Landscape

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Section Editor and Moderator
Non-invasive Alternatives to *Stachytarpheta cayennensis* (Nettleleaf porterweed) Grown in North and South FL

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Index Words. Invasive, native, cultivar trialing, flow cytometry, seed germination

**Significance to Industry:** The probability of plants becoming naturalized increases significantly with the number of years plants are marketed (Pemberton and Liu, 2009). If control is postponed until a late stage of widespread infestation, it is on average 40 times more expensive than early removal (Harris and Timmins, 2009). Nettleleaf porterweed (*Stachytarpheta cayennensis*) is a potentially invasive ornamental plant in Florida (FLEPPC, 2009). Field trials were conducted in north and south FL to compare nettleleaf porterweed with seven potential alternatives. During the course of the 28 week study, nettleleaf porterweed produced the greatest number of spiked inflorescences with up to 80% seed viability and 73% pollen stainability. Several cultivars were identified ('Mario Pollsa', 'Violacea', and 'Naples Lilac') as having no or low seed viability, low pollen stainability, and good landscape performance (visual quality and flowering).

**Nature of Work:** As the fastest growing segment of U.S. Agriculture, ornamental horticulture has been recognized as the main source of plant invasions worldwide (Dehnen-Schmutz et al., 2007). More than 2/3rds of the Category I and II invasives listed by the Florida Exotic Pest Plant Council (FLEPPC, 2009) were introduced for ornamental use, and of these we estimate that 27% are still in commercial production. Desirable attributes of nettleleaf porterweed are its long period of profuse and vibrantly colored flowers that attract butterflies, and adaptability to a range of landscape conditions; yet a consequence of this is its ability to self-seed and readily naturalize in areas far beyond its planting. Nettleleaf porterweed has been found in 18 conservation areas in Florida (Gann et al., 2008) and is problematic in other parts of the world including the Pacific Islands and Australia.

As potential alternatives to the resident species (or wildtype form) of nettleleaf porterweed, seven porterweed species (Table 1) were propagated and installed under full sun conditions in south FL (Fort Pierce, USDA zone 9b) and (north) FL (Quincy, USDA zone 8b). A randomized complete block experimental design was used with eight cultivars placed in three-plant plots replicated three times (blocks). Plants were
irrigated and fertilized similarly among sites. For 28 weeks, plants were evaluated each month for visual quality, flowering, and seed production. Assessments of foliage color and form were performed on a scale from 1 to 5 where 1 = very poor quality and 5 = excellent quality. Flowering was assessed on a scale from 1 to 5, where 1 = no flowers, 2 = flower spikes visible, but no open flowers, 3 = one to several spikes with open flowers, 4 = many spikes with open flowers, average to good flowering, and 5 = abundant flowering, peak bloom. Seeds were collected, counted, and cleaned prior to viability and germination tests. For pre-germination viability tests, seeds were cut longitudinally and stained for 18-24 h at 30-35 ºC in 1.0% tetrazolium (2, 3, 5-triphenyl chloride) solution with positive staining patterns confirming seed viability (Mid-West Seed Service Inc., Brookings, SD). For germination tests, four replications of 50 seeds per cultivar were placed in 10.9 x 10.9 cm transparent polystyrene germination boxes (Hoffman Manufacturing, Inc., Albany, OR) containing two sheets of germination paper moistened with 15 mL deionized water. Germination boxes were placed in temperature and light controlled chambers equipped with cool-white fluorescent lamps (Model 818, Precision Scientific, Winchester, VA) and set at 20/10, 25/15, 30/20 and 35/25 ºC with a 12 hr photoperiod. Germination of seed was monitored daily for a period of 28 days. A split block experimental design was used with temperature as the main block and cultivar as the split-plot. Percentage data were transformed by a sqrt arcsine prior to conducting an analysis of variance (ANOVA) within temperatures. Transformed means were separated by a Duncan’s multiple range test, $P=0.05$. Untransformed cultivar means are presented in tables.

Ploidy level of the porterweed cultivars were analyzed by flow cytometry. Several young, recently-matured leaves were collected from containerized stock plants and a small piece of leaf tissue ($\approx 0.5 \text{ cm}^2$) was chopped in extraction buffer. Staining buffer was added to the suspension of nuclei and the samples were analyzed on a ploidy analyzer (PA-1, Partec GmbH, Münster, Germany). To assess male fertility, anthers were removed from corollas and stained in lactophenol cotton blue for 2-4 days prior to examination of pollen under a microscope. Magnified digital images were used to score the pollen grains into two categories: stainable (well and uniformed stained) and non-stainable (not, poorly or unevenly stained). Ten flowers were examined from 3 plants of each cultivar. To assess the hybridization potential between the invasive nettleleaf and the native jamaican porterweed ($\textit{Stachytarpheta jamaicensis}$), manual crosses were performed between nettleleaf porterweed x jamaican porterweed and the reciprocal. Putative hybrid seeds were cleaned and germinated at 25/15 ºC for two weeks prior to transfer to the greenhouse for phenotype evaluation.

**Results and Discussion:** In northern Florida, 'Mario Pollsa', 'Violacea', 'Naples Lilac', 'Red Compact' and nettleleaf porterweed achieved high flower ratings between 4 (average to good flowering) and 5 (abundant flowering, peak bloom) during four or more months (data not presented). Also, 'Violacea' 'Red Compact', jamaican porterweed and nettleleaf porterweed achieved visual quality ratings between 4 and 5 (good to excellent quality) throughout most of the study. In southern Florida, the same cultivars received high flower ratings, but generally for shorter periods of time (data not presented). Also,
'Violacea' and 'Red Compact' consistently received visual quality ratings that were above 4 (good quality, very desirable).

During the course of the 28 week study, nettleleaf porterweed produced the greatest number of spiked inflorescences with up to 80% seed viability and 73% pollen stainability (Table 1). 'Violacea' did not produce any viable seed; and seed viability was less than 10% for 'Mario Pollsa', 'Naples Lilac', and coral porterweed. 'Violacea' and 'Naples Lilac' had pollen stainability less than 10%. More than 75% of nettleleaf porterweed seed germinated at 20/10, 25/15, 30/20, and 35/25 °C (Table 2). The jamaican porterweed also had high germination at 25/15 and 30/20 °C, but germination was dramatically reduced by 50% and 43% at the lowest (20/10 °C) and highest (35/25 °C) temperature treatments, respectively. All other cultivars had 11.5% or less germination (Table 2). The least number of mean days to achieve 50% of total germination varied with temperature and cultivar (Table 2).

'Red Compact' and 'J.P.'s Pink' were determined to be diploids (Table 1). The C-value of the other porterweed cultivars was 2 to 2.5-times that of 'Red Compact' or 'J.P.'s Pink', indicating that these cultivars might be tetraploids or pentaploids. Manual pollinations between nettleleaf porterweed and jamaican porterweed were successful. Fruit set in each of the three pollinated flower spikes for S. jamaicensis x S. urticifolia ranged from 10% to 20% with an average of 16.1%, and from 12.5% to 22.2% for the reciprocal, with an average of 16.4%. The ecological risks associated with native gene pool contamination, and the availability of highly ornamental, sterile, closely related porterweed alternatives, suggest limiting the production and use of nettleleaf porterweed in Florida.

Acknowledgments: We extend gratitude to Keona Muller, Patricia Frey and James Aldrich for providing field and technical assistance throughout the study.

Literature Cited:
Table 1. Nomenclature, plant description, and fertility of eight porterweed cultivars.

<table>
<thead>
<tr>
<th>Image</th>
<th>Botanical Name</th>
<th>Common Name</th>
<th>Plant Description and Fertility</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="72x604" alt="Image" /></td>
<td><em>Stachytarpheta cayennensis</em> (<em>S. urticifolia</em>)</td>
<td>Nettleleaf Porterweed</td>
<td>FLEPPC Category II invasive. Upright form, medium sized plant, purple-blue flowers. Polyploid: 79.5% seed viability; 72.8% pollen stainability (pollen uniform, all are triangular)</td>
</tr>
<tr>
<td><img src="72x604" alt="Image" /></td>
<td><em>Stachytarpheta jamaicensis</em></td>
<td>Jamaica Porterweed, Native Blue Porterweed</td>
<td>Native to Florida. Low growing horizontal habit, purple flowers. Polyploid: 92.5% seed viability; pollen stainability not assessed.</td>
</tr>
<tr>
<td><img src="72x604" alt="Image" /></td>
<td><em>Stachytarpheta</em>'Mario Pollsa’</td>
<td>Mario Pollsa Porterweed</td>
<td>Large plant, brought back from South America by Mario Pollsa, pubescent leaves and spikes, flowers lavender. Polyploid: 6.5% seed viability; 53.5% pollen stainability (pollen triangular and round)</td>
</tr>
<tr>
<td><img src="72x604" alt="Image" /></td>
<td><em>Stachytarpheta mutabilis</em></td>
<td>Coral Porterweed, Pink Porterweed</td>
<td>Large plant with leaves and spikes pubescent, flowers coral. Polyploid: 8.0% seed viability; 79.9% pollen stainability (pollen uniform, all are triangular)</td>
</tr>
<tr>
<td><img src="72x604" alt="Image" /></td>
<td><em>Stachytarpheta mutabilis</em> ’Violacea’ (<em>S. frantzii</em>)</td>
<td>Violet Purple Porterweed</td>
<td>Large plant with leaves and spikes pubescent, flowers violet. Polyploid: 0.0% seed viability; 4.0% pollen stainability (pollen round and some are irregular)</td>
</tr>
<tr>
<td><img src="72x604" alt="Image" /></td>
<td><em>Stachytarpheta</em> ’Naples Lilac’</td>
<td>Naples Lilac Porterweed</td>
<td>Large plant, cross between <em>S. cayennensis</em> and <em>S. mutabilis</em> ‘Violacea’, pubescent leaves and spikes purple flowers. Polyploid: 1.5% seed viability; 8.1% pollen stainability (majority of pollen are round, some are irregular)</td>
</tr>
<tr>
<td><img src="72x604" alt="Image" /></td>
<td><em>Stachytarpheta speciosa</em> ‘J.P’s Pink’</td>
<td>J.P.’s Dwarf Pink Porterweed</td>
<td>Compact form, found as a pink flowered sport from ‘Dwarf Red’. Diploid: 46.0% seed viability; 65.8% pollen stainability (majority of pollen are triangular)</td>
</tr>
<tr>
<td><img src="72x604" alt="Image" /></td>
<td><em>Stachytarpheta speciosa</em> ‘Red Compact’</td>
<td>Dwarf Red Porterweed</td>
<td>Compact form, bright red flowers. Diploid: 56.5% seed viability; 72.8% pollen stainability (uniform pollen, all are triangular)</td>
</tr>
</tbody>
</table>
Table 2. Pre-germination viability, final germination percent (day 28) and number of days to 50% of final germination (T50) of seed collected from eight porterweed cultivars grown in southern Florida. Seeds were germinated with light (12 h photoperiod) in germination boxes placed in growth chambers set at 20/10, 25/15, 30/20 and 35/25 °C for 28 days.

<table>
<thead>
<tr>
<th>Species/cultivar</th>
<th>Pre-germination viability</th>
<th>Germination (%)</th>
<th>T50 (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre-germ viability\textsuperscript{z}</td>
<td>20/10</td>
<td>25/15</td>
</tr>
<tr>
<td>Nettleleaf</td>
<td>79.5 a</td>
<td>75.5 a</td>
<td>79.5 a</td>
</tr>
<tr>
<td>Jamaican</td>
<td>92.5 a</td>
<td>43.0 b</td>
<td>85.5 a</td>
</tr>
<tr>
<td>'Mario Polisa'</td>
<td>6.5 c</td>
<td>10.5 c</td>
<td>9.0 b</td>
</tr>
<tr>
<td>Coral</td>
<td>8.0 c</td>
<td>2.5 d</td>
<td>9.5 b</td>
</tr>
<tr>
<td>'Violacea'</td>
<td>0.0 d</td>
<td>0.0 e</td>
<td>0.0 c</td>
</tr>
<tr>
<td>'Naples Lilac'</td>
<td>1.5 cd</td>
<td>1.5 d</td>
<td>1.5 c</td>
</tr>
<tr>
<td>'J.P’s Pink'</td>
<td>46.0 b</td>
<td>0.0 e</td>
<td>0.5 c</td>
</tr>
<tr>
<td>'Red Compact'</td>
<td>56.5 b</td>
<td>0.0 e</td>
<td>0.5 c</td>
</tr>
</tbody>
</table>

\textsuperscript{z} Performed on 200 seed (2 replications of 100). Mean separation was conducted by Duncan's multiple range test on transformed means. Different lowercase letters within columns are significantly different, \( P=0.05 \).

\textsuperscript{y} Performed on 200 seed (4 replications of 50). Mean separation was conducted by Duncan’s multiple range test on transformed means. Different lowercase letters within columns are significantly different, \( P=0.05 \).

\textsuperscript{x} T50 could not be calculated due to zero percent germination.
Effects of Outplanting Horticultural Species on Soil CO₂ Efflux

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Index Words: Climate Change, Alternative Substrates, Whole Tree, Clean Chip Residual, CO₂ Efflux

Significance to Industry: Increased atmospheric carbon dioxide (CO₂) concentration is widely thought to be the main driving factor behind global climate change. Much of the work on reducing greenhouse gas (GHG) emissions and methods of carbon (C) sequestration has been conducted in row crop and forest systems; however, virtually no work has focused on contributions from sectors of the specialty crop industry such as horticulture. As with all industries, horticulture has the potential to negatively impact the global atmosphere, but it also has tremendous potential to improve atmospheric GHG conditions through the sequestering of C in urban landscapes. The objective of this ongoing research is to determine the positive and negative effects of growth media on soil CO₂ efflux from commonly grown horticultural species planted in the landscape.

Nature of Work: Global warming and the possible impacts it may have on the global environment is one of the most researched topics of the last several decades. Annual CO₂ emissions have increased approximately 80% since the start of the industrial revolution (6). This increase in atmospheric CO₂ and other long-lived GHG [i.e., methane (CH₄) and nitrous oxide (N₂O)] are widely thought to be the main causes leading to predicted increase in global temperature. While it is difficult to prove that GHG are the only cause of global climate change, there are indications that the earth’s surface is warming which may result in negative environmental impacts (6, 7).

While agriculture is a major contributor to GHG emissions, it also has great potential to offset emissions by altering production and management practices. These practices have the capacity to increase C uptake and storage in biomass, wood products, and soils (i.e., carbon sequestration) (12). For example, row cropping systems utilizing no-till practices can reduce fossil fuel use while promoting C storage in soil (11). Improved forest management practices such as density control, nutrient management, and genetic improvement benefit forest production and C accumulation in biomass and soil; wood products also serve as long term C storage pools (12).

Horticulture is a multi-billion dollar industry, with an economic impact of $2.8 billion in Alabama alone (5). However no research to date has focused on this industry’s impact
on global change. There is great interest among ranchers and farmers in other agriculture sectors to earn new income in the emerging carbon trading market. Organizations such as the National Farmer’s Union have implemented new programs (in conjunction with the Chicago Climate Exchange’s Carbon Credit Program) in which farmers may be paid to reduce their C emissions or sign contracts pledging to alter production practices which provide C offsets (i.e., C credits) to other industries which want to reduce their C footprint (3, 10). In order for the horticulture industry to reduce GHG emissions and benefit from such new emerging programs, baseline estimates of C emissions and the ability of growers/landscapers to sequester C using current production practices must be established. The focus of this research is to determine how three different container growth media impact CO₂ emissions once planted into the landscape.

In order to determine the potential that the nursery and landscape industry has for C storage and to begin to understand the effects of growth media on soil CO₂ efflux, two commonly grown nursery crops [crapemyrtle (Lagerstroemia x ‘Acoma’) and magnolia (Magnolia grandiflora)] were transplanted from 3 in. and 4 in. liners, respectively, into 3 gallon containers on March 25, 2008. Plants were potted using one of three growing media; pinebark (PB), WholeTree (WT), or clean chip residual (CCR). Each substrate was mixed with sand (6:1, v:v) and 14 lbs Polyon (18-6-12), 5 lbs dolomitic lime, and 1.5 lbs Micromax (incorporated on a cubic yard basis). WholeTree (4) and CCR (1), which are by-products of the forestry industry, are being investigated as alternative potting media due to decreasing PB supplies (9). Plants were grown in the 3 gallon containers for an entire growing season and then outplanted to the field in December, 2008. Soil samples were collected in Summer, 2009 (data not shown) for determination of soil C and nitrogen. At this time, Automated Carbon Efflux Systems (ACES, USDA Forest Service, Southern Research Station Laboratory, Research Triangle Park, NC; US patent #6,692,970) were installed adjacent to the two plant species previously mentioned to continuously monitor (24 hr d⁻¹) C lost via soil respiration. Three replicate sampling chambers were placed on each potting media/species combination. In addition, three chambers were placed in non-plant (bare soil) areas. The experiment was designed as a randomized complete block and data were analyzed using the PROC MIXED procedure of SAS (8).

Results and Discussion: When comparing CO₂ efflux between species, crapemyrtle had higher soil CO₂ efflux than magnolia (Table 1), possibly due to a larger root system or faster growth rate of crapemyrtle (Table 1). Overall, PB and CCR had similar soil CO₂ efflux values; in crapemyrtle PB had lower efflux than CCR, while in magnolia this relationship was reversed. However, WT had significantly lower soil CO₂ efflux than either PB or CCR (Table 1). Boyer et al. (2) reported that PB and CCR had similar microbial respiration suggesting that these materials decompose at similar rates. WholeTree has a higher percentage of wood than either PB or CCR which may cause it to break down slower, resulting in lower soil CO₂ efflux. With crapemyrtle, all three media had significantly different soil CO₂ efflux values; there was no effect of media for magnolia (Table 1). These results indicate that C storage potential may increase with
utilization of WT as a growing media for container crops. Additional data such as plant biomass increase and changes in soil C levels over time will also be needed to fully understand the impact of these growing media on soil CO2 emission.

Literature Cited:
Table 1. Effects of species and growth media on soil CO$_2$ efflux$^a$. Means with associated separation statistics are shown.

<table>
<thead>
<tr>
<th>Species$^b$</th>
<th>Soil Flux</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>CM</td>
<td>7.67</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>MG</td>
<td>7.01</td>
<td></td>
</tr>
</tbody>
</table>

% Difference

MG vs CM 9.4

<table>
<thead>
<tr>
<th>Media$^c$</th>
<th>Soil Flux</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>PB</td>
<td>7.46</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>WT</td>
<td>7.00</td>
<td></td>
</tr>
<tr>
<td>CCR</td>
<td>7.57</td>
<td></td>
</tr>
</tbody>
</table>

% Difference

PB vs WT -6.2 <0.001
PB vs CCR 1.6 0.0265
WT vs CCR 8.1 <0.001

<table>
<thead>
<tr>
<th>Media</th>
<th>Soil Flux</th>
</tr>
</thead>
<tbody>
<tr>
<td>PB</td>
<td>7.68</td>
</tr>
<tr>
<td>WT</td>
<td>7.12</td>
</tr>
<tr>
<td>CCR</td>
<td>8.24</td>
</tr>
</tbody>
</table>

% Difference

PB vs WT -7.3 <0.001
PB vs CCR 7.3 <0.001
WT vs CCR 15.8 <0.001

<table>
<thead>
<tr>
<th>Media</th>
<th>Soil Flux</th>
</tr>
</thead>
<tbody>
<tr>
<td>PB</td>
<td>7.24</td>
</tr>
<tr>
<td>WT</td>
<td>6.89</td>
</tr>
<tr>
<td>CCR</td>
<td>6.90</td>
</tr>
</tbody>
</table>

% Difference

PB vs CCR -4.8 0.0163
WT vs PB -4.7 0.0176
WT vs CCR -0.1 0.9766

% Difference

MG vs CM in PB 6.0 0.0017
MG vs CM in WT 3.3 0.0988
MG vs CM in CCR 19.4 <0.001

$^a$Efflux in μmol CO$_2$ m$^{-2}$ s$^{-1}$; $^b$CM=Crape Myrtle, MG=Magnolia
$^c$PB=Pine Bark, CCR=Clean Chip Residual, WT=Whole Tree
People’s Choice Award Winners from the 2009 LSU AgCenter’s Landscape Horticulture Field Day

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Index Words: Landscape trials, bedding plants, landscape performance, cultivar trials

Significance to Industry: The LSU AgCenter conducts landscape evaluation trials on annual bedding plants and herbaceous perennials each year. Included are cool season trials and warm season trials. Results of these trials provides wholesale nursery growers, greenhouse growers, landscapers, and retail garden centers with valuable, useful information on performance of new cultivars.

Nature of Work: Green industry professionals attending the landscape horticulture field day at the LSU AgCenter’s Hammond Research Station, Hammond, LA (USDA hardiness zone 8B) in June 2009 were given the opportunity to “pick their winning plants” from the sun garden evaluation trial gardens at the station. Over 340 varieties were planted. The planting mostly consists of annual bedding plants and herbaceous perennials, but new roses and some “companion” woody ornamental shrubs (such as Southern Living plants) are also included. The majority are “new” plants to the industry, but a few are industry standards planted for “comparison” and “side-by-side” evaluation purposes.

Results and Discussion: Eighteen plants were designated winning plants in the People’s Choice awards in 2009. The gold winner was ‘Jade Princess’ pennisetum, the silver winner was ‘Purple Flash’ ornamental pepper, and the bronze winner was ‘Profusion Double Fire’ zinnia. In addition, 11 plants were named honorable mention winners. An additional 25 plants received votes/consideration.

Winners:

- ‘Bombay Lavender’ Scaevola (Syngenta Flowers)
- ‘Bombay Dark Blue’ Scaevola (Syngenta Flowers)
- ‘Early Bird Gold’ Rudbeckia (Dupont Nursery)
- ‘Profusion Double Fire’ Zinnia (Sakata Seed) – BRONZE WINNER
- ‘Dark Star’ Coleus (Proven Winners)
- ‘Easy Does It’ Rose (Weeks Roses)
- Ornamental Sweet Potato ‘Selection Number 8-23’ (LSU AgCenter)
- Candlestick Tree – Cassia alata
- ‘Aristata Sunburst’ Series Gaillardia (Syngenta Flowers)
- ‘Jade Princess’ Pennisetum (PanAmerican Seed) – GOLD WINNER
- ‘Purple Flash’ Ornamental Pepper (PanAmerican Seed) – SILVER WINNER
• ‘Purple Diamond’ Loropetalum (PDSI)
• ‘Mesa Yellow’ Gaillardia (PanAmerican Seed)
• ‘Corrie’s Gold’ Gaura
• ‘Louisiana Red’ Copper Plant
• ‘Chili Chilly’ Ornamental Pepper (PanAmerican Seed)
• ‘Tradewind Purple Bicolor’ Osteospermum (Syngenta Flowers)
• ‘Gold Edge’ Duranta

Honorable Mention:
• ‘Senorita Rosalita’ Cleome (Proven Winners)
• ‘Bouquet Rose Magic’ Dianthus (PanAmerican Seed)
• ‘Verde’ Talinum (PanAmerican Seed)
• ‘Maple Sugar’ Hibiscus (Proven Winners)
• ‘Lemon’ Talinum (PanAmerican Seed)
• ‘Ballerina Blush’ Gaura (Ball FloraPlant)
• ‘Aurora Black Cherry’ Coleus (Ball FloraPlant)
• ‘Swizzle Cherry Vanilla’ Zinnia (Goldsmith)
• ‘Red Hot Rio’ Coleus (Proven Winners)
• ‘Sunny Knock Out’ Rose (Conard-Pyle / Star Roses)
• ‘Antigua Gold’ Marigold (Goldsmith)

Also Receiving Votes:
• ‘Bombay White’ Scaevola (Syngenta Flowers)
• ‘Fireworks’ Gomphrena (PanAmerican Seed)
• ‘Cuban Gold’ Duranta (Athens Select)
• ‘Medusa’ Ornamental Pepper (PanAmerican Seed)
• ‘Purple Bouquet’ Dianthus (PanAmerican Seed)
• ‘Nirvana Cascade Pink’ Vinca (Syngenta Flowers)
• ‘Nirvana Sky Blue’ Vinca (Syngenta Flowers)
• ‘Luna Red’ Hibiscus (PanAmerican Seed)
• Ornamental Sweet Potato ‘Selection Number 08-18’ (LSU AgCenter)
• ‘Sweet Caroline Green/Yellow’ Ornamental Sweet Potato (Bodger Botanicals)
• ‘Bronze’ Copper Plant
• ‘Pink Chaos’ Coleus (Proven Winners)
• ‘Fishnet Stockings’ Coleus (Proven Winners)
• ‘Trusty Rusty’ Coleus (Ball FloraPlant)
• ‘Pink Marble’ Photinia (Conard-Pyle)
• ‘Emerald Snow’ Loropetalum (PDSI)
• ‘Taishan Yellow’ Marigold (PanAmerican Seed)
• ‘Corey Yellow’ Coreopsis (Syngenta Flowers)
• ‘Spring Secret’ Scaevola (Proven Winners)
• ‘Blue Print’ Scaevola (Ball FloraPlant)
• ‘Southern Belle’ Hibiscus
• ‘White Texas Star’ Hibiscus
• ‘New (Blue) Wonder’ Scaevola (Proven Winners)
• ‘Profusion Yellow’ Zinnia (Sakata Seed)
• ‘Profusion Double White’ Zinnia (Sakata Seed)
Effects of Fertilizer Type on Green Roof Runoff

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Index Words: Rooftop gardens, nitrogen, phosphorus, eutrophication

Significance to Industry: Rooftop gardens are becoming an important aspect of environmentally-friendly construction, imparting benefits of reduced building surface temperatures and decreasing summer cooling costs. However, green roof media is designed to retain minimal amounts of moisture, an effort to minimize loading of the building roof. It is important that the runoff water from these rooftop gardens have minimal amounts of fertilizer, specifically N and P, to prevent negative impacts as the water is directed into storm sewers. This study was conducted to compare the impact of three different fertilizer types on runoff water quality.

Nature of Work: Green roofs are an environmentally-friendly construction technique that can help reduce summer cooling costs and increase the lifespan of the roofing membrane. Green roofs intercept incoming radiation, decreasing the heat load on the building and ameliorating the urban heat island effect (U.S. EPA, 2003; Onmura et al., 2001; Osmundson, 1999). Green roofs increase insulation for buildings, decreasing utility costs and reducing energy consumption (Theodosiou, 2003).

Most green roofs, especially those placed on existing buildings, are considered extensive green roofs, with a growing media depth of less than 6”. This shallow media depth prevents the retention of excessive amounts of water and keeps building load within design specifications, typically less than 20 lbs/ft². Green roof media also typically contains media components such as expanded shale and perlite to reduce media water holding capacity. These media make plant nutrient management important, to ensure adequate plant growth but prevent excess fertilizer becoming environmental pollutants.

A study was conducted in the Texas A&M – Commerce greenhouses during March and April 2009. Delosperma cooperi (Hardy Ice Plant), a recommended green roof plant, was planted in 6” standard pots using a commercially available green roof growing media (Green Grid, Weston Solutions, Inc. Chicago, Ill.) Pots received one of four treatment regimens: 1) No fertilizer (control), 2) water soluble fertilizer (Peters 20-10-20 GP at 100 ppm N, once weekly), 3) slow-release fertilizer (15-9-12 Osmocote, 3-4 month at 3 lbs/yd³, Scotts Fertilizer, Marysville, Ohio), and 4) a gel fertilizer (Ferti-Sorb, at 3 lbs/yd³).
Plants were watered on an as-needed basis to maintain appearance and vigor. Once weekly for five weeks, sample runoff was collected using the Pour-Thru method (a full explanation of the Pour-Thru method can be obtained at http://www.pourthruinfo.com/). Water samples were stored in 20 ml nalgene bottles until analysis. All water samples were analyzed for EC, pH, NO₃-N, and P₂O₅ concentrations at the Stephen F. Austin soil and water testing laboratory.

Data was analyzed by week using Proc GLM (SAS Institute, Cary, NC). Means were separated using Duncan’s.

**Results and Discussion:** In terms of electrical conductivity, slow-release and gel fertilizers had lower readings than the control and water soluble treatments at every recording interval except week three (Table 1). EC readings were excessively high during week one, likely due to poor water quality at the beginning of the experiment or as an artifact of the mixing process. The slow-release and gel fertilizers release nutrients slowly into solution, explaining the repeatedly lower EC values.

Fertilizer treatments did result in different pH values, but trends varied across treatments and recording intervals (Table 2). Therefore, while differences do exist, these are likely due to variations in watering, water quality, and irrigation timing, and are not related to fertilizer differences.

Nitrate levels differed significantly across treatments (Table 3). The control group had the lowest nitrate levels at all recording intervals. Slow-release and gel fertilizers had initial spikes during weeks one and two, but levels declined rapidly. This initial spike is likely due to contamination of the external surfaces of the individual particles and breaking of individual particles during the mixing process. Water soluble nitrate levels were more similar across weeks and consistent with results expected with fertilization at 100 ppm N.

Water soluble had higher phosphorus levels than all other treatments, except during week one where gel fertilizer had significantly higher levels than other treatments (Table 4). It is unclear whether this is related to contamination of the fertilizer surface or immediate release of phosphorus into solution. The water soluble fertilizer was highest and most consistent across all treatments, again giving results expected at reported fertilization levels. As with nitrate, phosphorus levels in slow-release and gel treatments did not differ from the control in weeks two through five.

From the results of this study, it appears that, with the exception of rapid initial release of nutrients, slow-release and gel fertilizers provide adequate fertility but release the nutrients so slowly that water samples do not differ from the control after the first two weeks following application. This gives green roof gardeners and researchers a means of fertilization that provides the needed nutrients in a way that is safe for the environment.
The heavy reliance of materials such as expanded shale in green roof media means that formulations will have a relatively low CEC and little ability to retain nutrients supplied via water soluble methods. The use of slow-release fertilizers should provide a better strategy for plant nutrient management in extensive green roof gardens.

**Literature Cited**


**Table 1.** Electrical conductivity (mmhos/cm²) in simulated water runoff from green roof plantings using four different fertilizer treatments. Means were separated using Duncan’s. Readings with different letters in columns indicate significant differences.

<table>
<thead>
<tr>
<th>Fertilizer</th>
<th>Wk 1</th>
<th>Wk 2</th>
<th>Wk 3</th>
<th>Wk 4</th>
<th>Wk 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>3.1a</td>
<td>2.2a</td>
<td>1.7a</td>
<td>1.4a</td>
<td>1.5a</td>
</tr>
<tr>
<td>Water Soluble</td>
<td>2.8ab</td>
<td>2.0ab</td>
<td>1.7a</td>
<td>1.3a</td>
<td>1.4a</td>
</tr>
<tr>
<td>Slow-Release</td>
<td>2.1c</td>
<td>1.6bc</td>
<td>1.4a</td>
<td>0.8b</td>
<td>0.6b</td>
</tr>
<tr>
<td>Gel</td>
<td>2.4bc</td>
<td>1.4c</td>
<td>1.3a</td>
<td>0.8b</td>
<td>0.9b</td>
</tr>
</tbody>
</table>
Table 2. pH of simulated water runoff from green roof plantings using four different fertilizer treatments. Means were separated using Duncan’s. Readings with different letters within columns indicate significant differences.

<table>
<thead>
<tr>
<th>Fertilizer</th>
<th>Wk 1</th>
<th>Wk 2</th>
<th>Wk 3</th>
<th>Wk 4</th>
<th>Wk 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>7.8b</td>
<td>7.4ab</td>
<td>7.6a</td>
<td>7.7ab</td>
<td>7.8ab</td>
</tr>
<tr>
<td>Water Soluble</td>
<td>7.8ab</td>
<td>7.5a</td>
<td>7.5a</td>
<td>7.8a</td>
<td>7.9a</td>
</tr>
<tr>
<td>Slow-Release Gel</td>
<td>7.7c</td>
<td>7.4ab</td>
<td>7.5a</td>
<td>7.7b</td>
<td>7.8ab</td>
</tr>
<tr>
<td>Gel</td>
<td>7.8a</td>
<td>7.3b</td>
<td>7.4a</td>
<td>7.6b</td>
<td>7.6b</td>
</tr>
</tbody>
</table>

Table 3. NO₃-N concentrations in simulated water runoff from green roof plantings using four different fertilizer treatments. Means were separated with Duncan’s. Readings with different letters within columns indicate significant differences.

<table>
<thead>
<tr>
<th>Fertilizer</th>
<th>Wk 1</th>
<th>Wk 2</th>
<th>Wk 3</th>
<th>Wk 4</th>
<th>Wk 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>1.1a</td>
<td>1.4c</td>
<td>0.8b</td>
<td>0.6b</td>
<td>0.7b</td>
</tr>
<tr>
<td>Water Soluble</td>
<td>22.5a</td>
<td>29.2b</td>
<td>45.3a</td>
<td>30.8a</td>
<td>21.7a</td>
</tr>
<tr>
<td>Slow-Release Gel</td>
<td>12.6a</td>
<td>113.3a</td>
<td>52.7a</td>
<td>23.1a</td>
<td>7.9b</td>
</tr>
<tr>
<td>Gel</td>
<td>65.9b</td>
<td>18.9bc</td>
<td>5.9b</td>
<td>0.9b</td>
<td>0.8b</td>
</tr>
</tbody>
</table>
Table 4. $P_2O_5$-P concentrations in simulated water runoff from green roof plantings using four different fertilizer treatments. Means separated using Duncan’s. Readings with different letters within columns indicate significant differences.

<table>
<thead>
<tr>
<th>Fertilizer</th>
<th>Wk 1</th>
<th>Wk 2</th>
<th>Wk 3</th>
<th>Wk 4</th>
<th>Wk 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>6.4a</td>
<td>2.1b</td>
<td>0.8b</td>
<td>2.5b</td>
<td>1.8b</td>
</tr>
<tr>
<td>Water Soluble</td>
<td>8.6a</td>
<td>8.6a</td>
<td>13.7a</td>
<td>11.8a</td>
<td>10.6a</td>
</tr>
<tr>
<td>Slow-Release</td>
<td>14.9a</td>
<td>1.6b</td>
<td>2.0b</td>
<td>1.4b</td>
<td>2.2b</td>
</tr>
<tr>
<td>Gel</td>
<td>53.9b</td>
<td>4.5ab</td>
<td>3.3b</td>
<td>2.8b</td>
<td>3.0b</td>
</tr>
</tbody>
</table>
Evaluation of Woody Plant Selection, Maintenance, and Long Term Performance on a Rooftop Hospital Garden

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Index Words: Rooftop gardens, green roofs, native plants, landscape maintenance, design.

Significance to Industry: Greater communication is needed between the producers of plant material and the landscape designers and consumers of this material. This is particularly true as rooftop gardens and green roofs become more common since these specialized environments require considerable study and collaboration across diverse disciplines. Symbiotic relationships between the landscape designer and the grower can create interest and demand for new plants when these plants are demonstrated well in the designed landscape. Many notable examples can be found across the United States, such as in the work of Kurt Bluemel of Kurt Bluemel Inc., in concert with the well known landscape architects Wolfgang Oehme, who have together been instrumental in the ornamental grass movement and recognition of the ‘New American’ garden (2). In the southwest United States landscape architect Steve Martino and local growers have over the last thirty years redefined cultural expectations of the designed southwestern landscape (4). This paper is written from the perspective of a landscape architect with a specific interest in plants and the potential benefits of an increased dialogue between designers and growers and others associated with the green industry. This study involves an eight year evaluation of the performance of woody plant material on a hospital rooftop with discussion of the merits and challenges of several species with potential for further research.

Nature of Work: This study was conducted by making 4 visits over a period of 8 years to a rooftop hospital garden, formally known as The Rooftop Therapy Park at Fort Sanders Regional Medical Center in downtown Knoxville, Tennessee. The garden was visited four times between 2001 and 2009 and the performance of plant material was observed and recorded. The original garden was installed in 1995. At the first visit in 2001, six years post implementation, the majority of original plantings were still intact, although several trees were near death and two had already been replaced. In the years between 2001 and the most recent visit in the summer of 2009, nearly all original trees had been replaced. Refer to Table 1 for a complete list of non herbaceous plant material, dates of installation, and success rates for each. It is important to note that this hospital garden was constructed as a retrofit to an existing rooftop and designed by a local landscape architect. The rooftop may be considered both intensive and extensive. Soil depths just deep enough for trees were...
possible over building column locations. Without a structural design that would support heavy soil across the entire rooftop, the garden soils were designed to range in depth between 6" in extensive locations and a maximum of 10" in intensive locations above columns where trees were to be installed. Soils were engineered to be lightweight by creating a soil mix of 60% compost and 40% pine bark mixed with Styrofoam. The rooftop environment is canyon like as it is surrounded on three sides by adjacent buildings which rise between three and eight stories higher than the rooftop garden, with one side open to the street two stories below. This environment only allows a few hours of direct sunlight per day as adjacent buildings cast long shadows and the rooftop is oriented north-south, with the short open end facing north. The garden is irrigated during non freezing months, and maintenance including yearly application of granular all purpose fertilizers is performed by a local landscape contractor. Refer to Figures 1, 2, and 3 for views of the overall garden in relation to the hospital campus. In summation the growing environment is harsh and provides thorough testing grounds for evaluation of the performance of woody plants in an urban rooftop environment.

Results and Discussion: Of the 17 woody and non woody plants included in this observation, five are of particular interest and are presented here for discussion. These include, in alphabetical order, *Arundinaria gigantea*, *Cercis canadensis*, *Magnolia grandiflora ‘Little Gem’*, *Salix babylonica*, and *Tsuga canadensis*. Other plants included on the inventory were observed to perform well over the rooftop garden’s 14 year history and should not be overlooked though not discussed here in detail.

The River Cane, *Arundinaria gigantea*, is noteworthy as a native plant not typically offered in the nursery trade. Its design use as a rooftop plant was ingenious as it performed remarkably well. The intent of the designer was for the Cane to spread and provide a softening effect for the visually harsh rooftop garden, and spatial enclosure for the garden rooms. However, as is too often the case, original design intentions were not realized as hospital staff with no expertise in garden design or maintenance were left with the responsibility of overseeing garden maintenance. This lack of vision lead to a hedge mentality, zero tolerance for the loose character of the Cane, and its eventual removal. 4 *Tsuga canadensis* were part of the original installation, with three surviving in 2009 and growing at a slow rate from approximately a 5’ height at installation to an average of 10’ feet in 2009. The Hemlock that died was installed in a dark corner which received almost zero direct sunlight. This tree did survive approximately 8 years and to date has not been replaced. In light of general performance of *Tsuga canadensis* in stressful landscape settings performance on this rooftop is remarkable good and worthy of further study (1). 7 *Salix babylonica* were in installed in 1995. At first observation in 2001, 1 had already been replaced that year, with 2 nearly dead and the other four in an obvious state of decline. By 2003 all 7 were dead. It was clear that in the initial years of the garden the Willows grew quickly to a height and spread of over 16’ from an initial size of 8’ by 6’, but began a fast decline as available soil, nutrients, and moisture became scarce. These were each replaced by *Cercis canadensis* which have performed extremely well and show no signs of decline now 6-8 years after installation.
One of the original Willows was replaced with a *Magnolia grandiflora* ‘Little Gem’, which has nearly tripled in size in 8 years and is performing quite well.

The performance of these and other plants on rooftop gardens may not be predictable based on typical field observation. As is seen in these observations, plants typically subject to a high failure rate in landscape settings, such as *Tsuga canadensis*, have performed surprisingly well. Based on studies of landscape performance and environmental characteristics *Salix baylorica* performed as might be predicted today (3). Performance of native plants such as *Cercis canadensis*, *Arundinaria gigantea*, *Hydrangea quercifolia*, and others shown in Table 1 have shown excellent performance in addition to being regionally context appropriate choices.

This study points to the need for evaluation of many plant species in rooftop settings, particularly as demand and need for intensive rooftop gardens and their associated plants increases. These gardens will provide urban opportunities for usable outdoor space where shade and other landscape improvements make outdoor environments livable places for people.

Literature Cited:
Table 1. Inventory and Performance Evaluation of Major Rooftop Plantings

<table>
<thead>
<tr>
<th></th>
<th>Original Quantity in 1995</th>
<th>Quantity in 2009</th>
<th>Date of Install</th>
<th>Years in the Garden</th>
<th>Success Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Trees</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Acer palmatum 'Bloodgood'</em></td>
<td>1</td>
<td>0</td>
<td>1995</td>
<td>11</td>
<td>100%</td>
</tr>
<tr>
<td><em>Acer palmatum 'Dissectum'</em></td>
<td>1</td>
<td>3</td>
<td>1995, 2007</td>
<td>2</td>
<td>100%</td>
</tr>
<tr>
<td>Betula nigra</td>
<td>1</td>
<td>1</td>
<td>1995</td>
<td>14</td>
<td>100%</td>
</tr>
<tr>
<td>Cercis canadensis</td>
<td>0</td>
<td>7</td>
<td>2004</td>
<td>5 to 7</td>
<td>100%</td>
</tr>
<tr>
<td>Magnolia grandiflora 'Little Gem'</td>
<td>0</td>
<td>1</td>
<td>2001</td>
<td>8</td>
<td>100%</td>
</tr>
<tr>
<td>Salix babylonica</td>
<td>7</td>
<td>0</td>
<td>1995</td>
<td>8</td>
<td>0%</td>
</tr>
<tr>
<td>Tsuga canadensis</td>
<td>4</td>
<td>3</td>
<td>1995</td>
<td>8</td>
<td>75%</td>
</tr>
</tbody>
</table>

**Shrubs & Vines**

**Arundinaria gigantea** | 21 | 0 | 1995 | 6 to 8 | 100% |
Aucuba japonica        | 7  | 6  | 1995 | 14     | 85%  |
*Prunus laurocerasus 'Otto Luyken'* | 0 | 5 | 2007 | 2 | 100% |
Euonymus kiautschovicus | 14 | 14 | 1995 | 14     | 100% |
Hydrangea quercifolia  | 12 | 12 | 1995 | 14     | 100% |
Miscanthus sinensis    | 9  | 7  | 1995 | 14     | 77%  |
Gracillimus'           | 12 | 12 | 1995 | 14     | 100% |
Nandina domestica      | 18 | 18 | 1995 | 14     | 100% |
Rhododendron obtusum   | 2  | 2  | 1995 | 14     | 100% |
*Fashion'              |    |    |      |        |      |
Wisteria sinensis      |    |    |      |        |      |

* An addition was built in 2007 which required the removal of some plant material and addition of 3 new Acer palmatum 'Dissectum' and 5 Prunus laurocerasus 'Otto Luyken'.

** All of the Arundinaria gigantea had been removed by 2003 as it was deemed too aggressive.
Figure 1. Photo of the Rooftop garden looking north, taken by the author summer 2001. Note the thinning canopies of the *Salix babylonica*.

Figure 2. Photo of the north end of the rooftop garden, taken summer 2009 by the author. Note the lush *Cercis canadensis* and *Magnolia grandiflora* ‘Little Gem.’
Figure 3. Photo of the new south end of the garden, taken by the author summer 2009.
Landscape Performance of Winter-planted Petunias in South Mississippi

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Index Words: Annuals, cold hardiness, Petunia ×hybrida, Easy Wave petunias, Shock Wave petunias.

Significance to Industry: South Mississippi gardeners and landscapers traditionally plant spring crops of petunias in the landscape following the local frost-free date (approximately mid-April). In this region, petunia plants generally tend to decline by late spring with the onset of hot, humid weather, resulting in a short spring flower display before plants have to be removed. Trials in Poplarville, Mississippi (USDA Hardiness Zone 8b) during the first half of 2009 with the popular Easy Wave and Shock Wave series of spreading petunias demonstrated that petunia plants can be successfully planted in the ground during the winter. The young plants were tolerant of frosts and not adversely affected by some occasional nighttime temperature drops into the mid- or upper-20s F after planting. By establishing their root systems in the soil during the cooler weeks of winter, petunia plants were ready for rapid shoot growth and profuse blooming upon the arrival of warmer weather.

Nature of Work: Petunias are popular for planting in landscapes across the country, with approximately 500 million plants used annually (2). Plants tend to grow best with cool temperatures and bright light (2). Many cultivars can tolerate temperatures below freezing (1). Petunias can be grown as a winter/early spring crop landscape in central Florida (3). A previous study indicated that Easy Wave and Shock Wave petunias were winter hardy in the ground in south Mississippi, although plants did not flower during the colder weeks of winter (Blythe, unpublished data). The Easy Wave and Shock Wave series of petunias feature a spreading habit of growth and will flower under shorter photoperiods than some other varieties (4).

The objective of this study was to evaluate the spring performance of landscape-grown Easy Wave and Shock Wave petunias planted in the ground and allowed to establish during the winter months. Results with four varieties are presented in this report: 'Easy Wave Plum Vein', 'Easy Wave Salmon', 'Shock Wave Denim', and 'Shock Wave Rose'.

During fall 2008 and early winter 2009, four crops of Easy Wave and Shock Wave petunias were propagated from seed in plug trays and transplanted into 4-inch pots in a greenhouse. Plants were hardened-off for one week before planting outdoors in a Ruston fine sandy loam in 18”-wide, raised field beds covered with black plastic mulch (for weed control). Plants were spaced 5 feet apart in the rows using a completely
randomized design for each variety. One-half teaspoon of Expert Gardener All Purpose 19-6-12 6-month controlled-release fertilizer (Chemsico, St. Louis, MO) was placed at the bottom of each planting hole. Planting dates were Jan. 12, Feb. 2, Feb. 23, and Mar. 16, 2009. Plants were irrigated using drip tape at least twice weekly, depending on weather conditions. There were four plants per planting date per variety.

Each plant was evaluated for flowering every two weeks beginning March 22 and ending July 9 using a scale of 1 to 5 (1: no flowers; 3: acceptable display with flowers distributed unevenly and/or covering only a portion of the plant, 5: outstanding display with flowers profuse and well distributed over the entire plant). Using the biweekly ratings, total counts of ratings of 4 or 5 and counts of ratings of 3, 4, or 5 over the season were determined for each plant, with count data analyzed using a generalized linear model (Poisson distribution and log link function) with the GLIMMIX procedure of SAS (version 9.2; SAS Institute, Cary, NC). Plant size (ground coverage) was determined as the elliptical area calculated using the greatest plant width and the plant width perpendicular to the greatest width; this data was analyzed with repeated measures analysis with the MIXED procedure of SAS.

**Results and Discussion:** Nighttime temperatures occasionally dipped into the 20s and 30s (F) following the first three planting dates. No cold injury was noted on any of the plants. As expected, no flowers were produced during the winter. The first flowers opened just after mid-March, a full month before the local frost-free date when petunias would traditionally be planted in this region. Unusually hot temperatures occurred in June, shortening the season for petunias to some extent.

As might be anticipated, earlier planting dates tended to result in larger plants by May 30 than did the later planting dates (Table 1). Number of biweekly flowering ratings of 3 and greater and ratings of 4 and greater received by plants over the season tended to be similar among the planting dates for each variety (perhaps owing in part to the small number of replicates, limiting detectability of differences); however, larger plants provided a better visual display among plants with similar flowering ratings. Therefore, the earlier planting dates are more likely to result in a heightened impact for overall color display in the landscape.

Results demonstrated that Easy Wave and Shock Wave petunia plants can be successfully planted in the ground during the winter in south Mississippi. The young plants were tolerant of nighttime temperatures that sometimes dropped into the mid- or upper-20s F after planting. Petunias planted from 4-inch pots were able to become established in the ground during the winter, showing limited top growth during the cooler weeks, and then exhibiting more rapid growth and flowering as temperatures warmed around mid-March. The winter-planted petunias were providing a colorful show at a time when spring-planted petunias were just being planted in the ground. This early planting extended the flowering season by several weeks. An added bonus was that the winter-planted petunias were larger than spring-planted plant would be, thus supporting many more flowers on a single plant. Easy Wave and Shock Wave petunias come in various
colors, and some varieties can have hundreds of flowers open on a single plant at any one time.

**Literature Cited:**
Table 1. Spring flowering performance and plant size (ground coverage area) of four varieties of spreading petunias planted in the ground on four dates in winter 2009 (n=4).

<table>
<thead>
<tr>
<th>Variety</th>
<th>Planting date</th>
<th>Number of biweekly flowering ratings of 3 to 5</th>
<th>Number of biweekly flowering ratings of 4 to 5</th>
<th>Plant size (coverage area) on May 30 (sq. ft.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>'Easy Wave Plum Vein'</td>
<td>Jan. 12</td>
<td>7.8a&lt;sup&gt;y&lt;/sup&gt;</td>
<td>6.3a&lt;sup&gt;y&lt;/sup&gt;</td>
<td>10.7ab&lt;sup&gt;x&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>Feb. 2</td>
<td>6.5a</td>
<td>5.8a</td>
<td>11.4a</td>
</tr>
<tr>
<td></td>
<td>Feb. 23</td>
<td>6.5a</td>
<td>5.3a</td>
<td>8.5ab</td>
</tr>
<tr>
<td></td>
<td>Mar. 16</td>
<td>6.0a</td>
<td>5.3a</td>
<td>8.2b</td>
</tr>
<tr>
<td></td>
<td></td>
<td>L&lt;sub&gt;NS&lt;/sub&gt;&lt;sup&gt;w&lt;/sup&gt;</td>
<td>L&lt;sub&gt;NS&lt;/sub&gt;</td>
<td>L&lt;sup&gt;**&lt;/sup&gt;</td>
</tr>
<tr>
<td>'Easy Wave Salmon'</td>
<td>Jan. 12</td>
<td>8.0a</td>
<td>7.0a</td>
<td>10.0a</td>
</tr>
<tr>
<td></td>
<td>Feb. 2</td>
<td>6.3a</td>
<td>5.5a</td>
<td>8.9ab</td>
</tr>
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<td></td>
<td>Feb. 23</td>
<td>6.0a</td>
<td>4.5a</td>
<td>7.3ab</td>
</tr>
<tr>
<td></td>
<td>Mar. 16</td>
<td>7.3a</td>
<td>5.5a</td>
<td>6.4b</td>
</tr>
<tr>
<td></td>
<td></td>
<td>L&lt;sub&gt;NS&lt;/sub&gt;</td>
<td>L&lt;sub&gt;NS&lt;/sub&gt;</td>
<td>L&lt;sup&gt;***&lt;/sup&gt;</td>
</tr>
<tr>
<td>'Shock Wave Denim'</td>
<td>Jan. 12</td>
<td>8.3a</td>
<td>6.8a</td>
<td>7.2a</td>
</tr>
<tr>
<td></td>
<td>Feb. 2</td>
<td>7.5a</td>
<td>6.5a</td>
<td>7.3a</td>
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<tr>
<td></td>
<td>Feb. 23</td>
<td>6.5a</td>
<td>6.5a</td>
<td>7.3a</td>
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<td></td>
<td>Mar. 16</td>
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<td>6.0a</td>
<td>4.5b</td>
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<td></td>
<td></td>
<td>L&lt;sub&gt;NS&lt;/sub&gt;</td>
<td>L&lt;sub&gt;NS&lt;/sub&gt;</td>
<td>L&lt;sup&gt;***&lt;/sup&gt;</td>
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<tr>
<td>'Shock Wave Rose'</td>
<td>Jan. 12</td>
<td>7.5a</td>
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<td>Feb. 2</td>
<td>7.5a</td>
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<td>Feb. 23</td>
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<td>Mar. 16</td>
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<td>L&lt;sup&gt;**&lt;/sup&gt;</td>
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<sup>z</sup>Each plant was evaluated for flowering every two weeks beginning March 22 and ending July 9 of 2009 (total of nine ratings) using a scale of 1 to 5 (1: no flowers; 3: acceptable display with flowers distributed unevenly and/or covering only a portion of the plant; 5: outstanding display with flowers profuse and well distributed over the entire plant).

<sup>y</sup>Mean counts followed by the same letter within a variety are not significantly different at the 0.10 level according to the simulation method.

<sup>x</sup>Means for plant size followed by the same letter within a variety are not significantly different at the 0.10 level. Mean comparisons were made with the simulation method using repeated measures analysis of data collected at four consecutive biweekly evaluations ending May 30, 2009 (the period of most rapid growth).

<sup>w</sup>Linear trend is not significant (L<sub>NS</sub>) or significant at levels of 0.01 (L<sup>**</sup>) or 0.001 (L<sup>***</sup>).
Fig. 1. Daily high (solid line) and low (dashed line) air temperatures during the winter and spring of 2009 at the site of a petunia planting study in Poplarville, Mississippi. The left vertical axis and the three vertical lines in the left portion of the graph indicate the four dates of field planting in the study.
Survey of White-Tailed Deer (Odocoileus virginianus) Impacts on Ornamental Plants in Alabama


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Index Words: Deer browse, commercial deer repellents, deer management techniques

Significance to Industry: White-tailed deer (Odocoileus virginianus) numbers continue to increase in the state of Alabama, and many nursery and landscape professionals commonly experience deer damage. Deer can be considered an agricultural and urban pest due to their large populations and feeding damage to herbaceous and woody plant material. Understanding feeding preferences along with discovering the capability of commercial deterrents on the market will help in the effort to eliminate deer damage problems to nursery crops and landscaped areas (1). This survey will be used to determine what types of management techniques are commonly being used by nursery and landscape professionals along with their effectiveness. Nursery growers and landscape professionals can apply the information from this survey to select preventative measures to reduce deer damage by knowing which products will work best for their situation based upon other professional experience. Other important information to help nursery and landscape professionals make decisions to prevent white-tailed deer damage to ornamental plants was collected including: time of year most damage occurs, region of the state most susceptible to damage, and plants that deer most commonly browse.

Nature of Work: White-tailed deer (Odocoileus virginianus) damage to ornamental crops is becoming more prevalent throughout the southeastern United States, with an estimated 1.8 million white-tailed deer living in Alabama alone. The agricultural industry in the United States experiences $4.5 billion dollars of economic loss annually due to wildlife depredation (2). There are several possible strategies to control deer browse damage including: habitat modification, deer resistant plantings, fencing, scare tactics, harvesting, and repellents (3).

The objective of this survey was to determine the amount of deer damage that nursery and landscape professionals throughout Alabama experience, along with discovering the types of deterrent techniques that professionals are currently employing (Table 1). This survey will also help determine nursery and landscape professional’s familiarity with commercially available products on the market. The population of participants in this survey included current nursery and landscape professional members of the Alabama Landscape and Nursery Association (ALNLNA) whose businesses are located...
in Alabama. The total number of nursery and landscape professionals in the sample was 223.

The survey included 30 questions and was developed to determine the overall impact of deer browse damage to nursery and landscape professionals throughout the state of Alabama. The surveys were mailed to the recipients in ALNLA envelopes along with a pre-paid envelope for return of the survey. Two cover letters were also included in the survey, one of which was a letter affirming support from the ALNLA and requesting timely responses. The second cover letter explained the purpose of the survey along with a description of research related to the survey. Surveys were mailed to participants on September 25, 2009. Participants were then given one month to complete the survey, and surveys were to be post marked no later than October 25, 2009. This survey was also set up online through www.surveymonkey.com. The second cover letter contained the website, www.auburn.edu/deersurvey, where the online survey could be accessed.

After the conclusion of the survey all data were entered into an Excel spreadsheet (Microsoft 2007). Data were then uploaded into SPSS 17.1 (SPSS, 2008) to be analyzed.

**Results and Discussion:** After the conclusion of the survey, 78 mail surveys were returned and three internet surveys had been completed. This brought the total number of surveys returned to 81, for a response rate of 36.3%.

Respondents from east central Alabama (23%) and southwest Alabama (16%) report the most deer damage to nursery and landscape ornamentals (Figure 1). Sixty-eight percent of the total respondents from east central Alabama answered yes to damage problems. Similarly, in southwest Alabama 66% of the total respondents for the area answered yes for deer damage. Based on a white-tailed deer density map provided by the Alabama Department of Wildlife and Conservation, many counties in east central and southwest Alabama have more than 30 deer per square mile (4). These counties represent the highest populations within the state.

Respondents were also asked about the types of preventative methods they are currently using or have used in the past and to rate the overall effectiveness of those methods (Figure 2). High fencing, electric fencing, Liquid Fence®, and motion irrigation had the highest means of the eleven preventative measures, so these four products were rated most effective by respondents. Methods were rated on a scale from 0 to 4, with 0 being least effective and 4 being the most effective.

Nursery and landscape professionals were also asked to report three plants that typically exhibit signs of deer browse (Figure 3). Forty-five plants were mentioned in the survey. Indian hawthorn was reported to have the most damage, with twenty-six growers and landscapers reporting damage. Other plants that were rated high by respondents include: holly, pansy, azalea, rose, hosta, and hydrangea.
Time of the year that damage typically occurs was also determined with most deer damage occurring during winter and fall (Figure 4). Respondents reported the greatest amount of deer damage in January, February, October, November, and December. Because availability of natural foods for deer is typically lowest during this period, these results are not surprising.

**Literature Cited:**


Figure 1. Deer damage response for geographic sections of Alabama.
Figure 2. Effectiveness ratings of deer preventative methods by Alabama nursery and landscape professionals.

Figure 3. Top 7 plant species exhibiting damage, as indicated by Alabama growers and landscapers.
Figure 4. Month that most deer damage is experienced in the state of Alabama.
Table 1. Deer damage and repellent survey sample questions.

<table>
<thead>
<tr>
<th>Item #</th>
<th>Statement</th>
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<tbody>
<tr>
<td>1.</td>
<td>In which section of Alabama is your business located?</td>
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<td>□ Northwest Alabama</td>
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<td>□ Southwest Alabama</td>
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<td>2.</td>
<td>Do you experience any deer damage problems in your business?</td>
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<td>□ Yes</td>
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<td>□ No</td>
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<td>4.</td>
<td>What types of preventative methods are you using or have you used in the past, and how would you rate the overall effectiveness of those methods? (Not effective = 0 to highly effective = 4)</td>
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<td>High Fence</td>
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<td>Motion Lighting</td>
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<td>Frightening Sounds</td>
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<td>Other</td>
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<td>5.</td>
<td>What plants do deer typically browse (please list three plants by common or scientific name)?</td>
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<tr>
<td>7.</td>
<td>Please list the month that you experience the most deer damage.</td>
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</table>
Using Woody Landscape Plants for Phytoremediation

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Index Words: Best management practice, bioremediation, bioretention, BMP, Filterra®, hyperaccumulation, nitrogen, phosphorus, pollution, stormwater runoff, water quality

Significance to Industry: The Clean Water Act (CWA) is the cornerstone of surface water quality protection in the United States (3). Passed in 1972, and amended in 1997, this statute employs a variety of tools to, in part, manage polluted runoff. While initially focused primarily on "point source" (direct pollutant discharge) facilities (municipal sewage plants, industrial facilities), starting in the late 1980's efforts increased to address "non-point" runoff sources such as streets, parking areas, construction sites, farms, landscapes, and other "wet-weather" runoff sources. If woody landscape plants can be demonstrated to phytoremediate or clean-up polluted stormwater runoff an additional value will be added to our nursery and landscape plants.

Nature of Work: Pollutant loading found in urban runoff can have detrimental effects on water quality and water body ecosystems (6). Pollutants are a major concern in stormwater runoff since these parameters are harder to control from a nonpoint source. Pollutant effects can include oxygen depletion, eutrophication, species stress and toxicity (7). The impact of nutrients, mainly nitrogen (N) and phosphorus (P), on water quality is of particular concern, because nutrients in runoff can accelerate the natural eutrophication process by causing algal blooms which deplete dissolved oxygen levels and increase water turbidity. This can then result in poor water quality and low biodiversity. Nutrients in runoff can be contributed by fertilizers, atmospheric deposition, soil erosion, animal wastes and detergents. Nitrogen can exist as both organic forms and inorganic forms such as ammonia, nitrate and nitrite. Phosphorus can exist as both dissolved and particulate forms in runoff and both include organic and inorganic components (7).

Stormwater best management practices (BMPs) are used to lessen the impact of urban runoff on water quality, flooding, and erosion (6). The use of plants to remediate contaminated soils and wastewater has been practiced internationally for some time, but new research is being conducted to determine how effective plants are at removing contaminates from polluted stormwater and wastewater discharges (8). Phytoremediation is an emerging technology that uses plants to degrade, extract, contain, or immobilize contaminants such as metals, pesticides, explosives, oil, excess nutrients, and pathogens from soil and water (4). Phytoremediation has been identified as a more cost effective, noninvasive, natural, and publicly acceptable method of removing environmental contaminants than most chemical and physical methods (2).
Both nitrogen (N) and phosphorus (P) are macronutrients needed for agronomic and horticultural plant growth, and are components of all complete fertilizers. Fertilizer application to residential, commercial, and municipal lawns and landscapes is a major non-point source of pollution with potential for reduction via phytoremediation. Though runoff from farms is generally decreasing due to nutrient management, runoff control techniques, and an overall decline in farmland, runoff from urban and suburban areas continues to increase as more land is developed, more native filtering plants are removed, and more hardscape is installed.

The majority of plants currently used in phytoremediation applications, including stormwater or Best Management Ponds (BMPs), riparian buffers, rain gardens, green roofs, constructed wetlands, etc., are herbaceous or non-woody. New stormwater runoff systems that incorporate woody landscape plants into the systems, such as the Filtterra® Bioretention System (1), are being designed for streetscapes and landscapes. If commonly used landscape trees could be used for storm water (and soil) phytoremediation our trees would have an added environmental value. It is therefore important to screen commonly available landscape trees for their potential use in these systems.

The objectives of our initial research were to: 1. Use a modified hydroponic system, that was originally designed using water hyacinths, as the remediation plant as a nutrient uptake screening protocol for landscape trees and shrubs, and 2. Screen landscape plants in situ and in Filtterra® Bioretention System stormwater management units to compare nutrient and heavy metal accumulation from landscape soil vs. the Filtterra® system substrate.

In 2007 and 2008, using a protocol developed for phytoremediation screening with water hyacinths (5), several species of woody shrubs, including redtwig or redosier dogwood (Cornus sericia), buttonbush (Cephalanthus occidentalis), and deciduous holly or winterberry (Ilex verticillata) were subjected to increasing levels of N and P. Whole plants were harvested and dried, and leaves were weighed and subjected to N and P analysis using the method described for the water hyacinths.

Also in 2007 and 2008, to begin to compare the accumulation of N and P, matching species of shrubs were planted in landscape sites adjacent to Filterra® units already planted with shrubs. A unique feature of the Filterra® unit is that it holds a substrate into which a shrub or tree is planted. Several sites in Norfolk, VA and the Richmond, VA area were selected for evaluation. For statistical purposes, a requirement of each site was a minimum of three same sized Filterra® units planted with the same shrub. That shrub was then planted into landscape soil a few feet from the Filterra® unit. The major species used for this evaluation were several hollies (Ilex sp.), and redtwig dogwood. Each fall, mature leaves evenly distributed around the shrubs were harvested, dried, and weighed, and then subjected to N and P analysis again using the method described for the water hyacinths.
**Results and Discussion:** There was a definite trend for all species used in the modified hydroponic system to grow larger and accumulate more N and P in their tissue as the rate of N and P in the water increased. There was no visible injury to tissues that would indicate any accumulation of or damage from excessive nutrients (no marginal necrosis, etc.). Several species of willow were started in a nursery at HRAREC in 2006 to evaluate both their phytoremediation potential and their landscape suitability (size, growth rate, color, etc.), and were added to the hydroponic study in October, 2009.

One of the most important components of the Filterra® Bioretention System is the plant since it plays a critical role in pollutant uptake. Uptake of nutrients by plants from substrate absorption sites makes this a sustainable system. Though a range of N, P, and heavy metals percentages is available generically for deciduous and evergreen trees and shrubs, there are few ranges known for individual species and/or cultivars. The leaves of the shrubs planted in the landscape soil were used as a baseline nutrient content against which the shrubs in the Filterra® units could be compared. With a few exceptions and regardless of shrub species, there was more N and P in the leaves of the plants in the Filterra® units than in the landscape plants. This suggests that these shrubs may be able to “luxury feed” or act as hyperaccumulators, absorbing more N and P than they needed for actual plant growth.

Identifying trees and shrubs that can be used for phytoremediation would increase the perceived and real value of landscape plants, and would be an additional marketing tool available to nurseries. Incorporation of these plants into streetscapes and landscapes, or nursery buffers, could improve water quality and the image of the green industry that is seen as a contributor to water pollution. Many of these plants might be appropriate to use not only in specific stormwater treatment systems such as Filterra®, but also in bioretention cells, raingardens, riparian buffers, constructed wetlands and other landscape-based stormwater treatment features to increase the use of plants for phytoremediation. These hyperaccumulators could be available nationwide from nurseries and could thus be used by the green industry, governments, private businesses, non-profits, and communities.

Our preliminary research suggests that the identification of specific plants for bioaccumulation of pollutants seems possible. Future research is still needed for advancing phytoremediation as a technology. This includes studying how to screen and harvest plants, choosing an assortment of plants for particular pollutants of concern, understanding mechanisms for nutrient and heavy metals removal, and ideal environments for maximum plant uptake of pollutants.
References

Evaluation of Overhead Utility Compatible Trees in Hardiness Zones 6 and 8

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Index Words: Power lines, small stature trees, species performance, species selection, street trees, utility easements, UtiliTrees™

Significance to the Industry: In urbanized areas, landscape tree conflicts with overhead utility lines are common. Outreach and education efforts have raised awareness of tree – utility line conflicts in Virginia and encouraged wiser tree selection by landscape professionals and the public for planting near overhead utilities. However, the current repertoire of tree species recommended for use in utility easements is limited. Expanding this repertoire will give consumers more choices of utility compatible trees, creating greater demand for these tree varieties and new income opportunities for nursery producers and retailers. Landscape professionals will also benefit by having new tree varieties to use to achieve their landscape design goals.

Nature of Work: In many areas of the United States, there is a major and potentially disastrous conflict between overhead utility lines and inappropriately tall trees planted in or near line easements (1). Although numerous options, including burying utility lines and applying tree growth regulators, exist to deal with tree – utility line conflicts, one of the most practical solutions is the selection and planting of trees with mature heights compatible with overhead utility lines (2). Extension publications have been developed to raise awareness of this issue and to provide recommendations for utility compatible tree species (3). However, the diversity of field-tested tree species that are currently recommended as utility compatible for Virginia landscapes is relatively low, limiting choices for consumers and opportunities to enhance tree planting in utility easements. Some species/cultivars in similar hardiness zones are being evaluated for street trees (5, 6).

The purpose of the current study is to evaluate the performance of potential overhead utility compatible tree species that are underutilized in hardiness zones 6 through 8. The intended application of these performance trials is to expand the repertoire of field-tested tree species currently recommended to landscape professionals and the general public (3). Doing so will ensure that a wide variety of suitable species exists for utility easement plantings and help reduce over-reliance on the handful of existing species with proven track records. With many communities across the southeast focusing on increasing their urban tree canopy cover, overhead utility easements figure prominently...
as potential planting spaces because they are typically understocked due to lack of suitable tree species. Moreover, utility companies are eager to reduce vegetation management costs and increase utility reliability by removing large conflicting trees and replacing them with small stature species, which is an approach that residents in some communities have been shown to favor (4). These emerging tree planting efforts may create new income opportunities for nursery and landscape professionals.

In this study, approximately 20 varieties of small stature trees (Table 1) from the UtiliTree™ product line of J. Frank Schmidt & Son Co. have been the primary focus of evaluations (7). This product line includes tree varieties that are small stature and generally tolerant of inhospitable urban environments, but have unproven track records in the southeast specifically. Additional small stature species that are currently underutilized in urban landscapes are also being evaluated.

Field evaluation of tree performance in the current study began in spring 2006 when the first five varieties were planted out. Five to six additional varieties have been added to the evaluation in each subsequent year. Trees were received each March from J. Frank Schmidt & Son Co. as branched, bare root liners that were then planted in typical urbanized utility easements throughout Virginia. At each evaluation site, five replicates of each tree variety were planted and mulched according to standard landscape practices. Trees were periodically irrigated during the first growing season and mulched as needed. Baseline measurements included trunk caliper and tree height. At the end of each growing season, physical dimensions of each tree were re-measured and qualitative ratings of tree condition and basal sprouting intensity were recorded. Data from all evaluation sites were compiled and descriptive statistics calculated for each tree variety.

**Results and Discussion:** As of the fall 2009 evaluation, no trees had died due to perceived temperature or moisture conditions during the evaluation period. The few trees that did die were assumed to have been stock damaged during the harvest, holding, and/or shipping period. All trees increased in height and caliper, with slight but not statistically significantly larger increases in Zone 8 compared to Zone 6.

Several species/cultivars produced numerous sprouts from the root system or rootstock on 50% or more of the replicate trees being evaluated. Heavy sprouting trees included *Crataegus laevigata* ‘Crimson Cloud’, *Fraxinus pennsylvanica* ‘Johnson’, *Malus* ‘Red Barron’, *M. Sentinel*, *Prunus* ‘First Lady’, *Styrax japonicus* ‘JFS-E’, and *Zelkova serrata* ‘Schmidtlow’. Excessive sprouting could increase needed pruning beyond an economically acceptable maintenance level.

No significant disease development has thus far occurred on any of the trees. During every test year in Zone 8, most members of the *Rosaceae* (rose) family suffered 50% or more defoliation from Japanese beetle feeding. Heavily-infested trees included *Amelanchier x grandiflora* ‘Autumn Brilliance’, *A. laevis* ‘Snowcloud’, *Crataegus laevigata* ‘Crimson Cloud’, *Malus* ‘Red Barron’, *M. Sentinel*, and *Prunus* ‘First Lady’. In
addition, *Acer negundo* ‘Flamingo’ and *Zelkova serrata* ‘Schmidtlow’ also suffered similar severe feeding and defoliation. Japanese beetle feeding has been mild to non-existent in Zone 6. In Zone 8, therefore, and in particular where trees also exhibited excessive sprouting, these species/cultivars might not be recommended for any landscape use.

This evaluation will continue at both locations, adding five new species/cultivars each year from the UtiliTree™ product line. Many of these trees are also being individually evaluated at four utility line arboreta in Abingdon, Chesapeake, Danville, and Lynchburg, VA (2).

**Acknowledgements:** The authors want to thank the Virginia Department of Forestry for its ongoing financial support of this project through its Urban and Community Forestry Assistance Grant program. The authors also thank J. Frank Schmidt & Son Co. for providing trees from their UtiliTree™ product line for evaluation in this research. Finally, the authors thank students and staff at Hampton Roads AREC and Virginia Tech – Blacksburg for their assistance with planting, maintaining, and evaluating trial trees.

**Literature Cited:**
Table 1. Tree species and cultivars evaluated for compatibility with overhead utility lines in Virginia hardiness zones 6 and 8. Selections from the J. Frank Schmidt & Son Co. UtiliTree™ product line are delineated with an asterisk.

*Acer ginnala* ‘Flame’*
*A. negundo* ‘Flamingo’*
*A. platanoides* ‘Globosa’*
*A. tataricum* ‘JFS-KW2’*
*Amelanchier x grandiflora* ‘Autumn Brilliance’*
*A. laevis* ‘Snowcloud’*
*Crataegus laevigata* ‘Crimson Cloud’*
*Fraxinus pennsylvanica* ‘Johnson’*
*Maackia amurensis* *
*Malus* ‘Schmidtcutleaf’*
*M. ‘Red Barron’*
*M. ‘Sentinel’*
*Prunus* ‘First Lady’
*P. x hilleri* ‘Spire’*
*Pyrus calleryana* ‘Jackzam’*
*Styrax japonicus* ‘JFS-E’
*Syringa pekinensis* ‘DTR 124’*
*S. reticulata* ‘Ivory Silk’*
*Ulmus propinqua* ‘JFS-Bieberich’
*Zelkova serrata* ‘Schmidtlow’*
Bare Rooting Trees at Planting

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Index Words. Air excavation, balled and burlapped, container-grown, pressure washing, root washing, transplanting

Significance to Industry: A perceived epidemic of tree decline exists in the United States, with an estimated 80 percent of all landscape tree problems originating below ground and relating to quality and placement of the root system. Root defects and planting depth issues can occur during all stages of tree production and establishment including nursery propagation and production, landscape specification development and planting, and post-planting/transplanting maintenance. A proposed technique for revealing tree roots prior to finishing the planting or transplanting process, so that root defects can be seen and if possible, corrected, and planting height can be properly adjusted, is bare rooting. Bare root planting of landscape caliper-sized trees has both advantages and disadvantages compared to planting intact field or container-grown root balls per current industry standards, but bare root planting is the planting technique that was used when the nursery and landscape industry began in the United States.

Nature of Work: “It has been said that 80 percent of all landscape tree problems start below ground” (11). With increases in the sophistication of tree production and harvest methods at nurseries in the United States has come an apparent increase in root-related establishment and growth problems. Add to this the confounding problem of improper installation (namely root depth and lack of defective root system modification), and a perceived, whether real or not, epidemic of tree decline in the United States is said to exist (6).

Trees nursery-produced in the 1700’s and 1800’s were all harvested and planted or transplanted bare root, and were predominately fruit trees. In the latter half of the 1800’s a significant increase in non-food or landscape and ornamental plants was added to commercial production, with the most prominent plants being roses, vines such as clematis, honeysuckle, and English ivy, perennials such as peonies and spring bulbs, camellias, numerous deciduous shrubs, yews, and trees such as American elm, Lombardy poplar, magnolia, larch, mountain ash, and American holly. Again, plants were harvested, sold, and planted bare root (7). In their 1938 book The Modern Nursery, Laurie and Chadwick (9) describe the harvest, storage, packing and grading of fruit and landscape trees, both deciduous and evergreen, and again, said operations almost exclusively involved handling trees bare root.
During the 1800’s and early 1900’s trees that were not harvested bare root were dug by hand with a soil ball, thus the beginning of balled-in-burlap (B&B) harvest, shipping, and planting. The production, harvest, and shipping of trees with container-grown root systems started at the end of World War II with the use of #10 egg and fruit cans. The first record of the hydraulic digger harvest of nursery trees is 1956 (7), again producing plants that were then shipped and planted B&B.

In the 1906 fourth edition of the New Cyclopedia of American Horticulture (3), Liberty Hyde Bailey, the father of American horticulture, described transplanting as “…a general term used to designate the removal of living plants whereby they may become established in new quarters.” He stated that only small herbaceous plants were sometimes transplanted while actively growing, but that most plants should be transplanted when dormant. He went on to describe a dormant transplanting method for large trees that involved “picking out and caving down” soil from within a tree root system. As the roots were uncovered they were tied in bundles with lath yarn, and if they were to be out of the ground over one day in dry weather the bundles were to be wrapped in clay mud, damp moss and straw, or burlap. When placed in their final landscape destination the roots were systematically uncovered and then settled into their planting hole by means of a mud slurry and “planting sticks”.

In a 1943 National Shade Tree Conference and National Arborist Association publication, a technique similar to the above is recommended: “Digging Specifications: Remove the loose soil or soil above the roots, from the area to be dug. Planting Practices: After the B&B specimen is set in the hole, it is advisable to remove the burlap. Puncturing or breaking the ball - often times plants dug from heavy clay soil will arrive at the planting site with the outer inch or more of the soil ball sufficiently dried out to form a hard crust. Balls planted in this condition are not satisfactory for rapid re-establishment of the roots. The crust may be so hard that it inhibits ready movement of air and water to the roots, and furthermore, the new roots penetrate the crust very slowly, if at all. A method of removing soil from the roots uses a tined spading fork to comb out the roots by inserting the fork into the soil ball and prying against the root ball. Continue working inward until most of the roots are exposed. If practical leave a partial ball or some soil clinging to the roots.” (1).

“The four to eleven large roots that radiate from the base of the tree trunk (“the root collar” are usually easy to see. They are either on the surface of the soil or only a few inches below.” This statement from Perry (10) is contradicted by the fact that present surveys of both trees in nursery and landscape settings are being found in large numbers to have their major structural or first order lateral roots located well below a few inches of the soil surface

In recent years bare root tree planting has mainly been reserved for the planting of small, mainly deciduous seedlings for reforestation, establishment of riparian buffers,
and similar tree replacement projects; for lining-out whips for larger tree production at nurseries; for planting small evergreen seedlings for Christmas tree production; and for the planting of fruit trees. The bulk of these types of planting projects use trees that are dormant. Bare root plants also represent the bulk of the means by which plants are shipped mail order in the United States.

Web and literature searches (September 20, 2008) regarding bare root planting almost exclusively related to plants harvested and planted or transplanted bare root, not bare rooted at planting or transplant time. *Creating the Urban Forest: The Bare Root Method* by Buckstrup and Bassuk (5) is the only major publication the authors could find that currently addresses bare root planting in detail, but does not mention bare rooting at planting or transplanting.

A search of the popular literature produced only three articles on bare rooting at planting (2, 6, 8). A majority of the most recent references regarding landscaping and tree care do not give any recommendations for root modification or root depth adjustment when trees are bare root planted or bare rooted at planting or transplanting.

**The Origin of Improper Structural Root Depths** - Some deep structural roots get their start during nursery propagation or production. Others start during landscape installation or maintenance, and still other times deep structural roots are a result of cumulative events or handling practices. The following lists enumerate causes of deep structural roots, and can be used to make production, installation, and maintenance changes to minimize or prevent deep structural root development.

**Field Propagation, Production, and Harvesting:** Seeds planted too deep in direct field propagation; seedlings dragged or “swept” into planting rows creating “J” roots; seedlings, rooted liners, whips, or grafted rootstock roots covered by soil during cultivation for weed control; seedlings, etc. planted too deep because root-to-stem transition zone, root collar, or stem flare not obvious or observed; seedlings, etc. planted too deep to prevent blow over; budded and grafted trees lined out too deep to bury the graft union (or seedling cut back referred to as the “dog leg”); root balls topped with additional soil to create a crowned root ball at harvest.

**Container Propagation and Production:** Deep propagation containers used that tend to concentrate rooted liner roots at the bottom of the container; seedlings and rooted liners potted with their roots too deep in production containers; seedlings planted too deep because root-to-stem transition zone not obvious; seedlings or liners planted too deep to prevent blow over; seedlings and rooted liners potted off center or “swept” into containers creating “J” roots; substrate settling around seedlings or liners over time; budded and grafted trees lined out too deep to bury the graft union (or seedling cut back “dog leg”).

**Landscape Installation and Maintenance:** Roots initially too deep in the nursery container or field root ball resulting in planting hole dug too deep. (Fallacy of using soil
mark on stem or stem flare as defining mark for establishing hole depth [4].); planting hole dug too deep due to incorrect planting specifications or digging errors; soft soil underneath the root ball compacts or settles in the bottom of the planting hole; soil displaced by root ball put atop the roots; excess mulch put atop the roots; post-installation grade changes.

**The Origin of Defective Roots** - As with deep structural roots, root defects can get their start during nursery propagation or production, or can start or be perpetuated during landscape installation or maintenance. They may also be mandated by outdated landscape specifications. The following lists enumerate causes of defective roots, and can likewise be used to make production, installation, and maintenance changes to minimize or prevent development or perpetuation of root defects.

**Field Propagation and Production:** Seedlings, liners, whips, or grafted rootstocks started in propagation and/or small production containers and then lined out without removal or correction of circling roots; seedlings, etc. settled into narrow planting furrows or trenches via root dragging or “sweeping” (produces “J” roots).

**Container Propagation and Production:** Seedlings, liners, whips, or grafted rootstock started in propagation containers and then potted up into large containers without removal or correction of circling roots; trees shifted up (“up canned”) to larger size production containers without removal or correction of circling roots; field-grown liners or finished trees potted up into containers without removal or correction of circling of J-roots.

**Landscape Installation and Maintenance:** Planting or transplanting field or container-grown trees with deep structural and/or defective roots; not roughing up or creating root passages in planting hole walls when augering creates slicked or impenetrable walls (mainly in heavy clay soils); digging plants holes deeper than the actual depth of the tree root system (leading to stem girdling roots [SGRs]); using outdated landscape planting or transplanting specifications.

**Results and Discussion:**

**Advantages to Bare Rooting during Production, Harvesting, Shipping, and Planting and Transplanting** - Bare rooting, or the removal of field soil or container substrate, at planting and transplanting has many advantages that can address the above mentioned structural root depth and defective root system problems. Bare rooting also has advantages relative to other production, harvesting, shipping, and planting and transplanting components, with the following being a compilation of the major advantages across all phases of plant handling:

- Root defects and structural root depth can be corrected prior to tree harvest if bare rooting occurs during each propagation or production stage, or during planting or transplanting.
- Root pruning stimulates new root growth.
- Field soil and container substrate can be retained at the production nursery.
Transmission or transport of soil-borne weeds, insects, and pathogens can be minimized.

May help in dealing with quarantines relative to soil-borne insects and pathogens.

May give nurseries that produce quality root systems a marketing and pricing advantage.

Trees may be less expensive and easier to store at the nursery prior to shipping.

By correctly locating structural roots, and therefore the point from which to measure up 6” or 12” for caliper their trees (according to American Nursery and Landscape Association ANSI Z60.1 – 2004, Figure 9), growers will get a more accurate, and generally larger, tree caliper for inventory and sales purposes.

Trees will be less expensive to ship and therefore potentially less expensive to the buyer.

Trees can be transported into more confined spaces if both their branches and their roots can be compressed.

Trees will be easier to handle from a weight perspective.

Planting holes will be easier to dig and will require less heavy digging equipment (with a side advantage of reduced soil compaction).

Removes problems that can result from incorrect installation handling of balling burlap, ropes, and straps, and wire baskets.

Resolves soil and container substrate disparity or hydrologic discontinuity problems.

Root systems are more uniformly moistened by “mudding in” (creating a soil slurry to settle into and atop the bare root system), and large air pockets are removed.

All structural and absorbing roots are in contact with the planting site soil, not just the roots/root tips on the outside of the root ball.

“Mudding in” creates greater direct root anchorage and reduces the need for supplemental stabilization (staking or root anchoring). This in turn reduces maintenance cost and potential tree and human hazards when no stabilization method needs to be removed.

Fewer injuries should occur to green industry personnel.

Potential to increase the period of time of the tree guarantee or warranty.

Trees with poor quality roots can be refused or returned with proof of the structural defect or root depth problem.

An additional, non-production or installation advantage noted by the senior author during his years as a municipal arborist was increased volunteer participation in tree planting activities due to the lighter weight, more consumer friendly bare root tree.
Disadvantages (real or perceived) to Bare Rooting at Planting and Transplanting -

Just as bare rooting, or the removal of field soil or container substrate, at planting and transplanting has many advantages that can address structural root depth and defective root system problems, there are likewise disadvantages that should be considered. The following is a compilation of the major disadvantages across all phases of plant handling:

- Though diseased, damaged, and/or structurally malformed roots can be removed, the removed roots may account for a large portion of the tree’s roots. Regardless, if said problematic roots are not removed, the tree may die anyway.
- Improper handling during the bare rooting process including the need to prevent root desiccation.
- The need to dispose of substrate (soil or potting) removed from root systems during the bare rooting process.
- The need to alter tree planting specifications to reflect reconfiguring the planting hole with varying dimensions.
- Differences in species adaptation to bare rooting including phenological growth stages (timing of bare rooting, especially relative to bud break) and ability to rapidly recover following planting or transplanting.
- Resistance to the principle of bare rooting by nursery growers, landscape designers, architects, and contractors, and arborists.
- The cost (labor and equipment) to bare root and plant a B&B or container-grown tree vs. the cost to “drill and drop” plant B&B, or “pop and drop” container-grown trees, especially if large numbers of trees are being planted.
- Post planting or transplanting maintenance requirements for successful tree establishment (primarily stabilization and irrigation) will vary depending on soil and site (especially environmental) characteristics, root quality, and root biomass vs. soil volume.
- Research shows that bare rooting, via “root washing” or soaking for a period of time in water, may remove or dilute stored nutrients and may also remove desirable rhizosphere organisms (mycorrhizal fungi, etc.).
- Nurserymen and landscape contractors may refuse to guarantee or warranty bare root planted and transplanted trees.

Literature Cited