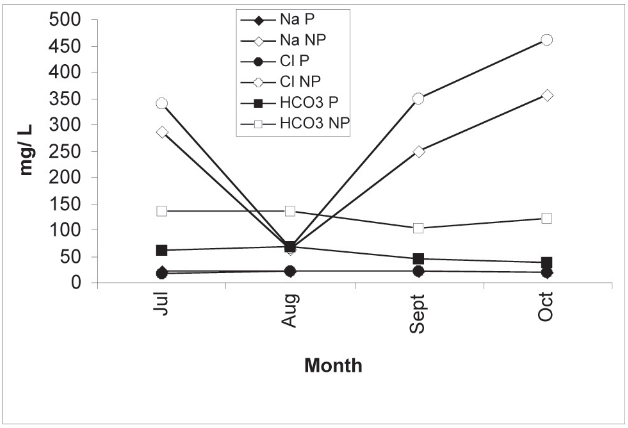

Figure 3. Soil sodium (Na) and chloride (Cl) levels July through October, 2004, for beds drip- irrigated with potable (P) and non-potable (NP) water treatments. Each point represents the average of three replications.

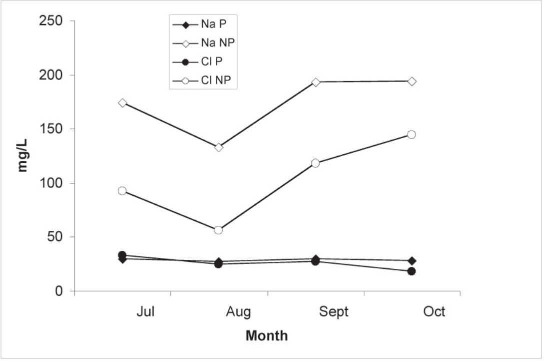

Figure 4. Rainfall totals for HRSD VIP 2004 and City of Norfolk average.

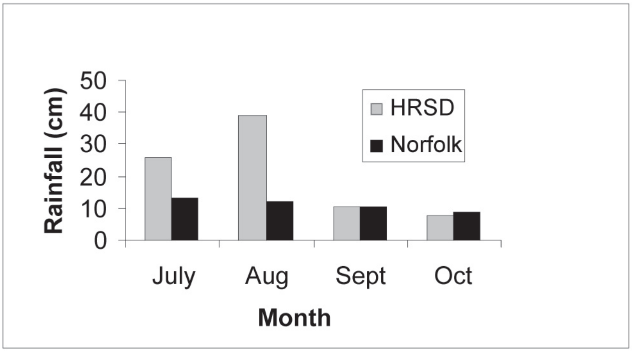

Table 1. Species used.

Annual
- annual vinca (*Catharanthus roseus* L. 'Red Cooler')
- geranium (*Pelargonium* x *hortulanum* L.H. Bail.)
- marigold (*Tagetes erecta* L. 'Janie Deep Orange')
- petunia (*Petunia* x *hybrida* L. 'Dreams Red')

Perennial
- black-eyed Susan (*Rudbeckia fulgida* var. *sullivantii* Boynt. & Beadle 'Goldsturm')
- daylily (*Hemerocallis* L. 'Stella d'Oro')
- liriope (*Liriope muscari* (Decne.) L.H. Bail. 'Variegata')
- sage (*Salvia nemorosa* L. 'May Night')
- sedum (*Sedum* L. x 'Autumn Joy')

Shrub
- arborvitae (*Thuja occidentalis* L. 'Emerald')
- abelia (*Abelia* x *grandiflora* (Andre) Rehd. 'Little Richard')
- barberry (*Berberis thunbergii* DC. 'Crimson Pygmy')
- boxwood (*Buxus microphylla* Sieb. & Zucc. 'Wintergreen')
- cherrylaurel (*Prunus laurocerasus* L. 'Otto Luyken')
- gardenia (*Gardenia augusta* (L.) Merrill. 'Chuck Hayes')
- juniper (*Juniperus chinensis* L. var. *sargentii* 'Viridis')
- dwarf nandina (*Nandina domestica* Thunb. 'Harbor Dwarf')
- mugo pine (*Pinus mugo* Turra.)
- pyracantha (*Pyracantha koidzumii* (Hayara) Rehd. 'Victory')
- St. John's wort (*Hypericum patulum* L. 'Hidcote')
- Japanese spiraea (*Spiraea japonica* L. 'Neon Flash')
- dwarf viburnum (*Viburnum tinus* L. 'Compactum')

Tree
- red maple (*Acer rubrum* L. 'Red Sunset')
- river birch (*Betula nigra* L.)

Invasive Plant Species – What Are They and What Do We Do About Them?

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Significance to the Industry: The nursery and landscape industries are facing increased attention and scrutiny on the topic of invasive non-indigenous plant species (NIS). This attention is due to the fact that invasive NIS result in formidable economic costs and profound environmental impacts. To date, these industries have not taken substantive efforts to address the invasive NIS problem. These industries should educate their personnel on the fundamentals of invasive NIS so that personnel may make informed decisions on the sale and planting of invasive NIS.

Nature of Work: The nursery and landscape industries sell and plant hundreds of NIS. The vast majority of these have graced our landscapes with untold positive impacts. However, these industries are responsible for introducing numerous invasive NIS that are associated with negative economic and environmental impacts ranging from minor to major. Reichard (8) calculated that 85% of the 235 known invasive woody NIS in the U.S. owe their introduction to the nursery and landscape trade. Invasive NIS affect natural areas and the loss of biodiversity is incalculable. Media exposure has increased citizen awareness of invasive NIS. In the first four months of 2006, the Washington Post published 22 articles on invasive NIS. Legislators are also aware of invasive NIS. Laws in New Hampshire (http://gencourt.state.nh.us/rules/agr3800.html) and Massachusetts (http://www.mass.gov/ agr/farmproducts/proposed_prohibited_plant_list_v12-12-05.htm) ban the sale, distribution, and propagation of three very common landscape species, Norway maple, Japanese barberry, and burning bush. Thus, the movement to regulate NIS is clearly gaining momentum. The nursery and landscape industries have not made a substantive effort to educate its personnel on invasive NIS. This lack of action gives the impression that these industries are avoiding the issue at hand, and gives environmental groups a one-sided forum, and legislators a free hand to enact laws without a scientific foundation.

There is much confusion and debate about the definition of an invasive species. There are two fundamental interpretations of the definition of invasive species. Some ecologists interpret invasive as being described as a non-indigenous species which spreads into a new area (2,9). The other interpretation regards invasive as a non-indigenous species which spreads into a new area and has an impact on that area (3,7). The meaning of impact is also subject to interpretation and will be addressed later. The U.S. legal definition of invasive plant (Invasive Species Executive Order 13112; Federal Register, Presidential Documents 1999) is “Invasive species means an alien species whose introduction does or is likely to cause economic or environmental harm or harm to human health.”

What is impact? The impact criterion is imbued with ambiguity and can be viewed in different criteria depending on one's perspective. Daehler (2) contends that "All species that meet the spread criterion probably have ecological and environmental impacts, although for most non-indigenous species, these impacts have not been adequately quantified." Davis and Thompson (4) counter Daehler's contentions by stating that "outside of the discipline of ecology, "invasive species" are usually explicitly defined on the basis of their impact." They also contend that consolidating all NIS into the "invader" category contributes "to a belief that invasions are a unique ecological phenomenon, which we believe has hindered ecologists' efforts to understand the invasion process." They see value in segregating invasive plants on the basis of impact which may then lead to discovering the traits that are unique to "high impact" invaders. To lump all invasive NIS into one group is, from a practical perspective, too inclusive since the impact of invasive NIS can range from relatively innocuous to very environmentally disruptive (5). This is an especially relevant point considering the ornamental horticulture industry sells many plants that spread outside of planted sites but have no apparent environmental impact.

The contention that NIS are a major environmental concern should be tempered with the fact that the proportion of NIS plants that become invasive is quite small. Williamson and Fitter (10) developed the "tens rule" that, in essence, states that only one percent of introduced species becomes a pest (negative economic effect). Isaacson (6), in an inventory of North American seed and nursery catalogs (1988-1989), records almost 60,000 plant taxa sold. Applying the tens rule to this 60,000 number, approximately 60 taxa would become a pest. Sixty can be construed as a relatively small number; however, this apparently low count belies the negative ecological effects of even a single species such as the catastrophic environmental and economic effects of kudzu in the southeastern U.S or melaleuca in the Florida Everglades. The tens rule does not also take into account the unique situation of garden plants in which plants are sold year after year and planted in all parts of the country.

The first and foremost step for the ornamental horticulture industry to take is to educate industry personnel. Personnel need to know: 1) the fundamental aspects of invasive species, 2) the landscape species which have been scientifically documented to be invasive and what impact they have on natural environments, 3) the region in which these invasive NIS are a problem, and 4) alternative species to be used in place of invasive NIS. The most efficient and cost-effective venue for this information will be a web site funded by the American Landscape and Nursery Association (ANLA) that is developed by an impartial science-based party such as university faculty. The benefits of the educational invasive plant web site are: 1) Nursery/landscape industry personnel will be empowered with objective information to address invasive plant issues and make region-dependent, species selection decisions based on scientific documentation.
2) The nursery/landscape industry will demonstrate a proactive approach towards invasive NIS, and thereby will be perceived as a responsible steward of the land. This approach will constitute a "best management practices" effort and serve as leverage in any legal battles concerning potential invasive NIS legislation. 3) The invasive NIS situation is dynamic and the web site can be updated as needed.

The ornamental horticulture industry must emerge from its quiet position on invasive NIS and educate its personnel. Such a proactive measure will yield environmental and public image dividends.

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Trees: A Vital Component of a Novel Design for Storm Water Management

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Index Words: *Acer rubrum*, *Fraxinus pennsylvanica*, *Quercus bicolor*, *Quercus velutina*, drainage, root growth, soil compaction, structural soil, transpiration, urban

Significance to Industry: Two experiments are described that test the efficacy of trees as a vital component of a novel stormwater management system for urban areas. In this system, stormwater is stored under pavement in a special substrate (structural soil) that meets engineering specifications for load bearing yet sustains healthy tree growth. Data presented here suggest that trees will be able to thrive in systems where drainage is not severely retarded and that trees may help water drain below such systems if roots are able to penetrate the subsoil. Such a system will provide a pleasing, tree-shaded urban landscape while aiding in stormwater management.

Nature of work: Trees in urban settings frequently suffer, decline and die prematurely as a result of the limited rooting volume imposed by intentional or unintentional soil compaction [1, 2]. One solution is the use of "structural soils", such as that developed at Cornell University in Ithaca, NY, which meet engineering specifications for load bearing yet still provide large voids that can be penetrated by roots [3]. Another challenge in urban settings is stormwater management. An increase in paved surfaces have resulted in a huge increase in stormwater runoff, and thus pollution of water bodies [4] whereas legal mandates for retention in areas where available land is very limited and expensive have created a critical need for novel solutions [5].

The overall objective of this study is to determine if a combination of structural soil and trees is a suitable system to manage stormwater in urban settings. Such a system will potentially consist of a parking lot with healthy trees in which stormwater is directed into a reservoir of structural soil below. Besides the usual amenities associated with healthy urban trees, trees may also aid in stormwater abatement through transpiration and facilitation of drainage below the structural soil profile through root growth into the subsoil below. Our research seeks to answer two major questions: 1) Will such system support tree growth? and 2) Do trees contribute to storm water removal?

Experiment 1 utilizes two bottomland species, swamp white Oak (*Quercus bicolor*) and green ash (*Fraxinus pennsylvanica*). It has been reported that such bottomland species may be inherently more tolerant of the compacted soils common in urban environments because they are able to exploit wet soils that are soft, yet low in oxygen [6]. In spring 2005, two-year-old trees of both species were obtained from J. Frank Scmidt and Sons Nursery, Inc. (Boring, OR) and planted bare root into 25-gal containers without drainage holes on June 1, 2005.

Containers were filled with Cornel Structural Soil (CSS; http://www.hort.cornell.edu/uhi/outreach/csc/) or Stalight, an expanded rock product (Carolina Stalite, Salisbury, NC; http://www.stalite.com/). Both species were planted in CSS, whereas green ash was also planted in Stalite. All trees were exposed to fluctuating water tables, intended to mimic slow, medium, or high infiltration rate of subsoil, beginning July 27, 2005. For this purpose, we developed a system with a transparent ¾” diameter tube which penetrates the growing container about ½” above the bottom. With this system we are able to monitor the water table and lower the water table by releasing water through the tube (Figs. 1 and 2). A container with a full water table held 16 inches of water. Spigots allowed for drainage down to 8 inches, 4 inches, or 0 inches deep. Treatment 1 (high drainage rate) containers were filled with16 inches of water one morning and emptied the next morning (2-day cycle). Treatment 2 (medium drainage) was filled with water one morning, lowered to 8 inches the next morning, and emptied the third morning (3-day cycle). Treatment 3 was filled with water one morning, lowered to 12 inches, 8 inches, 4 inches, and 0 inches in five day intervals (25 day cycle). The ability of the trees to lower water table will be measured frequently with a porometer and a sap flow gage throughout the summer of 2006. At the end of 2006, we will evaluate top growth and root development in these different fluctuating water table scenarios. Leaf area and root system morphology will be measured at the end of the experiment.

In Experiment 2, two-year-old black oak (*Quercus velutina*) and red maple (*Acer rubrum*) bare-root seedlings were obtained from Heritage seedlings, Inc., Salem, OR. Trees were planted on February 10, 2006 in a 6-inch diameter by 5-inch deep cylinder of pine bark substrate which was embedded in compacted (two grades of compaction) or not compacted C-horizon clay loam subsoil (removed below a Groseclose silt loam soil) in 7-gallon containers (Fig. 3). Mineral soil was evenly compacted below and around the cylinders of pine bark by utilizing a previously determined number of hits with a standard Proctor hammer against a wooden block placed on top of the soil. Compaction levels of high (severely compacted) and medium (medium compacted) were achieved as well as an uncompacted control. Bulk density measurements will be made at the end of the experiment to confirm compaction levels. There were approximately 5 inches of soil between the bottom of the pine bark cylinder and the bottom of the container. Infiltration was measured on May 15 by pouring 0.26 gal (1 liter) of water into the pine bark cylinder and noting the time required for water to begin to drain out from bottom drainage holes. All soil and substrate were soaked for two days and allowed to reach container capacity before measurement of infiltration. Changes in infiltration rate will be measured throughout 2006 to determine whether infiltration rate is significantly improved due to tree root growth into the surrounding mineral soil.

In addition to the experiments described above, a model parking lot system was constructed in which water table levels and root growth will be monitored via mini-rhizotron systems. This manuscript reports on early porometer data from experiment 1 and infiltration data from experiment 2.

Results and Discussion: In experiment 1, first results suggest a relationship between the infiltration rate and the transpiration rate (Figs. 4-6). Except for green ash grown in Stalite, trees show the lowest transpiration rate for the lowest infiltration rate regime and the highest transpiration rate for the medium infiltration rate regime. The high water tables in the low infiltration treatment apparently had a negative effect on transpiration rate due to low aeration. Although no effect on top growth or appearance of trees in the low infiltration treatment was obvious (data not shown), symptoms may develop with extended time. Water tables at the medium infiltration rate probably provide sufficient water and oxygen for these species. An unexplained lower transpiration rate is evident for green ash in Stalite vs. CSS (Figs. 4 and 5). This generally lower transpiration rate will be closely monitored to see if it is transitory. Figure 6 suggests that swamp white oak is adapted to medium infiltration rates, reflecting the ecology of this flood plain species.

Experiment 2 indicates lower infiltration rate (longer time to infiltrate) for the highly compacted subsoil compared to medium soil compaction (Fig. 7). It also indicates that root growth of black oak was more influential on drainage than roots of red maple. This species difference may be due to root structure differences. Black oak appears to have a much coarser root system and may open up drainage channels more effectively. In addition, red maples suffered somewhat from aphid and mite infestation which influenced their growth in general. The low (uncompacted) treatment had unexpectedly low infiltration rates. These low rates may be undetermined artifacts from the setup process.

In summary, stormwater management systems are necessary to decrease pollution of public waterways caused by urban runoff, and they are increasingly mandated to be on site. One solution may be a combination of structural soil and trees. Our data indicate that green ash and swamp white oak are tolerant of the fluctuating water tables that will likely be part of such a system, although very slow drainage may negatively affect transpiration rate and consequently reduce the capacity to remove water from the reservoir by transpiration. The contribution to stormwater removal by trees in this system is not clear at this point. Root growth into the subsoil below such systems should aid infiltration.

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Figure 1. Schematic drawing of flooding treatments for Experiment 1.

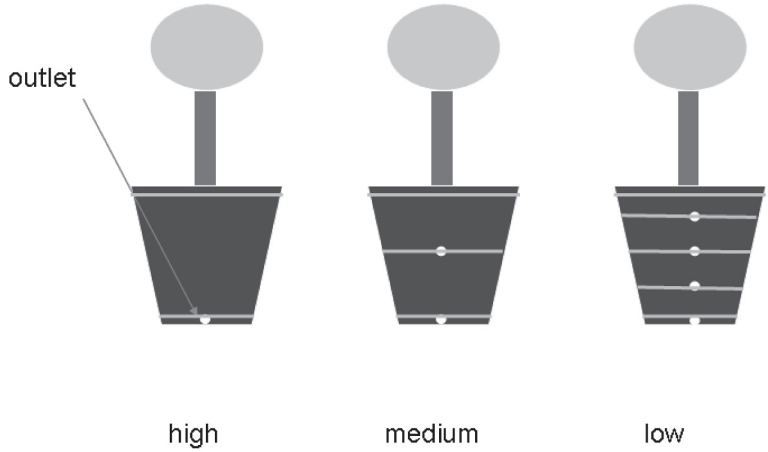


Figure 2. Picture of setup for Experiment 1.

Figure 3. Schematic drawing of Experiment 2.

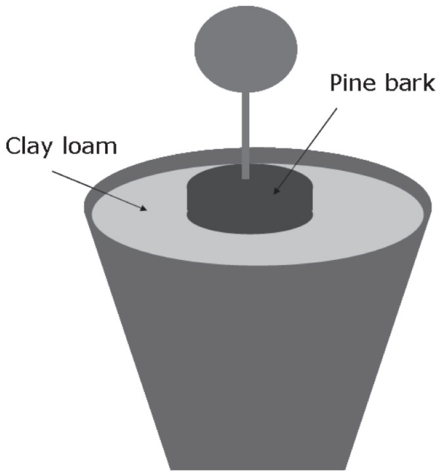


Figure 4. *Experiment 1.* Day-long transpiration rates of green ash growing in Stalite and subjected to three drainage regimes. Measurements were made with a Porometer on May 09, 2006. n=5.

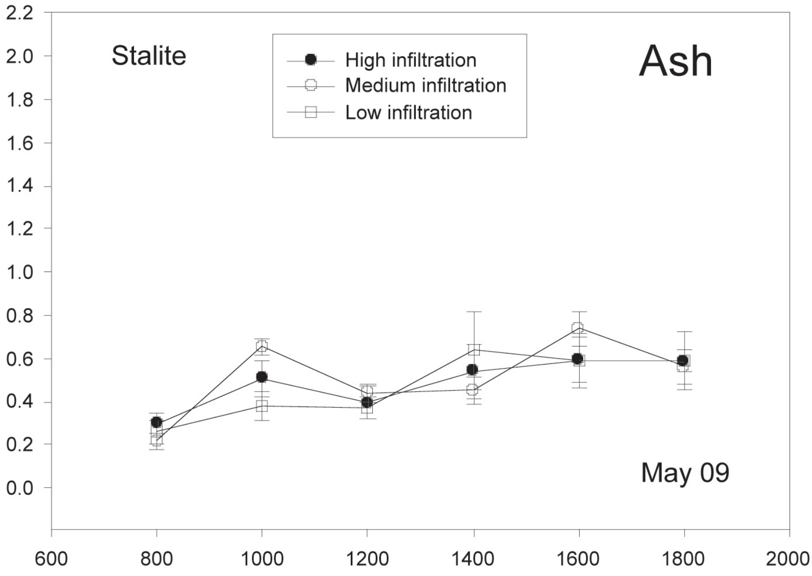


Figure 5. *Experiment 1.* Day-long transpiration rates of green ash growing in Cornell Structural Soil (CSS) and subjected to three drainage regimes. Measurements were made with a Porometer on May 09, 2006. n=5.

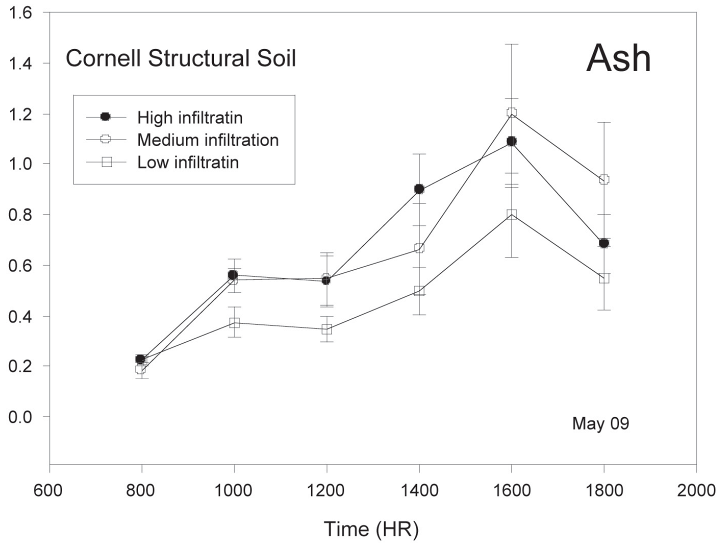


Figure 6. *Experiment 1.* Day-long transpiration rates of swamp white oak growing in Cornell Structural Soil (CSS) and subjected to three drainage regimes. Measurements were made with a Porometer on May 09, 2006. n=5.

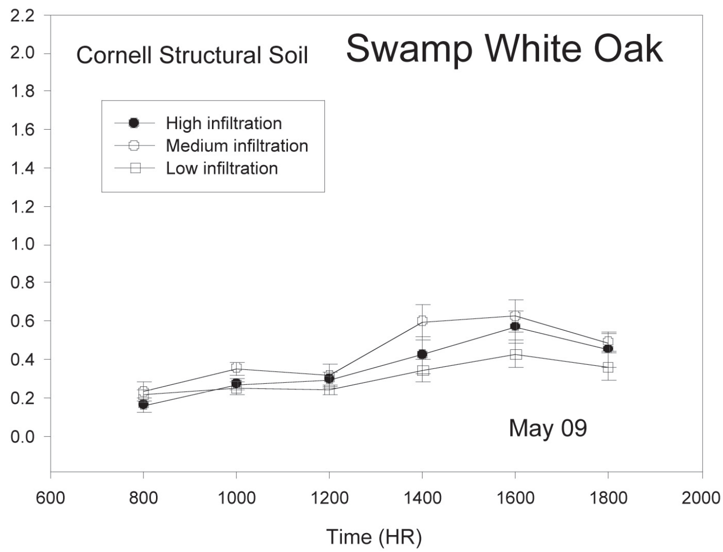
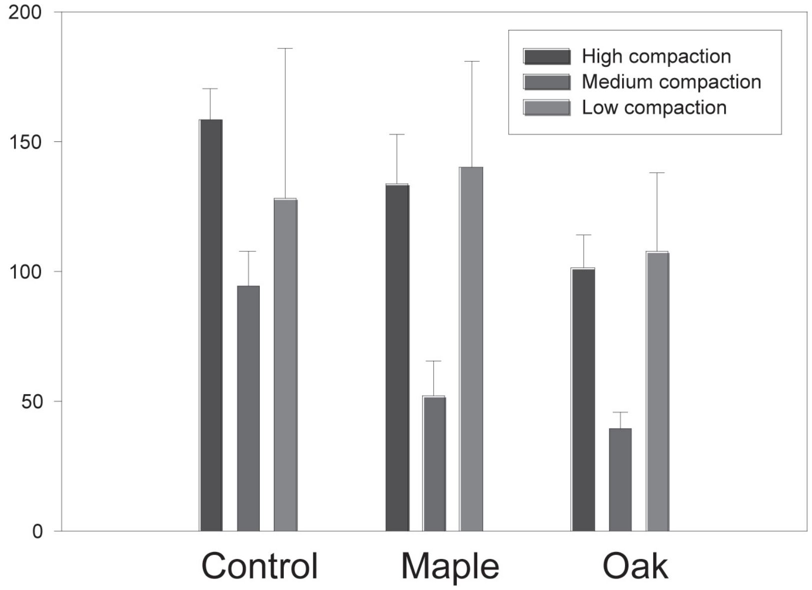


Figure 7. *Experiment 2.* Time required for irrigation water to drain through subsoil of three compaction levels for red oak and red maple. N=5.



Influences of Soil Amendments and Microtopography on Young Tree Growth at a Created Wetland in Eastern Virginia

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Index Words: *Taxodium distichum*, compost, topsoil, wetland mitigation, tree establishment, tree adaptation

Significance to Industry: Wetland creation practices used today often have negative impacts to the timely development of wetland functions in created ecosystems because they drastically compact the soil, remove organic material and alter the natural microtopography from the site. Changing construction practices so that organic matter and microtopography are reinstated may improve tree growth and establishment in created wetlands, thereby ultimately reestablishing desirable wetland functions. Production of wetland mitigation plants can be a profitable niche for nursery growers

Nature of Work: In October 2003, five soil treatments: 1) control (existing sandy dredge spoil), 2) 1 x (78 wet Mg/ha or 35 tons/acre) yardwaste compost (Grind-All LLC, Richmond, VA), 3) 2 x (156 wet Mg/ha or 70 tons/acre) yardwaste compost, 4) 1 x yardwaste compost + topsoil and 5) topsoil alone, were installed in a completely random design to 21, 6.1 m x 6.1 m (20 ft x 20 ft) treatment plots at the Weanack Wetland Mitigation Site in Charles City, VA. All treatments (including the control) received 10-10-10 fertilizer (LESCO Brand provided by Wetsel, Inc., Harrisonburg, VA) applied at 280 kg/ha (250 lbs/acre). Four replications were made for each soil treatment except for the control which has five replications. After the installation of these plots, microtopography (pits and adjacent mounds) were hand installed to each plot. Pits were approximately 75 cm (2.5 ft) wide and 20 cm (8 in) deep. The soil removed from the pit was used to make the mounds, making them approximately 75 cm (2.5 ft) wide and 20 cm (8 in) tall. In April 2004, two-year-old containerized bald cypress (*Taxodium distichum*) trees were planted in each pit and mound. One-to-three additional bald cypress trees were planted in each plot at level elevation. In May 2006, all trees were numbered and measured at the research site. Height, trunk diameter 10 cm (4 in) above ground, trunk diameter 30.5 cm (12 in) above ground, the difference between trunk diameter at four inches and 30. 5 cm (12 in), crown (branch) spread (measured as average between widest and perpendicular direction), and number of branches originating from trunk were measured on 25 May 25 2006. The trunk diameter at 10 cm (4 in), 30.5 cm (12 in) and the difference are considered measures of acclimation to wetland conditions for bald cypress.

Results and Discussion: All data were analyzed within the GLM procedure of SAS (SAS Institute, Inc., Carey, NC). Table 1 reports the resulting *p*-values from the 2-way ANOVA for all measured characteristics for treatments (soil treatment and microtopography) and interactions between treatments (soil treatment x microtopography). There was very little evidence for an interaction effect or an effect of soil treatment for all measured characteristics. In addition, there was very little evidence for effects of microtopography on crown diameter or on the number of main branches. However, there was strong evidence for microtopography effects on height and trunk diameter measurements, so treatment means were separated utilizing Duncan's Multiple Range Test (DMRT).

Table 2 shows the results from DMRT for microtopography effects. Treatment effect on height was not evident, but regardless of soil treatment, trees growing in pits were significantly larger in mean trunk diameter at four inches, mean trunk diameter at 30.5 cm (12 in) and the difference between these two measurements.

These results suggest that trees growing in pit microtopography yields the largest trees and that these trees show adaptation to the wetland conditions. Increased basal swelling (hypertrophy) for bald cypress trees should be expected to be larger for a tree growing in the pit microtopography since the elevation is lower and total saturation of the soil is more likely. These trees may be better adapted to the periodic flooding that takes place in wetlands. Although soil treatments and interactions between soil treatment and microtopography did not influence any of the measured tree characteristics, herbaceous plant populations will be assessed in the future, and soil treatment may have a greater impact on these types of plants.

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Table 1. *p*-values from 2-way Analysis of Variance for mean height (HT), trunk diameter 4” above ground (DIA 4), 12” above ground (DIA 12), difference between trunk diameter at 4” and 12” above ground (D4-D12), crown diameter (CR DIA) and number of branches originating from trunk (BRANCH)[z].

	P>F					
Treatment	HT (cm)	DIA 4 (mm)	DIA 12 (mm)	D4-D12 (mm)	CR DIA (cm)	BRANCH
Soil treatment (ST)	0.7744	0.8397	0.8579	0.7183	0.9805	0.3805
Microtopography (MI)	0.0635	< 0.0001	< 0.0001	0.0003	0.3468	0.6031
ST x MI	0.8661	0.8349	0.9163	0.2658	0.8419	0.7717

[z]N= 20 for pit, 18 for mound, and 22 for level.

Table 2. Mean height (HT), trunk diameter 4” above ground (DIA 4), 12” above ground (DIA 12), and difference between trunk diameter at 4” and 12” above ground (D4-D12)[z].

Microtopography	HT (cm)	DIA 4 (mm)	DIA 12 (mm)	D4-D12 (mm)
Pit	128.55 a[y]	27.05 a	20.31 a	6.74 a
Mound	115.25 a	19.11 b	14.78 b	4.33 b
Level	114.21 a	19.36 b	13.96 b	5.40 b

[z]N= 20 for pit, 18 for mound, and 22 for level.

[y]Letters indicate difference among means according to Duncan’s Multiple Range Test (α =0.05).