UK Nursery and Landscape Program

Faculty, Staff, and Student Cooperators

About Our Cover

Dryopteris x *autralis* – Dixie Wood Fern is a Theodore Klein Plant Award winner for 2010. It was selected because of its outstanding upright foliage, which grows 3 to 4 feet tall or more and is considered tough and adaptable by those who grow it in Kentucky. This plant is a naturally occurring hybrid between *D. celsa* (log fern) and *D. ludoviciana* (southern wood fern) that is found in native groups from Virginia to Louisiana. Dixie Wood Fern has been observed as a dieback plant in zone 5 but is semi-evergreen south of that area. Old fronds should be removed when new growth starts. Propogtion is limited to division, and the tendency of ferns to naturalize in a garden is restricted by the wood fern's lack of spore production. As is typical of many perennials, propagation can be carried out in late summer to early autumn or in early spring. This plant is tolerant of dry conditions and full sun and is considered a plant for the difficult dry shade climate under trees. However, it does better in part to full shade with adequate moisture available.

Ronald L. Jones' *Plant Life in Kentucky* reports that both parents of the hybrid Dixie Wood Fern are found in Kentucky, so it is possible that the hybrid might also be found here.

Dixie Wood Fern is a spectacular addition to any garden, but it is very useful in the woodland garden. <http://www.ca.uky.edu/HLA/Dunwell/DryopterisxautralisTKPA10.html>

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Nursery and Landscape Program

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UK Nursery and Landscape Program Overview—2009

The UK Nursery and Landscape Program coordinates the efforts of faculty, staff, and students in several departments within the College of Agriculture for the benefit of the Kentucky nursery and landscape industry. Our 2009 report has been organized according to our primary areas of emphasis: production and economics, pest management, and plant evaluation. These areas reflect stated industry needs, expertise available at UK, and the nature of research projects around the world that generate information applicable to Kentucky. If you have questions or suggestions about a particular research project, please do not hesitate to contact us.

Although the purpose of this publication is to report research, we have also highlighted some of our extension programs and undergraduate and graduate student activities that are addressing the needs of the nursery and landscape industries.

Extension Highlights

Amy Fulcher, University of Kentucky extension associate for nursery crops, received the Friends of IPM "Future Leader" Award on February 13 for her leadership in integrated pest management (IPM). The award presentation took place during the Annual Southern Nursery Association Research Conference and Trade Show in Atlanta, Georgia.

Also at that SNA Research Conference, Amy began the Southern Nursery Integrated Pest Management working group. The group includes extension professionals from Georgia, Kentucky, North Carolina, South Carolina, and Tennessee who represent entomology, horticulture, and plant pathology. They are collaborating on a multi-state nursery crops project that includes the development of a crop profile and a strategic plan for pest management.

A nursery industry survey is being conducted by personnel in university research and Cooperative Extension from Georgia, Kentucky, North Carolina, and South Carolina, and Tennessee. The goal is to determine which components of IPM are widely used. Funding for IPM programs in Kentucky and the region will be based on survey results. The survey is supported by the Southern Region IPM Center and green industry commodity groups in all five states. It is critical to continuing competitiveness for funding that make Kentucky's nursery IPM programs possible. Please have the person who makes pesticide management decisions in your firm complete the survey, which can be filled out online at <http://ceres.cals.ncsu.edu/surveybuilder/Form.cfm?TestID=8177> If you prefer to have assistance filing out a paper version of the survey, please contact Amy Fulcher at afulcher@ uky.edu 859-257-1273 or Winston Dunwell at wdunwell@uky.edu 270-365-7541 ext. 209.

The University of Kentucky Department of Horticulture continues to provide leadership for the national eXtension site for gardens, lawns, and landscapes (www.extension.org/horticulture) under the leadership of Richard Durham, PhD, national chair of the community of practice for consumer horticulture. Several Kentucky extension personnel are also active in the project. The gardens, lawns, and landscapes site compiles extension information on home horticulture from across the nation into one, easy-to-use site. The site has information arranged by topics and has a database of frequently asked questions that contains over 2,000 answers on horticultural topics from fruits and vegetables to ornamentals to houseplants. Many of these questions were imported from the no-longer-active University of Kentucky GardenData.org site, which currently redirects people to the eXtension site. A news feed also provides access to timely articles written by horticultural specialists and extension staff from across the country.

Titik Nur Aeny, visiting instructor and diagnostician from Lampung University, Sumatra, Indonesia, visited the UK Plant Disease Diagnostic Laboratory in Lexington. While working with Julie Beale, plant diagnostician, and Sara Long, diagnostic assistant, for a month in May and June, she learned about diagnosis of plant diseases, including diseases of woody plants and nursery crops. Under the guidance of Bernadette Amsden, research analyst in plant pathology, Titik also gained experience in the use of enzyme-linked immunosorbent assay (ELISA) and polymerase chain reaction (PCR) for plant disease diagnosis. She also attended classes in plant disease diagnosis taught by Kenny Seebold, PhD, and John Hartman, PhD.

Information Development— In an effort to contact industry in a more timely fashion, the University of Kentucky Nursery Crop Development Center is now on Twitter at http://twitter.com/WDunwellUKNCDC. This spring the Kentucky Nursery Crops IPM will use social networking to provide immediate alerts to pest problems and education opportunities.

Undergraduate Program Highlights

The department offers areas of emphasis in horticultural enterprise management and horticultural science within a bachelor of science degree in horticulture, plant and soil science. Following are a few highlights of our undergraduate program in 2008-2009:

Matthew Piersawl and Lucas Hanks, students in UK plant and soil science, along with Emilie Jenoyer and Audrey Canel, students at ENESAD (Etablissement National D'Enseignement Supérieur Agronomique) in Dijon, France, gained hands-on experience in management of black spot disease throughout much of the summer at The Arboretum in Lexington, where they assisted in fungicide treatment for its 2,000 roses.

The plant and soil science degree program had 65 students, one-half of which were horticulture students in horticulture and another one-third were students whose emphasis was turfgrass.

We believe that a significant portion of an undergraduate education in horticulture must come outside the classroom. In addition to the local activities of the UK Horticulture Club and field trips during course laboratories, students have excellent off-campus learning experiences. Here are the highlights of such opportunities in 2008:

- Students visited nursery/landscape businesses in Costa Rica in a tour led by Robert Geneve, PhD.
- Horticulture students competed in the 2009 Professional Landscape Network (PLANET) Career Day competition. (Robert Geneve, PhD, faculty advisor).
- Students accompanied faculty to the following regional/national/international meetings: Eastern Region of the International Plant Propagators' Society; the Kentucky Landscape Industries Conference; the Mid-States Horticultural Expo; the short course sponsored by OFA, Ohio's association for florist professionals; and the summer outing of the Kentucky Nursery and Landscape Association.

Graduate Program Highlights

The demand for graduates with master's degrees or doctorates in horticulture, entomology, plant pathology, and agricultural economics is high. Our graduates with master's degrees are being employed in the industry, the Cooperative Extension Service, secondary and postsecondary education, and governmental agencies. Last year, nine graduate students in these degree programs conducted research directly related to the Kentucky nursery and landscape industry. Graduate students contribute significantly to our ability to address problems and opportunities important to the Kentucky nursery and landscape industry.

Natural Season, Container-Grown Garden Mum Production Demonstration

Steve Berberich, Department of Horticulture

Introduction

On-farm demonstrations are conducted to help new and existing growers understand and apply technologies of profitable production systems. An on-farm, container-grown garden mum production demonstration was conducted in Bourbon County in 2009. The purpose of this natural-season mum plot was to demonstrate cultural practices necessary for successful outdoor garden mum production using drip irrigation and appropriate fertilizer injectors. The growers/cooperators were full-time cattle and tobacco farmers who had recently started growing vegetables and flowers. They produced 250 garden mums to be marketed at the Bourbon County Farmers Market.

For this demonstration, labor and daily management of the crop was provided by the cooperator. The Extension associate made regular visits to the plot to assess progress of the crop and make recommendations. The county Extension agent scheduled and coordinated a field day at the site.

Materials and Methods

In preparation for the demonstration, irrigation water was analyzed at the University of Kentucky Regulatory Services laboratory and the fertigation program was formulated. The alkalinity and conductivity were determined to be acceptable for production of container-grown plants. However, calcium and magnesium were extremely low and needed to be supplemented.

A 15 ft. x 200 ft. plot adjacent to the vegetable plot was covered with black woven polypropylene ground cover (DeWitt Company, Sikeston, MO 63801), and drip irrigation lines with pressure compensating emitters (Netafim USA, Fresno, CA 93727) were installed for 30-inch center-to-center pot spacing. A 1:100 ratio proportional fertilizer injector (Chemilizer Products, Inc., Largo, FL 33770), along with appropriate filters, regulators, and valves, was installed.

Liners of six garden mum cultivars, *Chrysanthemum* x *morifolium* 'Urano Orange,' 'Camino,' 'Cesara,' 'Cliori, ' 'Golden Marilyn,' and 'Izola Orange,' were received in 50 cell trays. On Jun 5 the liners were transferred to 12-inch mum pans (Nursery Supplies, Inc. Classic 1200S) in SunGro Metro-Mix 560 Coir (SunGro Horticulture Distribution, Inc., Bellevue, WA 98008). On Jun 15 the plants received a Banrot (Scotts Company LLC, Marysville, Ohio 43041) drench at label rate as a preventative treatment for root rot diseases.

20-10-20 Peat-Lite Special (Scotts Company, LLC, Marysville, Ohio 43041) water-soluble fertilizer was used as the primary fertilizer for the continuous liquid feed program. The plants were fertigated as needed throughout the growing season. The fertilizer concentration was 150 ppm N for weeks 1 and 2, 400 ppm N for weeks 3 through 6, and 300 ppm N for weeks 6 through 10. For the remainder of the growing season, the plants were fertigated every third day with potassium nitrate at 200 ppm N. Calcium and magnesium were provided by weekly applications of calcium nitrate at 1 pound per 100 gallons water and biweekly applications of magnesium sulfate at 1 pound per 100 gallons of water. The electrical conductivity (EC) of the container media was checked regularly by pour-through media analysis in an attempt to maintain an EC value between 1.5 and 2.0 mS/cm. Media samples were sent to the laboratory for analysis the second week of each month.

Results and Discussion

The weather conditions during the 2009 growing season made it difficult for successful production of quality garden mums. The rainfall was above average and the temperatures below average, so foliar diseases and slow growth were common issues. However, this was still a successful crop for the growers/cooperators, and they intend to expand production next year. The average price for garden mums sold was $7. Though garden mums are not a high-value crop for many potted plant producers, they have the potential to be profitable. They are a very important fall flower crop for growers selling at roadside stands and farmers markets, so growers generally try to differentiate their product by producing larger, better quality mums. Although production costs may vary considerably from grower to grower, a new grower can use the costs listed below as an estimate of those typically associated with garden mum production (Table 1).

Table 1. Production budget for 250 natural-season, container-grown garden mums in 2009.

	Qty	Unit	Price per unit ($)	Total ($)
Sales				
12-inch	250	each	7.00	1,750.00
			Total sales	**1,750.00**
Expenses - Variable				
Liners	250	each	0.41	102.50
12-inch container (Nursery Supplies C1200S)	250	each	0.55	137.50
Media (2,8 cu. ft. Metro Mix 540 coir)	31	bags	7.80	241.80
Fertilizer	29	pounds	1.28	37.12
Fuel	16	gallons	2.50	40.00
Total Variable Expenses			0.77	**558.92**
Expenses - Fixed (prorated over 5 years)				
Woven ground cover	3,000	ft^2	0.05	30.00
Fertilizer injector (Chemilizer 11GPM)	1	each	195.00	39.00
Misc. PVC fittings, filters, regulators, etc.		each	100.00	20.00
Irrigation supplies (lines, emitters, spray stakes)	63	4-way assembly	2.00	25.20
Backpack sprayer	1	each	95.00	19.00
pH/EC meter	1	each	140.00	28.00
Total Annual Fixed Expenses				161.20
			Total expenses	720.12
			Profit (total sales – total expenses)	1,029.38
			Profit per plant (profit ÷ total plants sold)	4.12
			Labor (hours)	
			Preparation of growing area (prorated over 5 years)	2.9
			Production	56.0
			Total labor	58.9
			Return per hour (profit ÷ total labor)	17.48

Use of the Whole-Tree, Mixed-Species Product, Forest Floor, as a Sustainable Container Substrate for Herbaceous and Woody Crops

Amy Fulcher and Rebecca Schnelle, Department of Horticulture

Nature of Work

Traditionally, annuals and perennials have been produced in containers with a peat-based substrate. Trees and shrubs have been both container and field-produced. Container substrates for woody plants have typically been pine bark-based in the southern US and often contain peat moss as a component (Davidson et al., 1994). Both peat and pine bark are in limited supply. Pine bark is limited due to an increase in the import of foreign logs, a decrease in domestic forestry, and increased demand as a fuel and mulch material (Lu et al. 2006). Canadian peat, a major source of peat used in the United States, is subjected to the flux in fuel prices and can be expensive to transport to the Southern US. Additionally, environmental issues surround the use of peat. Peat bogs are diminishing in both Europe and Canada, and, as a nonrenewable resource, peat is not a sustainable choice for container substrates (Rydin and Jeglum 2006).

Whole loblolly pine tree (*Pinus taeda*) products have been successfully used in both herbaceous and woody plant production of a range of shrubs and annuals, including *Ageratum houstonianum*, *Buddleia davidii, Impatiens walleriana, Ilex crenata*, *Rhododendron obtusum*, and *Salvia* x *superba,* as well as eight perennial species (Boyer at al., 2008a; Boyer at al., 2008b; Boyer et al., 2009; Fain et al., 2008; Jackson et al. 2008; Wright and Browder 2005*).* Additionally, post-planting performance has been investigated for a number of herbaceous plants produced in a whole pine tree substrate and found to be comparable to that of bedding plants grown in traditional substrates (Wright et al., 2009). However, whole tree substrates of mixed species origin have not been researched. Recently, a new substrate called “Forest Floor” was developed by a local company, Creech Services, Inc., Lexington, KY. Forest Floor is composed of leaves, needles, wood and bark of multiple species collected from tree trimming services. While these trimmings are currently in abundance due to a January 2009 ice storm, routine highway and power line maintenance, and residential trimming and tree removals produce a relatively constant and predictable supply of mixed species, whole tree trimmings. The trimmings are ground and composted with 25% horse bedding compost. Forest Floor is approximately one third the cost of a pine bark-based substrate. Successful research and development of this product promises a local, inexpensive, and renewable resource for Kentucky nursery producers.

Herbaceous Perennials. Seeds of *Hibiscus moscheutos* ‘Luna Blush’ and *Lavendula angustifolia* ‘Lady’ were sown April 29, 2009 in 72 cell trays filled with a peat-lite substrate (Sunshine LA4; SunGro Horticulture, Vancouver, BC, Canada). On June 1, the rooted seedlings were potted into # 1 trade gallon containers filled with a peat-lite substrate (Sunshine SB 300), Forest Floor (Creech Services, Inc., Lexington, KY), or a 1:1 mixture of the two media. Plants were grown in a fan and pad cooled greenhouse located at the Horticulture Research Farm in Lexington, KY. All plants received constant liquid feed at 150 ppm of 15-5-15 CalMag (The Scotts Company, LLC, Maryville, OH). Data were taken when the plants had reached marketable size (July 21). Height and width were measured to calculate the growth index using the formula [(Height + (Width1+Width2)/2)/2]. Quality ratings were taken using the following rubric: 0=Unmarketable plants having greater than 30% of leaves discolored and no blooms or buds 1=poor quality plants having 15-30% of leaves discolored, buds may or may not be present 2=Acceptable plants with 1-15% of leaves discolored and buds or open blooms were present 3=High quality plants having no discolored leaves and open blooms. EC and pH measurements were taken using the pour through method at the termination of the experiment. Plants were destructively harvested and shoot fresh and dry weights were taken. Root weights were not taken as these species have fine, fibrous root systems that are difficult to reliably extract from the substrate. The experiment was a completely randomized design with ten replicates.

Woody Plants. Liners of flowering dogwood, *Cornus florida* (container-grown, 24” tall) and river birch, *Betula nigra* (bareroot, 36” tall) were potted into #7 trade gallon containers (Nursery Supplies Inc., McMinnville, OR) with a standard pine bark-based substrate (Barky Beaver, Professional Grow Mix, Moss, TN) or Forest Floor (Creech Services, Inc., Lexington, KY). Plants were top-coated with 8-9 month Osmocote 15-9-12 (The Scotts Company, LLC, Maryville, OH) controlled release fertilizer at the substrate rate and irrigated with one emitter per pot, as needed. Plants were grown in a pot-in-pot production system at the Horticulture Research Farm in Lexington, KY. Height and width were measured on August 5, 2009. Quality was rated on August 19, 2009 (0=very healthy plant, vigorous, full, normal size leaves, healthy green color to leaves, 1=slightly unhealthy 1-29% leaves off color, small, 2=moderate unhealthy, 30-50% of leaves off color or stunted, overall plant is somewhat stunted, 3=overall unhealthy plant, >50% of plant displaying poor vigor, stunted, few and or small leaves). EC and pH measurements were taken on August 21, 2009 following the saturated paste extract technique. Plants were harvested on August 21, 2009 for dry weights and for foliar nutrient analysis. Growth index was [(Height + (Width1+Width2)/2)/2]. The experiment was a completely randomized design with 20 birch replicates and 11 dogwood replicates.

Results and discussion

Hibiscus. Hibiscus grown in Forest Floor were smaller, produced 50% or less dry matter, and were of lower visual quality than those grown in SB300 or a 1:1 mix of Forest Floor and SB300 (Table 1). *Hibiscus moscheutos*, commonly referred to as "swamp mallow" is a marginally aquatic plant which is documented to grow larger and flower more prolifically with an ample water supply (Nau, 1996). Forest Floor dried much more rapidly than SB300. The 1:1 mix of the two substrates was intermediate. With these observations, it is logical that the hibiscus plants in the fast drying Forest Floor had less water available to them between irrigations than those in SB300, at least partially resulting in the reduced growth. Soluble fertilizer was used, so some of the reduction in growth may also be due to reduced nutrient availability. In addition, the pH of the Forest Floor substrate at the end of the experiment was 7.2 which is high enough to restrict availability of micronutrients (Table 2).

Lavender. Lavender grows and flowers best in well drained substrates and is prone to root borne diseases in consistently damp substrates (Nau, 1996). Lavender plants grown in the 1:1 mix of Forest Floor with SB300 were of higher quality and had higher fresh and dry weight than those grown in Forest Floor or SB300. However, there was no significant difference in growth index of plants grown in the 1:1 mix and SB300, while those grown in Forest Floor were significantly smaller (Table 1). The electrical conductivity of the 1:1 mix of Forest Floor and SB300 was 2.0 mS/cm at experiment termination compared to 2.7 mS/cm in SB300 (Table 2). Lavender production guidelines call for EC in the 1.5-2.0 mS/cm range for best growth (Nau, 1996). The higher than optimal salt concentration in SB300 may account for the reduced growth of lavender plants in this substrate.

Table 1. Biometrics for hibiscus (*Hibiscus moscheutos* 'Luna Blush') and lavender (*Lanvandula angustifolia* 'Lady') in SB 300, a commercial peat based substrate, a 1:1 mix of SB 300 to Forest Floor, a whole tree, mixed species-based substrate, or Forest Floor. Growth index is calculated by the formula [(height + average width)/2].

Taxa	Substrate	Growth Index (cm)	Shoot Fresh Weight (g)	Shoot Dry Weight (g)
Hibiscus	SB 300	68.7 a^z	523.9 a	87.0a
	1 SB 300 : 1 Forest Floor	66.5 a	387.5 b	70.0 b
	Forest Floor	52.5 b	152.5 c	30.8 c
Lavender	SB 300	31.7 a	139.8 b	16.3 b
	1 SB 300 : 1 Forest Floor	32.1 a	180.0 a	21.2 a
	Forest Floor	25.3 b	77.0 c	9.6 c

z means within a column for each species followed by the same letter were not different (Tukeys HSD α=0.05).

Table 2. Electrical conductivity (EC), pH, and quality ratings for hibiscus (*Hibiscus moscheutos* 'Luna Blush') and lavender (*Lanvandula angustifolia* 'Lady') grown in SB 300, a commercial peat based substrate, a 1:1 mix of SB 300 to Forest Floor, a whole tree, mixed species-based substrate, or Forest Floor.

Taxa	Substrate	EC (mS/cm)	pH	Quality Rating^z
Hibiscus	SB 300	2.3 az	5.9 a	2.3 a
	1 SB 300 : 1 Forest Floor	2.0 a	6.6 b	2.0 b
	Forest Floor	1.5 b	7.1 c	1.6 c
Lavender	SB 300	2.7 a	5.7 a	2.1 b
	1 SB 300 : 1 Forest Floor	2.0 b	6.4 b	2.4 a
	Forest Floor	1.7 b	7.0 c	1.8 c

z means within a column for each species followed by the same letter were not different (Tukeys HSD α=0.05).

Dogwood. For dogwood, there was no effect of substrate on height, width, growth index, root, shoot or total dry weight, or quality (Tables 3 & 4). Electrical conductivity was greater for the Forest Floor substrate (Table 4). The pine bark-based substrate had a significantly lower pH than Forest Floor (Table 4). Although Forest Floor contains many large pieces of wood, it appeared to hold more moisture than the pine bark-based substrate. Dogwoods require evenly moist rhizosphere conditions and do not tolerate saturated, compacted, or dry conditions (Dirr 2009, Day et al. 2000). Rainfall was extremely high, 9.29" over the average, during the period of the experiments. It is possible that more differences weren't detected for dogwood because both substrates were very moist throughout most of the growing season, negating other effects of Forest Floor. Physical inspection of the root systems revealed that the dogwood roots were much smaller in Forest Floor than in pine bark substrate (Figure 1). Additionally, dogwood roots were limited to the upper portion of the Forest Floor substrate, which may indicate that the lower portion was too wet to support root growth. The higher EC values for the Forest Floor substrate compared with the pine bark substrate, 0.39 vs. 0.15 mS/cm, respectively, may reflect reduced nutrient uptake by plants growing in Forest Floor due to the limited root system. Foliar analysis was conducted on a single composite sample (no replication) of leaves from each plant grouped by treatments and species. Therefore, inferences made from these data must be made with caution. No observable differences in foliar macronutrients were detected in dogwood (data not shown). Overall, other nutrients were sufficient, low, or deficient. This may be due to the extremely small size and poor health of the root system.

Birch. River birch is adapted to bottomlands and occasional flooding, but not drought conditions (Dirr 2009). River birch grown in pine bark had a significantly greater height, width, growth index, and root, shoot, and total dry weights than plants grown in Forest Floor (Table 3). For birch there was no difference in EC or quality due to substrate (Table 4). The pine bark-based substrate had a significantly lower pH than Forest Floor (Table

Figure 1. Flowering dogwood grown in Forest Floor, a whole-tree, mixed-species substrate, (left) and a pine bark-based substrate (right).

4). River birch grew well in either substrate according to the quality rating but substantially greater biomass was attained from the pine bark substrate. River birch may be sensitive to the high pH of the whole tree substrate; it is reported to grow best below a pH of 6.5 (Dirr 2009). No observable differences in foliar macronutrients were detected in the river birch regardless of substrate (data not shown). Micronutrients were at sufficient or high levels except for manganese which was deficient in birch grown in the pine bark and zinc and iron which were both excessive in birch grown in pine bark.

Table 3. Biometrics for river birch and flowering dogwoods grown in either a pine bark-based substrate or a whole tree, mixed species-based substrate, Forest Floor.

Taxa	Substrate	Height (cm)	Width (cm)	Growth Index	Root Dry Weight (kg)	Shoot Dry Weight (kg)	Total Dry Weight (kg)
River birch	Pine bark	154a[z]	99a	124a	0.20a	0.33a	0.53a
	Forest Floor	127b	67b	94b	0.10b	0.14b	0.24b
Flowering dogwood	Pine bark	93a	56a	71a	0.13a	0.13a	0.26a
	Forest Floor	82a	49a	62a	0.10a	0.11a	0.22a

Table 4. Electrical conductivity (EC), pH, and quality ratings for river birch and flowering dogwoods grown in either a pine bark-based substrate or a whole tree, mixed species-based substrate, Forest Floor.

Taxa	Substrate	EC (mS/cm)	pH	Quality Rating
River birch	Pine bark	0.47a[z]	4.2a	0.8a
	Forest Floor	0.40a	7.4b	1.3a
Flowering dogwood	Pine bark	0.15a	4.6a	1.7a
	Forest Floor	0.39b	7.2b	2.2a

z means within a column for each species followed by the same letter were not different (Tukeys HSD α=0.05).

Biomass metrics are greater for river birch than for dogwood. River birch is moisture tolerant, fast growing species compared to dogwood, and may have been better able to take advantage the extra substrate moisture. While there were differences in dogwood quality due to substrate, dogwood quality was lower than birch quality, regardless of substrate, which may support the hypothesis that excessive moisture negated other substrate effects. The difference in substrate pH is likely due to the inherent characteristics of the substrate components and the fact that the substrates were not pH adjusted, i.e., no limestone was added. Pine bark inherently has a low pH, while wood, hardwood bark and the composted waste in Forest Floor would increase pH (Davidson 2000; Ribiero et al. 2007).

Forest Floor and other mixed species-based substrates show potential for the production of some herbaceous and woody nursery crops. However, caution is necessary when implementing this or any new substrate in nursery production. For all species tested, the pH of the Forest Floor substrate was significantly higher than the industry standard substrates which would be problematic for crops that are sensitive to high pH. In this study, the substrate composed entirely of coarse whole tree residue (Forest Floor) dried too quickly in gallon sized pots to be practical for perennial production in a nursery but tended to retain too much water in larger containers. However, a blend of Forest Floor and a finer substrate such as SB300 would be suitable for production of species like lavender that require periodic drying down of the substrate to promote root health. Future work assessing blends of Forest Floor and pine bark are needed to determine the utility of a blended substrate for woody plant production in larger containers.

Significance to the Industry

The current national economic recession has decreased the demand for landscape plants, which has lowered prices. Peat-based container substrates have become increasingly expensive and are not a sustainable resource. Pine bark-based substrates are also in decreasing supply. An inexpensive, renewable substrate that would decrease production costs could allow Kentucky nursery growers to remain competitive and operate in a more sustainable manner.

Forest Floor and other mixed-species-based substrates show potential for the production of some herbaceous and woody nursery crops. However, caution is necessary when implementing this or any new substrate in nursery production, but must be tested on an individual basis. For all species tested, the pH of the Forest Floor substrate was significantly higher than the industry standard substrates, which would be problematic for crops that are sensitive to high pH. Additionally, moisture management may need to be refined with the addition of any new substrate.

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National Nursery Survey for *Phytophthora ramorum* in Kentucky, 2009

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Background

Phytophthora ramorum, the cause of Ramorum blight and sudden oak death, continues to be a problem in California and Oregon. This disease, first observed in California in the mid-1990s, has caused widespread death of many oak and tanoak species in the western United States. Other hosts for this pathogen include camellia, rhododendron, viburnum, lilac, and mountain laurel. Regulations and quarantines have been established to limit the spread of this pathogen, but concerns still remain about potential movement in contaminated nursery stock. Moving of plants, plant parts, soil, and water can cause long-distance spreading of the pathogen. *P. ramorum* infection and symptom expression takes place when the leaves, shoots, and stems are wet for 12 hours a day for 10 days or more at temperatures between 37 and 82°F. The Appalachian region is considered to be a high risk area for the establishment of *P. ramorum* because appropriate weather conditions often occur and because several native plant species in the region are identified as hosts.

Nature of the Work

The National Nursery Survey for *P. ramorum* in Kentucky continued through the 2009 growing season. This survey, a collaborative effort between the Department of Plant Pathology and the Office of the State Entomologist (Department of Entomology) at the University of Kentucky and the USDA Animal Plant Health Inspection Service (APHIS) has been ongoing each year since 2004. Procedures for collecting and testing followed protocols established by the USDA-APHIS-PPQ (Plant Protection and Quarantine). Samples were collected from nurseries, parks, and home gardens from across Kentucky. Ninety-three samples with foliar symptoms suggestive of general *Phytophthora* infection were collected from 16 counties: Breathitt, Boone, Clark, Daviess, Fayette, Franklin, Hardin, Jefferson, Jessamine, Kenton, McCreary, Meade, Nelson, Pike, Pulaski, and Russell. These samples were double-bagged and sent to the UK Plant Disease Diagnostic Lab (PDDL) in Lexington for testing. An immunological assay (ELISA) was used to detect the presence of proteins typical of several species of *Phytophthora* as an initial screen of these samples. DNA was then extracted from samples testing positive for general *Phytophthora* infection. Extracted DNA samples were sent to USDA-APHIS approved testing laboratories for further identification via polymerase chain reaction (PCR).

Results

Of the 93 total samples collected throughout the state, 24 tested positive for infection by *Phytophthora* species. Extracted DNA from these samples was sent to the USDA-APHIS laboratory in Beltsville, Maryland, for further testing via polymerase chain reaction (PCR). The *P. ramorum* PCR test for each of these samples was negative. *Phytophthora ramorum* was not found in the state of Kentucky this growing season. Results are summarized in Table 1.

Table 1. Number and type of plants sampled and results of ELISA assays for *Phytophthora* in general and PCR for *Phytophthora ramorum* during the National Nursery Survey for *Phytophthora ramorum* in Kentucky in 2009.

Plant Species	Number of Samples	ELISA positive-*Phytophthora sp.*	PCR positive-*P. ramorum*
Rhododendron	63	21	0
Viburnum	10	0	0
Pieris	10	3	0
Magnolia	6	0	0
Forsythia	2	0	0
Kalmia (Mt. Laurel)	1	0	0
Camellia	1	0	0
Total	93	24	0

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2009 Landscape Plant Disease Observations from the University of Kentucky Plant Disease Diagnostic Laboratory

Julie Beale, Paul Bachi, Sara Long, and John Hartman, Department of Plant Pathology

Nature of the Work

Plant disease diagnosis is an ongoing educational and research activity of the UK Department of Plant Pathology. We maintain two branches of the Plant Disease Diagnostic Laboratory, one on campus in Lexington and one at the Research and Education Center in Princeton. Of the more than 3,000 plant specimens examined to date in 2009, nearly 40% were landscape ornamentals (1).

Making a diagnosis involves a great deal of research into the possible causes of the plant problem. Most visual diagnoses involve microscopy to determine what plant parts are affected and to identify the microbe involved. In addition, many specimens require special tests such as moist chamber incubation, culturing, enzyme-linked immunosorbent assay (ELISA), electron microscopy, nematode extraction, or soil pH and soluble salts tests. The laboratory is also using polymerase chain reaction (PCR) testing, which although very expensive, allows more precise and accurate diagnoses. Computer-based laboratory records are maintained to provide information that is used for conducting plant disease surveys, identifying new disease outbreaks, and formulating educational programs. In addition, information from the laboratory forms the basis for timely news of landscape disease problems through the *Kentucky Pest News* newsletter, radio and television tapes, and workshops on plant health care.

To assist county Extension agents in dealing with plant disease issues, we also operate a Web-based digital consulting system. When the system is used to assist in diagnosis, the images submitted can help to determine where best to collect physical samples for submission to the laboratory. The system is especially useful in providing advice about landscape tree and shrub diseases and disorders, because whole plants are difficult to send to the laboratory. In 2009, approximately 30% of digital consulting cases dealt with landscape and nursery plants.

The 2009 growing season was characterized overall by cooler and wetter conditions than the 2008 season. January had above-normal rainfall and below-normal temperatures. The month ended with a winter storm that inundated the Bluegrass State with ice and caused over 600,000 households to lose power. Some areas received a combination of over an inch of ice plus 6 inches of snow and sleet from this one storm. Many landscape trees were significantly injured. After two months of below-normal rainfall in February and March, April brought closer-to-normal precipitation and temperatures. Conditions were generally wet for the start of the growing season. The big story for the weather for May and June was the lack of significant dry weather periods; flooding was common across the state. The result was a very slow-to-start growing and planting season. July went into the record books as the second coolest and eighth wettest July in the past 115 years. August was somewhat cool but also drier for most of the state than previous months. September was the 10th wettest September in the past 115 years.

Landscape plant diseases were common this year and included those favored by wet weather (e.g., leaf spot diseases, root rots). The following important or unusual diseases were observed:

Deciduous trees

- Ash, dogwood, hornbeam, linden, maple, oak, sycamore, walnut, and yellowwood anthracnose (*Discula, Gloeosporium, Gnomonia, Kabatiella, Apiognomonia*), dogwood spot anthracnose (*Elsinoe*), and blackgum spot anthracnose (*Sphaceloma*)
- Ash, dogwood, cherry, crapemyrtle, and tuliptree powdery mildew (*Erysiphe, Microsphaera, Phyllactinia, Podosphaera*)
- Oak leaf blister (*Taphrina*) and Actinopelte leaf spot (*Tubakia*)
- Flowering pear, hawthorn, and flowering crabapple fire blight (*Erwinia*)
- Flowering cherry leaf spot diseases (*Coccomyces, Cercospora, Xanthomonas*)
- Maple, oak, and willow cankers (*Botryosphaeria, Cryptodiaporthe*)
- Maple, oak, and sycamore bacterial leaf scorch (*Xylella*)
- Maple and smoketree wilt (*Verticillium*)
- Maple leaf spots (*Phyllosticta, Cristulariella*) and tar spot (*Rhytisma*)
- Mulberry leaf spot (*Phloeospora*)
- Dutch elm disease (*Ophiostoma*)
- Elm root rot (*Phytophthora*)

Needle Evergreens

- Juniper galls from cedar-apple rust (*Gymnosporangium*)
- Pine tip blight (*Diplodia*)
- Spruce needle cast (*Rhiozsphaeria*) and canker (*Cytospora*)
- Arborvitae, hemlock, juniper, chamaecyparis, pine, spruce, and taxus root rot (*Phytophthora*)
- White pine root decline (*Verticicladiella*)
- White pine decline (physiological)

Shrubs

- Azlaea leaf/flower gall (*Exobasidium*)
- Boxwood canker (*Pseudonectria*)
- Buddleia downy mildew (*Peronospora*)
- Cherry laurel, cotoneaster, rhododendron, and viburnum root rot (*Phytophthora*)
- Holly black root rot (*Thielaviopsis*)

- Hydrangea bacterial leaf spot (*Xanthomonas*), fungal leaf spot (*Cercospora*), and rust (*Pucciniastrum*)
- Hazelnut [filbert] blight (*Anisogramma*) and thread blight (*Corticium*)
- Lilac powdery mildew *(Microsphaera*)
- Photinia leaf spot (*Entomosporium*)
- Rose black spot (*Diplocarpon*), blight (*Botrytis*), leaf spot (*Cercospora*), powdery mildew (*Sphaerotheca*), downy mildew (*Peronospora*), and rosette (possible phytoplasma, leaf curl mite-transmitted)

Herbaceous Annuals and Perennials

- Chrysanthemum bacterial leaf spot (*Pseudomonas*)
- Petunia root/crown rot (*Rhizoctonia*)
- Daylily leaf streak (*Aureobasidium*)
- Geranium bacterial leaf spot (*Pseudomonas*)
- Hosta crown rot (*Sclerotium*)
- Asiatic lily blight (*Botrytis*)
- Liriope anthracnose (*Colletotrichum*) and crown rot (*Phytophthora*)
- Sunflower downy mildew (*Plasmopara*) and foliar nematodes (*Aphelenchoides*)
- Echinacea aster yellows (*Aster yellows phytoplasma*)
- Peony blotch (*Cladosporium*) and powdery mildew (*Erysiphe*)

Significance to Industry

This report is a synopsis of information about plant disease provided for landscape professionals.

Plant diseases play a significant role in production and maintenance of landscape plants in Kentucky. To serve their clients effectively, landscape industry professionals such as arborists, nursery operators, and those in landscape installation and maintenance organizations need to be aware of recent plant disease history and the implications for landscape maintenance.

The first step in appropriate pest management in the landscape and nursery is an accurate diagnosis of the problem. The UK Plant Disease Diagnostic Laboratory assists the landscape industry of Kentucky in this effort.

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Ant Exclusion for Sustainable Management of Soft Scale Outbreaks on Woody Landscape Plants

Sarah J. Vanek and Daniel A. Potter, Department of Entomology

Nature of the Work

Soft scale insects (Coccidae) are important pests of shade trees and ornamental plants, and more than a dozen species persist in Kentucky landscapes. These insects damage their hosts by sucking sap to remove photosynthates and nutrients and by inducing cell necrosis with their phytotoxic saliva. Infestations may lead to twig dieback, plant stress, and foliar chlorosis. In addition, soft scales excrete copious amounts of sugary honeydew that accumulates under heavily infested trees. Removal of these trees may be necessary to prevent honeydew from damaging vehicles and other structures below. By serving as a favorable medium for black sooty molds, honeydew can be highly detrimental to plants as well. These molds blacken plant surfaces and can greatly reduce the photosynthetic ability (Rabbinge, et al. 1981) as well as the aesthetic value of plants. In addition, honeydew attracts large numbers of flies and stinging insects, creating a nuisance and hazard in some settings.

Current treatment methods for scale insects include the use of insecticidal sprays and injections as well as horticultural oils (Hubbard and Potter 2006). However, these methods are not consistently effective, may be impractical, and have a number of potential drawbacks including high cost, hazard from spray drift, and impact on beneficial insects that may lead to secondary pest outbreaks. The goal of this research was to evaluate ant exclusion as a sustainable alternative for managing soft scales pests.

It has long been known that mutualistic relationships exist between ants and honeydew-producing insects. Ants use honeydew as a source of sugar and nutrients, and in turn, aggressively protect honeydew producers from predators and parasitoids (Way 1963, Buckley 1987). The strength of such mutualisms is made clear by a number of studies showing that ant exclusion can significantly reduce or even eliminate (Bess 1958, Reimer et al. 1993, Abbott and Green 2007) soft scale infestations. The strong associations found between ants and honeydew-producing pests have led to the application or suggested application of ant exclusion techniques in various agricultural settings. Examples include grape vineyards (Cooper et al. 2008), citrus groves (James et al. 1998), and coffee plantations (Young 1982). While the effects of ant exclusion on soft scale outbreaks have been studied in a variety of habitats, they have not been evaluated in the urban landscape. Our objective was to evaluate ant exclusion as a means of suppressing magnolia scale, *Neolecanium cornuparvum* (Thro), and calico scale, *Eulecanium cerasorum* (Cockerell), in the landscape setting.

Large sugar maple trees (12-14 cm trunk diameter) with established calico scale infestations and extensive ant (*Formica subsericea*) activity were located at a horse farm near Midway, KY, and paired according to levels of infestation. Within each of six pairs, a physical barrier was used to exclude ants from one of the two trees. These barriers were applied to the tree trunks at 1 m height and consisted of burlap, duct tape, and an adhesive substance (Tanglefoot®). Bands were applied 4 May 2008 and 23 March 2009 prior to heavy honeydew production by adult scales. To further ensure ant exclusion, the lower 0.5 m of trunk of each banded tree was sprayed to runoff with bifenthrin (Talstar®), a pyrethroid insecticide. Control trees were not banded or sprayed. Two methods were used to evaluate effectiveness of ant exclusion techniques throughout 2008 and 2009. Ants were counted either 1) during beat sheet sampling, or 2) as they crossed a line on each tree trunk during a 5-min period; each line was 1.5 m from the ground, or 0.5 m above the bands.

On 2 June 2009, 60 unmarked adult scales were collected from the same trees to assess parasitism rates of adults. The scales were examined for parasitoid emergence holes and dissected to count parasitoid larvae, pupae, or adults that had died or had not yet emerged. Parasitoids and predators were collected from each tree on multiple dates using a beat sheet. On each sampling date, a total of eight branches per tree were struck eight times each. Insects and spiders were collected from the sheet with an aspirator and stored in 70% ethanol until identification.

Scale populations at the horse farm were estimated by counting live nymphs on the underside of 50 leaves from each tree 1 October 2008 and 29 September 2009. To minimize variability caused by leaf size, scales were counted only within a circular area of 7 cm^2 at the base of the leaves. In 2009, all scales within this area which showed obvious signs of parasitism were also counted. In addition, 100 scale nymphs from each of four trees including two banded and two control trees were further examined for evidence of parasitism. Scales were removed from leaves with a razor blade and examined under a binocular microscope with a backlight for the presence of parasitoid larvae or pupae.

Fifty leaves from each tree were also evaluated for sooty mold accumulation. The upper sides of the leaves were visually rated with the following scale: 0) no sooty mold, 1) moderate accumulation along veins and light accumulation on leaf surface, 2) heavy accumulation along veins and moderate accumulation on less than 50% of leaf surface, 3) heavy accumulation along veins and moderate accumulation on more than 50% of leaf surface, 4) heavy accumulation on less than 50% of leaf surface, 5) heavy accumulation on more than 50% of leaf surface. Accumulation was considered heavy when it formed a continuous black or nearly black layer with portions beginning to flake off.

For a second study, 16 container-grown Royal Star magnolias, *Magnolia stellata* 'Royal Star' (height of 75-85 cm) were paired and planted on the University of Kentucky campus in Lexington, KY, on 22 April 2008. Paired shrubs were planted 2 m apart in a large mulch bed surrounded by a grass lawn. Each shrub was artificially infested with live magnolia scale crawlers on 15 September 2008. The lowest branches on all shrubs were removed to facilitate the use of ant-excluding bands. The same ant exclusion methods described above were applied to one shrub within each pair starting 21 August 2008 and 23 March 2009. Effectiveness of ant exclusion methods was evaluated by counting the total number of ants on each plant. Live adult scales were counted on each shrub 8 July 2009 by closely examining each branch of the plants.

Results and Discussion

Ant exclusion was highly effective at both study sites. The mean number of ants on banded and control trees was significantly different on all five sampling dates at the horse farm (Table 1). Similar results were found 20 August on small magnolias (0.0 ± 0.0 on banded versus 16.5 ± 6.1 on control trees, $t = 2.7$, $P = 0.02$).

Parasitism of adult scales was not significantly different ($P > 0.3$) between banded and control trees (22.3 ± 8.1, 19.8 ± 8.3 parasitized scales respectively). The most abundant groups of natural enemies collected from beat sheet sampling are shown in Figure 1. Ant exclusion had the greatest effect on green lacewing larvae (*Chrysopa rufilabris*), which were significantly more abundant in banded versus control trees during the months of July through September.

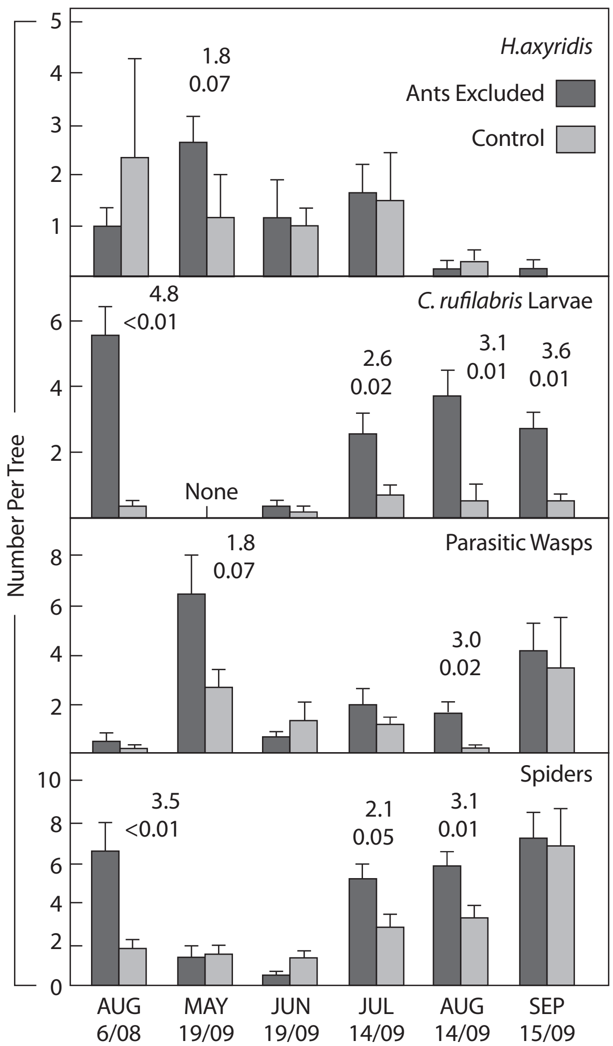
Scale density was significantly reduced by ant exclusion in 2008 and 2009 at the horse farm. In 2008, densities of settled scale nymphs were 53.6% lower on banded versus control trees (559.8 ± 172.1, 1206.0 ± 167.1 surviving scale nymphs respectively, $t = 6.3$, $P < 0.001$). In 2009, this difference increased to 68.5% (445.0 ± 123.8, 1414.3 ± 193.0 respectively, $t = 6.0$, $P < 0.001$). Evaluation of scale nymph parasitism rates at the horse farm in 2009 indicated that parasitism was not a significant factor in scale mortality. More than 11,000 live scales were counted in the samples, but only one nymph was found with obvious signs of parasitism. Further examination of scale nymphs confirmed that parasitism rates on 29 September 2009 were extremely low at the horse farm. Of 400 hundred nymphs examined under a microscope, no individual contained a parasitoid larva, pupa, or exit hole.

Visual ratings of foliar sooty mold accumulation showed that ant exclusion substantially reduced sooty mold growth. Mean ratings were significantly lower on banded versus control trees (0.9 ± 0.4, 2.1 ± 0.3 respectively, $t = 2.34$, $P = 0.03$). This indicates that honeydew accumulation was greater in the presence of ants despite their ability to consume the liquid. Presumably, ants

Table 1. Mean (±SEM) number of ants per tree on banded and control trees.

Year	Sampling Method	Date	Banded	Control	*t*-Value	*P*-Value
2008	Trunk Count	13 May	0.00 ± 0.00	40.33 ± 10.48	3.85	<0.01
		12 Jun	1.50 ± 0.67	17.83 ± 5.69	2.79	0.02
		13 Aug	0.00 ± 0.00	33.00 ± 7.90	4.18	<0.01
	Beat Sheet	6 Aug	0.33 ± 0.33	18.50 ± 4.15	4.54	<0.01
2009	Trunk Count	19 May	0.67 ± 0.42	51.17 ± 19.98	6.32	<0.01
	Beat Sheet	14 Aug	0.00 ± 0.00	17.00 ± 2.44	6.98	<0.01

Figure 1. Mean (± SEM) number of natural enemies collected from banded and control trees on six dates. Values of *t* and *P* are included respectively where $P < 0.1$.



indirectly contribute to sooty mold accumulation by promoting populous scale infestations and their honeydew by-product.

Based on our results, we believe that *Formica subsericea* protects calico scale nymphs from natural enemies such as lacewing larvae and that ant exclusion can reduce soft scale infestations by allowing increased predation upon scale nymphs.

In the second study involving magnolia scale, ant exclusion led to an 81.7% reduction in the number of scales to successfully reach the adult stage (10.3 ± 3.5, 56.3 ± 22.4 scales on banded versus control shrubs respectively, $t = 2.05$, $P = .04$). Predator densities were not evaluated on these plants since their appearance was rarely noticed. However, a number of beetles, *Hyperaspis* sp., were seen on the shrubs during mid-May. Observations showed that the beetles pursued scale nymphs but were deterred by ant attendants.

Presented here are two cases in which ant exclusion led to significant reductions in soft scale populations. However, ant exclusion will not always lead to this outcome. A variety of factors must be considered including the aggressiveness of the ant species involved and the impact of natural enemies even in the absence of ants. Similar studies, not included in this paper, were conducted at two separate sites. Although ant exclusion was accomplished, scale populations were not clearly affected at these locations.

Significance to the Industry

This research supports the use of a new and sustainable approach for managing soft scales in the urban landscape. Application of a simple trunk band to exclude ants has potential to increase scale insect mortality from natural enemies and suppress infestations below economic thresholds. This would provide a safe, convenient, and inexpensive management option for landscape managers and homeowners. In nurseries, where banding individual trees might not be practical, the scales' ant bodyguards might be eliminated using liquid sugar baits.

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Host Plant Resistance among *Magnolia* spp. and *Quercus* spp. to Soft Scale Pests

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Nature of the Work

Soft scale insects (Coccidae) are major pests of trees and shrubs in the urban landscape and are an increasing problem in production nurseries. More than a dozen species of soft scales infest Kentucky landscapes, causing severe damage by sucking sap to remove photosynthates and nutrients from their hosts and by inducing cell necrosis with their phytotoxic saliva. Infestations may result in twig dieback, plant stress, and foliar chlorosis.

These insects also excrete copious amounts of sugary honeydew that can accumulate under heavily infested trees. Tree removal is sometimes required to prevent dripping honeydew from damaging vehicles and other structures. Honeydew also is a favorable medium for growth of black sooty molds that blacken leaves, branches, and trunks and can greatly reduce the photosynthetic ability (Rabbinge, et al. 1981) as well as the aesthetic value of plants. In addition, honeydew attracts large numbers of flies and stinging insects, creating a nuisance and hazard in some settings.

Current treatment methods for scale insects include the use of insecticidal sprays and injections as well as horticultural oils (Hubbard and Potter 2006). However, these methods are not consistently effective, may be impractical, and have other drawbacks, including high cost, hazard from spray drift, and impact on beneficial insects that may lead to secondary pest outbreaks.

Host plant resistance (HPR), which is a dominant factor regulating herbivorous insect populations in natural ecosystems, is an ideal method for managing pests of shade trees as well as ornamental plants (Herms 2002). HPR may be used to reduce costs associated with tree loss or with maintenance due to pest damage. HPR is practical not only because resistant plants require less pesticide use, but because its implementation has low initial cost and good potential for long-term effectiveness (Herms 2002). It is especially beneficial for plants that persist in the environment for decades, or even centuries, as may be the case for many shade trees.

The objective of this study was to evaluate HPR among 11 oak (*Quercus* spp., Fagaceae) species and six magnolia (*Magnolia* spp., Magnoliaceae) species against their respective soft scale pests, oak lecanium, *Parthenolecanium quercifex* (Fitch) and magnolia scale, *Neolecanium cornuparvum* (Thro). While multiple host records exist for each of these scales (Lambdin and Watson 1980, Herms and Nielsen 2004), evaluation of HPR has not been formally conducted for either species.

In Spring 2008, oak trees (1.25 to 1.5 m height) and magnolia shrubs (0.7 to 1.25 m height) were planted in two separate randomized complete block designs, both with eight replications. The trees and shrubs were planted in a plowed and disked field at the University of Kentucky Horticulture Research Farm with 3.0 m spacing between each row and 1.8 m spacing within each row. All plants were irrigated regularly May–September 2008 with a drip irrigation system.

Most of the oak trees were received as bare-root whips and were heeled in until planting. Two species, *Q. michauxii* and *Q. Montana,* were received in containers with bamboo stakes and soil loosely covering the roots. Very few *Q. phellos* survived transplanting, so these trees were replaced with transplanted *Q. phellos* after leaf bud break. Magnolias were received either as bare-root or container-grown shrubs. Those that were bare-root were stored in a cooler and then heeled in a few days prior to planting. Magnolias received in containers were stored in a high-tunnel greenhouse until planting.

Oaks were infested with oak lecanium using infested willow oak (*Q. phellos*) cuttings, each with a total of 40 gravid adult female scales. Cuttings were tied to newly planted trees June 5, 2008. Artificial infestation of oaks was repeated 29 May 2009 using the same technique. Total oak lecanium individuals to reach the adult stage were counted 5 May 2009 and will be counted again in 2010. Magnolias were infested using live magnolia scale crawlers 19 September 2008 and 9 September 2009. Centrifuge tubes were filled with 0.1 ml of crawlers (about 4,500 individuals) and tied onto each magnolia shrub. Adult magnolia scales were counted 10 July 2009 and will also be counted in 2010.

Data collected from the oaks were converted with a log transformation and analyzed using a randomized complete block analysis of variance. This analysis was conducted separately for red (section *Lobatae*) and white (section *Quercus*) oaks and then for all oaks together. Oak sections which had a significant F statistic were further analyzed with LSD for mean separation ($P = 0.05$). Linear contrasts were used to compare host susceptibility among red versus white oaks and among native versus non-native oaks. Analysis of Variance (ANOVA) assumptions could not be met for the magnolia data because two cultivars had all zeroes (no scales). Therefore, the non-parametric Kruskal-Wallis test followed by the Kruskal Wallis All Pairwise Comparisons test, was used to compare the mean ranks of each magnolia species ($P = 0.05$). All statistical analyses were done with Statistix 9.0 (Analytical Software 2008).

Results and Discussion

Three replications in the oak plot had very low mean numbers of oak lecanium adults (2.2 ± 1.4, 1.2 ± 0.6, 0.5 ± 0.3) in comparison to the other five replications (9.8 ± 5.6, 12.0 ± 3.8, 21.2 ± 9.3, 20.3 ± 13.8, 19.9 ± 7.9), possibly due to wind exposure or other unknown factors. Because these replications had far fewer scales, data collected from the oaks were analyzed first with all eight replications and again with only the five replications having the greatest mean number of scales. The overall F statistic was significant ($P < 0.05$) in both cases (Table 1). All species of oaks showed some degree of susceptibility to oak lecanium. Among the red oaks, no species was significantly more or less susceptible than the others. Among the white oaks, two species, *Q. michauxii* and *Q. montana*, were the least susceptible, and *Q. bicolor* was the most susceptible species. A comparison of the red and white oaks showed that white oaks were less susceptible than red oaks only when all replications were included. When only the five most heavily infested replications were considered, this conclusion was only shown as a trend ($P = 0.07$). Native oaks had more scales than non-native oaks, but this difference was not significant when only the most heavily infested replications were included and was only marginally significant when all replications were included (Table 1). Differences in P values between analyses with all replications versus only five replications were likely caused by differences in variance. The three replications that were excluded in the second analysis contained numerous zero or near-zero values (no scales), which decreased the variances within and between each cultivar.

The number of adult magnolia scales differed significantly among the different magnolia species (Kruskal-Wallis statistic = 22.8, $P < 0.01$). *M. grandiflora* 'Little Gem' and *M. virginiana*, upon which no scales were found, likely are resistant. *M. × loebneri 'Merrill'* had relatively small numbers of scales, although this species did not differ significantly from *M. acuminata, M. liliiflora 'Jane,' and M. stellata 'Royal Star,'* which are all highly susceptible (Table 2).

Table 1. Counts of oak lecanium, *Parthenolecanium quercifex*, adults on 11 May 2009 in a replicated plot of oaks (*Quercus* spp.) that had been artificially infested with scale crawlers at the University of Kentucky Horticulture Research Farm, Lexington.

	Mean (± SEM) adult scales per tree for	
Species	**All Replications**	**Top Five Replications**
Red Oaks (*Lobatae*)		
Q. coccinea	7.0 ± 3.2	10.8 ± 4.3
Q. ellipsoidalis	10.1 ± 5.3	15.8 ± 7.6
Q. imbricaria	5.6 ± 3.3	8.3 ± 5.7
Q. phello	14.8 ± 7.2	19.6 ± 11.1
Q. shumardii	32.4 ± 18.3	51.6 ± 26.3
*ANOVA: *F* (df)	0.7 (4, 27)	0.5 (4, 15)
P-value	0.6	0.7
White Oaks (*Quercus*)		
Q. bicolor	19.8 ± 9.6a	31.6 ± 12.9a
Q. macrocarpa	10.3 ± 6.1a	14.8 ± 9.6ab
Q. michauxii	0.1 ± 0.1b	0.3 ± 0.3b
Q. montana	1.3 ± 1.1b	2.0 ± 1.8b
Q. robur	12.3 ± 8.6ab	18.5 ±12.0ab
ANOVA: *F* (df)	3.3 (4, 25)	3.6 (4, 14)
P-value	0.03	0.03
Cerris Oaks		
Q. acutissima	0.3 ± 0.3	0.5 ± 0.5
Overall ANOVA:		
F (df)	3.2 (10, 64)	2.8 (10, 36)
P-value	< 0.01	0.01
Contrasts *t* (*P*):		
Red vs. White	2.4 (0.02)	1.9 (0.07)
Native vs. Non-native	2.0 (0.05)	1.5 (0.13)

NOTE: Analyses were conducted using log-transformed data.
Means not followed by the same letter differ significantly (P<0.05).
*Analysis of Variance.

Table 2. Counts of magnolia scale, *Neolecanium cornuparvum*, adults on 10 July 2009 on *Magnolia* spp. that had been artificially infested with scale crawlers at the University of Kentucky Horticulture Research Farm, Lexington.

Species	**Status**	**Mean (±) no. scales per tree**
Magnolia subgenus *Magnolia*		
M. grandiflora 'Little Gem'	Native	0.0 ± 0.0b
M. virginiana	Native	0.0 ± 0.0b
Magnolia subgenus *Yulania*		
M. acuminata	Native	41.3 ± 20.3ab
M. liliiflora 'Jane'	Non-Native	47.8 ± 17.0a
M. stellata 'Royal Star'	Non-Native	36.0 ± 12.3a
M. × loebneri 'Merrill'	Non-Native	8.0 ± 3.9ab
Kruskal-Wallis (*H*) statistic		22.8
P-value		< 0.01

NOTE: Kruskal Wallis All Pairwise Comparisons test was used to compare the mean ranks of each magnolia species (α = 0.05).

One factor that may have affected the outcome of this study was plant stress. Trees and shrubs were obtained from multiple sources and were in various conditions during the months following transplanting. Several oak trees had a limited number of leaves at the time of oak lecanium crawler emergence. This could have affected survival rates, since immature oak lecanium must locate and settle on a leaf in order to survive the summer and early fall seasons. Magnolia scale may also be affected by variation in host quality. For this reason, all plants were artificially infested a second time in 2009 and will be evaluated again in 2010.

Significance to the Industry

Host plant resistance can be used to minimize unnecessary costs associated with tree loss or maintenance due to pest damage. Results from this research provide practical implications for implementing HPR in landscape management practices. When selecting an oak tree, it should be considered that *Q. michauxii* and *Q. montana* are less likely to experience serious oak lecanium outbreaks compared to red oaks and other white oak species. When more susceptible species, such as *Q. bicolor*, *Q. macrocarpa*, or the red oaks are selected, the trees should be dispersed amongst non-oak trees in order to reduce the risk of an extensive outbreak. In addition, efforts to monitor oak lecanium infestations should focus primarily on these susceptible oak species. Similarly, use of magnolia scale-susceptible hosts, such as *M. acuminata*, *M. liliiflora*, *M. stellata*, and *M. × loebneri*, will require greater monitoring efforts and should be accompanied by landscape diversification efforts as well. However, the best approach for preventing magnolia scale outbreaks is to select species exhibiting stronger resistance. For this reason, *M. grandiflora* and *M. virginiana* are recommended over the other magnolia species evaluated in this study.

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National Elm Trial—Kentucky Data, 2009

John Hartman and Ed Dixon, Plant Pathology; Dan Potter, Entomology; Jerry Hart, Physical Plant Division-Grounds; and William Fountain, Horticulture

Nature of the Work

The National Elm Trial was established to evaluate landscape-suitable elm cultivars for disease and insect tolerance and horticultural characteristics at 15 locations from California to Vermont and south to Kentucky. Locally, 14 elm cultivars were planted April 13-15, 2005, in a grassy area on the University of Kentucky campus in Lexington. An additional three cultivars were planted in April, 2006, and three more cultivars were planted in April, 2007. Plots were located south and east of the sports complex across from the entrance to The Arboretum along Alumni Drive (North 38 deg, 1 min; West 84 deg, 30 min, elev. 990 ft). The site had been graded for construction some years before and consisted of a mixture of topsoil, subsoil, and construction debris. In the planting, a double-allée, each cultivar was replicated five times and arranged in a randomized complete block design. Additional randomized space was left in each block for elm cultivars to be planted in future years. Trees were staked as needed, watered during dry periods, and all trees were mulched over grass that had been killed with an application of Roundup herbicide.

The 20 elm cultivars planted for this study include the following:

1. 'JFS Bieberich' Emerald Sunshine - *Ulmus propinqua*
2. 'Emer II' Allee - *U. parvifolia*
3. 'Frontier' - *U. carpinifolia x U. parvifolia*
4. 'Homestead' - *U. glabra* x *U. carpinifolia* x *U. pumila*
5. 'Morton Glossy' Triumph - *U. pumila* x *U. japonica* x *U. wilsoniana*
6. 'Morton Plainsman' Vanguard - *U. pumila* x *U. japonica*
7. 'Morton Red Tip' Danada Charm - *U. japonica* x *U. wilsoniana*
8. 'Morton Stalwart' Commendation - *U. carpinifolia* x *U. pumila* x *U. wilsoniana*
9. 'Morton' Accolade - *U. japonica* x *U. wilsoniana*
10. 'New Horizon' - *U. pumila* x *U. japonica*
11. 'Patriot' - (*U. glabra* x *U. carpinifolia* x *U. pumila*) x *U. wilsoniana*
12. 'Pioneer' - *U. glabra* x *U. carpinifolia*
13. 'Prospector' - *U. wilsoniana*
14. 'Valley Forge' - *U. americana*
15. 'Princeton' - *U. americana*
16. 'Jefferson' - *U. americana*
17. 'New Harmony' - *U. americana*
18. Athena' - *U. parvifolia*
19. 'Everclear' - *U. parvifolia*
20. 'Prairie Expedition' - *U. americana*

Trees came from the nursery in 2005, 2006, and 2007 as bare-root transplants about 5-8 ft tall (except 'Jefferson,' which was much smaller). Elms in all plots were pruned in early spring 2008 to eliminate crossing and broken branches and to establish a central leader. In the plots, new mulch was added to existing mulch in early summer, and trees were provided with adequate water throughout the season by frequent and plentiful rainfall. In summer 2009 tree trunk diameters were measured with a caliper, and tree height and width were determined. Japanese beetle damage and leaf miner infestations were assessed by entomologist collaborators, and these results are reported elsewhere.

Results and Discussion

Results from the elm plots are presented in Table 1. All of the elm cultivars are well established and are increasing in height, width, and trunk diameter. Although differences in insect pest levels are observed most years, as of 2009 there have been no incidences of bacterial leaf scorch, elm yellows, or Dutch elm disease.

Table 1. Size of elms, 2009.

Cultivar number and name	Average trunk diameter, inches dbh* (increase from 2008)	Average height in feet (increase from 2008)	Average crown width in feet (increase from 2008)
1. JFS Bieberich	1.75 (0.37)	13.6 (1.2)	5.4 (0.6)
2. Emer II Allee	1.37 (0.27)	11.3 (1.5)	9.3 (2.0)
3. Frontier	1.34 (0.34)	12.3 (0.9)	6.3 (0.9)
4. Homestead	2.06 (0.60)	13.6 (2.7)	8.1 (1.0)
5. Morton Glossy	1.88 (0.68)	12.5 (2.2)	5.9 (1.2)
6. Morton Plainsman	1.98 (0.40)	12.0 (1.0)	7.6 (0.9)
7. Morton Red Tip	2.50 (0.48)	13.0 (0.8)	8.4 (1.1)
8. Morton Stalwart	2.28 (0.58)	13.8 (2.2)	6.8 (0.7)
9. Morton Accolade	1.88 (0.52)	12.6 (1.6)	7.0 (1.5)
10. New Horizon	2.12 (0.60)	13.8 (1.9)	7.1 (1.2)
11. Patriot	2.05 (0.50)	15.5 (1.4)	7.4 (0.5)
12. Pioneer	1.70 (0.34)	12.0 (0.7)	6.6 (0.2)
13. Prospector	1.92 (0.40)	11.0 (2.4)	6.7 (0.5)
14. Valley Forge	1.98 (0.60)	13.7 (1.6)	8.0 (1.3)
15. Princeton	2.04 (0.68)	16.7 (2.1)	4.8 (0.9)
16. Jefferson	0.98 (0.20)	10.4 (4.0)	3.8 (1.5)
17. New Harmony	1.54 (0.48)	13.7 (2.4)	4.4 (0.9)
18. Athena	1.10 (0.30)	7.5 (2.2)	4.1 (2.0)
19. Everclear	0.78 (0.23)	8.8 (1.7)	2.6 (0.9)
20. Prairie Expedition	0.95 (0.17)	8.4 (2.1)	4.0 (1.1)

*Trunk diameter taken at 4.5 ft.

Significance to Industry

The widespread use of elms in the landscape has been lost largely due to Dutch elm disease. Knowledge of how elms perform in Kentucky in the face of diseases such as Dutch elm disease, elm yellows, and bacterial leaf scorch and insect pests such as Japanese beetles, elm leaf miners, and other pests will benefit arborists and the landscape maintenance and nursery industries.

Adventitious Root Formation in Poplar (Populus) Internodal Stem Cuttings Grown In Vitro

Micah E. Stevens, S.T. Kester, and R.L. Geneve, Department of Horticulture

Nature of the Work

The ideal model system for studying adventitious rooting in a woody perennial should use the following important criteria:

- Employment of a small tissue sample for rooting to reduce the number of non-participating cells
- Auxin-responsiveness and failure to root unless auxin is provided
- A clear sequence of defined anatomical events leading to rooting
- Availability of clones or mutants that vary in their rooting potential
- A sequenced genome
- Availability of a protocol for genetic transformation
- A reduction in rooting potential in the plant as it matures

Several woody perennial systems have been developed in the past including pine (Brinker et al. 2004), apple (Welander et al. 2007) and English ivy (Geneve et al. 1988). However, each of these systems falls short for several of these ideal criteria. It is our contention that poplar could meet all of these criteria if a suitable rooting system could be developed. Therefore, the objective of this project is to develop a protocol that would be suitable for studying anatomical, physiological, and molecular aspects of adventitious rooting using easy-to-root and difficult-to-root poplar hybrid clones.

Plant material and culture conditions: In vitro cultures of hybrid poplars (*P. tremula* x *P. tremuloides and P. canescens* x *P. gradidentata*) were maintained and subcultured on woody plant medium (WPM) containing charcoal and supplemented with 1 µM benzylaminopurine (Yu et al. 2001). These subcultures served as the explant source for the rooting assays. Plants were cultured under a 16/8 hour photoperiod provided by cool white fluorescent lamps (PAR 45 $\mu mol \cdot sec^{-1} \cdot m^{-2}$) at 25°C.

Rooting assay: Internode explants were prepared by cutting stem sections to 0.5 cm in length then placing them horizontally in 9-cm petri dishes with 25 ml sterile one-half strength MS media (Murashige and Skoog 1962) supplemented with 30g/l sucrose, 7 g/l agar and 100 µM indole-3-butyric acid (IBA). The cuttings were treated for one to three days in the light or dark prior to being moved to one-half strength basal MS medium. The number of roots per cutting was documented after 14 days on the basal medium.

Developmental stages of rooting: Anatomical changes were observed during rooting after fixation in formalin acetic-acid (FAA). Explants were treated with 100 µM IBA for one day prior to moving to basal medium. The easy-to-root clone was collected on day 5 and day 8. The hard-to-root clone was collected on day 8 and day16. After fixation, samples were dehydrated using a tertiary-butanol series then imbedded in paraffin. Serial 14-µm sections were cut using a rotary microtome before being stained using safranin and fast green (Johansen 1940).

Results and Discussion

Internode explants failed to root without auxin regardless of the clone or rooting environment (Table 1). Preliminary research showed that explants rooted poorly when cultured continuously on an auxin medium but responded well to brief exposure to auxin (data not shown). There was a clear difference in adventitious rooting potential between the two clones. In all treatments and environments, *P. canescens* x *P. gradidentata* consistently rooted at a higher percentage and produced more roots per cutting compared to *P. tremula* x *P. tremuloides*. (Table 1). Altering the auxin dose and duration did not improve rooting in the difficult-to-root clone (data not shown). Explants from the easy-to-root clone rooted better in the light environment with auxin durations of one and two days (Table 1). Explants from both clones failed to root without auxin application.

Anatomical studies suggested that the pattern of root formation differed between the easy and difficult-to-root clones. Explants from *P. canescens* x *P. gradidentata* rooted quickly with root initials evident after eight days (Figure 1 A-C), while explants from *P. tremula* x *P. tremuloides* either failed to root or produced root initials that were evident after 16 days in culture (Figure 1 D-F). The easy-to-root clone appeared to root directly from the phloem parenchyma region, while root initials of the hard-to-root clone were observed to organize farther from the xylem than those of the easy-to-root clone (Fig. 1 C, F).

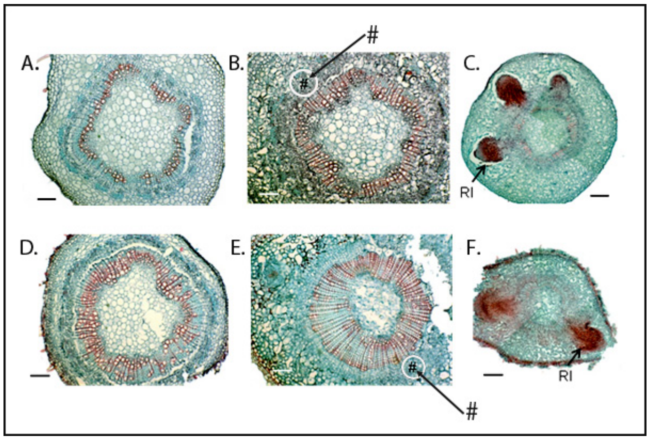
Poplar seems to be an excellent choice for studying adventitious rooting, as it meets all the criteria for the ideal model system. It can be grown in vitro, is amenable to biotechnology (Confalonieri et al. 2003), and has a sequenced genome. The current research demonstrates that a suitable rooting system could be created using poplar clones that employed small

Table 1. Adventitious root formation in easy- and difficult-to-root poplar internode explants treated with 100 µM IBA for 1 to 3 days in the light or dark before being moved to basal MS medium in the light.

Poplar clone	Treatment duration (days)	Environment	Rooting %	Roots per cutting
Populus canescens x P. gradidentata	1	Dark	50	0.8 c[z]
	1	Light	80	3.1 a
	2	Light	80	3.30a
	3	Light	70	2.0 b
Populus tremuloides x P. tremula	1	Dark	0	0
	1	Light	20	0.4 d
	2	Light	0	0
	3	Light	10	0.2 d

[z] Means followed by the same letter were not significantly different at the 5% level by Tukey's HSD test.

Figure 1. Adventitious root formation in poplar internode explants. A-C is *Populus canescens* x *P. gradidentata;* D-F is *Populus tremuloides* x *P. tremula.* A and D are day 0, reference bar (–) is 200 microns. B and E are day 5 and 8, respectively. Reference bar is 100 microns. C and F are day 8 and 16, respectively. Reference bar is 50 microns. # (B. and E.) indicates phloem parenchyma, and RI (C. and F.) is root initial.



explants responsive to auxin for rooting. Similar to studies done with apple (Welander et al. 2007), explants were found to respond better to auxin when it was applied only for a brief period. However, exposure length and concentration were found to be different in poplar compared to apple leaf discs. The poplar rooting system also affords a comparison between explants that were easy or difficult to root. The importance of having access to explants that differ in rooting potential has been well documented (Hartmann et al. 2002).

Anatomical studies are essential for determining the sequence of events leading to root formation and whether there is a different pattern of root initiation for easy and difficult-to-root explants. It appears that the extended period required for rooting in the difficult-to-root poplar clone indicates that it may be rooting following an indirect pattern. This rooting pattern has been found in other woody species such as English ivy and ficus (Geneve et al. 1988 and Davies, Jr. et al. 1982). The poplar rooting protocol created in this study will allow for an in-depth comparison of nonrooting (basal medium), direct rooting, and indirect rooting at the physiological and molecular levels.

Significance to the Industry

Cutting propagation is an important tool for clonal nursery propagation. Currently a significant number of woody perennial species (especially trees) cannot be rooted from cuttings. Adventitious rooting is a complex process influenced by many factors, including hormone levels, light, rooting cofactors, and plant maturation (Hartmann et al. 2002). However, the two major factors determining root initiation are auxin availability and the plant's ability to respond to auxin. Although researchers have spent decades trying to understand the basic physiology behind adventitious root formation, we still know very little about the genes controlling this process. It has become increasingly clear that the next significant improvement for rooting cuttings from recalcitrant species will not be discovered until we have a better understanding of the molecular mechanisms controlling rooting and maturation-related loss in rooting potential.

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Update of Industry Support for the University of Kentucky Nursery and Landscape Program

The UK Nursery/Landscape Fund provides an avenue for companies and individuals to invest financial resources in support of UK research and educational activities that will benefit the industry. The majority of contributions to the UK Nursery/Landscape Fund are used to employ students to work in the program and purchase specialized materials and equipment. These investments have allowed us to initiate new research and to collect more in-depth data than has been possible before.

Fifteen individuals and companies have each contributed or pledged to at least $10,000 over a 10-year period. Those contributing at this level are Nursery/Landscape Fund/Endowment Fellows and may designate an individual or couple as University of Kentucky Fellows and members of the Scovell Society in the College of Agriculture.

A family of five endowments has been established to support the UK Nursery/Landscape program. Four of these are named endowments. This year, income from this family of endowments provided over $12,000 to support research for our industry.

Named endowments include:

- James and Cora Sanders Nursery/Landscape Research Endowment, provided by the Sanders Family and friends
- Don Corum and National Nursery Products Endowment, funded by Bob Corum
- Ammon Nursery/Landscape Research Endowment, established by Richard and Greg Ammon
- Robert E. McNiel Horticulture Enrichment Fund

The General UK Nursery/Landscape Research Endowment was established with donations from several individuals and companies, which were matched with state funds.

Contributions to support the UK Nursery/Landscape Program may be made to the annual gift account for immediate expenditure in the program or may be made to any one of the currently established endowments. To contribute to an endowment or the annual giving program, please contact Dewayne Ingram at (859) 257-8903, Winston Dunwell at (270) 365-7541 ext. 209, or the UK College of Agriculture Development Office at (859) 257-7200.

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