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UNIVERSITY OF KENTUCKY College of Agriculture

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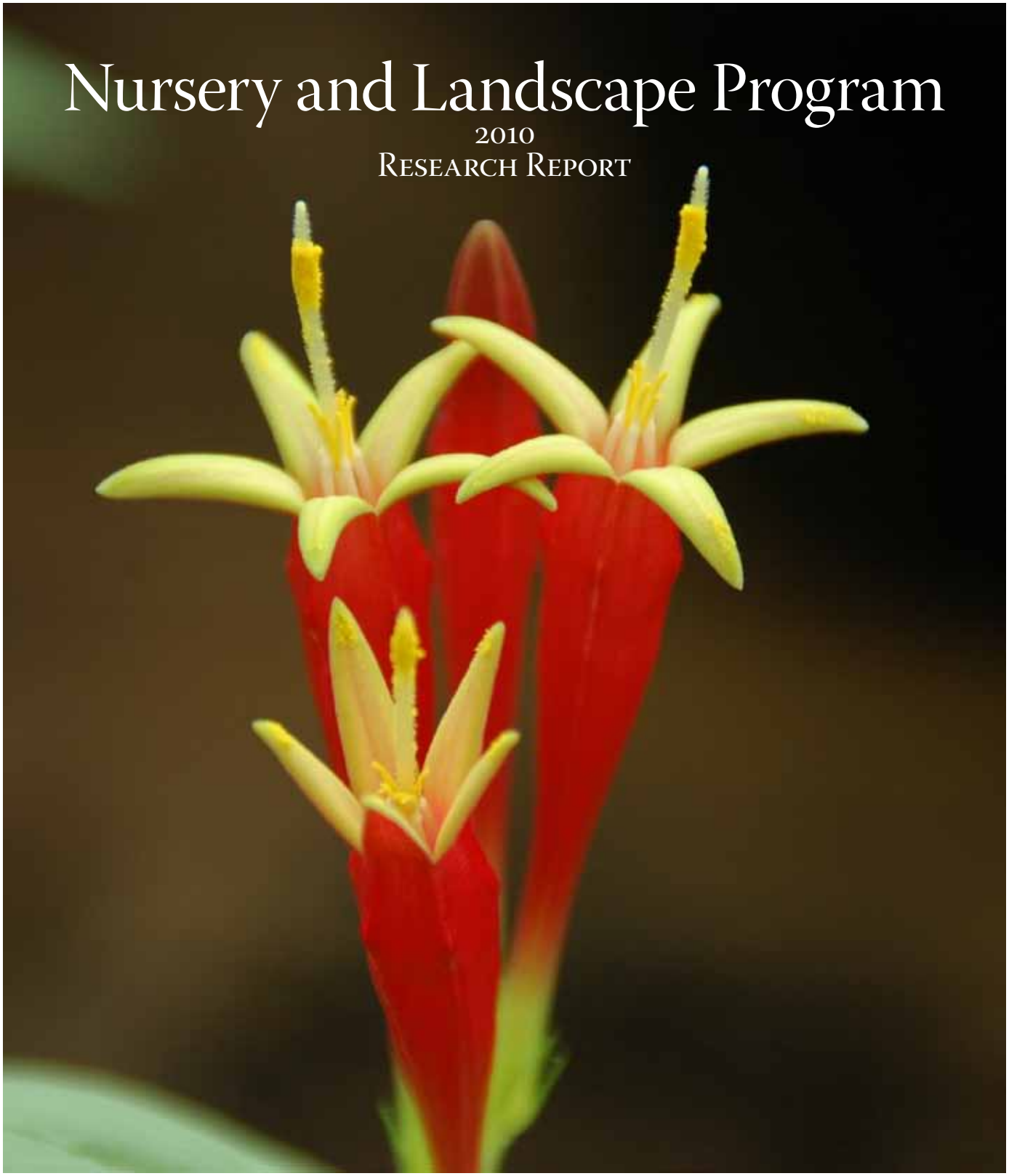
Nursery and Landscape Program

2010 Research Report



UKAg RESEARCH

Department of Horticulture

About Our Cover

Spigelia marilandica, Indian Pink, is an underutilized Kentucky native. Infrequent in southern Kentucky (Wharton and Barbour 1971), it is found as a roadside plant on a variety of soil types. Over its range—Florida into east Texas, southeast Oklahoma, southwest Indiana, northwest Georgia, and east South Carolina—it is common (Duncan and Duncan 1999). The red tubular flowers with five folded lobes showing the yellow interior color are stunning; they "stop people dead in their tracks" (Armitage 1997). An average of 13 (8-17 on 68 stems on a five-year-old division) of the 2-inch (5-cm) upright flowers are found on a one-sided cyme. The glossy ovate, opposite, sessile leaves add to the attractive appearance of the plant. West Kentucky plants grow 18-24 inches (46-61 cm) tall in sun or shade landscape environments. The bloom period starts in late May and continues through June; occasionally scattered blooms will occur in the fall. Rick Darke (2002) says they will re-bloom heavily if cut back after June flowering. Individual plants in the University of Kentucky Research and Education Center Botanical Garden, Princeton, KY are now seven years old and show signs of indefinite longevity. *Spigelia marilandica* is known to attract hummingbirds (Cullina 2000; Glick 2002). This characteristic, added to the beauty of the flowers, the size of the plant, its environmental and pest tolerances, and longevity in the landscape, indicate *Spigelia marilandica* is an plant that should be more widely used in landscapes—in particular, Kentucky landscapes. A quick search of catalogs and nursery contacts indicate that the plant is much more available than in the past thanks to tissue culture propagation. *Spigelia marilandica* won Kentucky's 2010 Theodore Klein Plant Award (go to http://www.ca.uky.edu/HLA/Dunwell/SpigeliamarilandicaTKPA2011.html). For *Spigelia marilandica* propagation information and references see http://www.ca.uky.edu/HLA/Dunwell/Spigeliaprop.html

UK Nursery and Landscape Program

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Nursery and Landscape Program

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UK Nursery and Landscape Program Overview—2010

The UK Nursery and Landscape Program coordinates the efforts of faculty, staff, and students in several departments within the College of Agriculture tor the benefit of the Kentucky nursery and landscape industry. Our 2010 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 activities of undergraduate and graduate students that are addressing the needs of the nursery and landscape industries.

Extension Highlights

Carey Grable and Win Dunwell have established a UK Nursery Crops IPM blog and a wiki. The wiki already contains 28 articles of importance to nursery industry people. You can access the blog at https://citc.ca.uky.edu/groups/nurserycrop-sipm/blog. This work is supported by Kentucky Horticulture Council and a grant from Kentucky IPM.

Amy Fulcher's Southern Nursery Integrated Pest Management (SNIPM) working group continues to move forward with programs for the nursery industry based on the previous year's survey. Extension professionals from Georgia, Kentucky, North Carolina, South Carolina, and Tennessee, representing entomology, horticulture, and plant pathology, are collaborating on a multi-state nursery crops project that includes the development of a Crop Profile and a Pest Management Strategic Plan.

The UK Department of Horticulture, under the leadership of Community of Practice Consumer Horticulture National Chair Richard Durham, continues to provide leadership for the national Gardens, Lawns, and Landscapes eXtension site (http://www.extension.org/horticulture). Several Kentucky extension personnel are also active in the project.

Rebecca Schnelle's statewide bedding plant trial garden program is entering its third year in 2011. This program compiles landscape performance data for both annual and perennial flowering plants across the state. With the ever-changing array of bedding plant varieties on the market, these data will help keep Kentucky's growers and landscapers ahead of the curve. The results and more are available online at http://www.uky.edu/Ag/Horticulture/trialgarden/gardenhome.html.

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 2010:

The horticulture/plant and soil science degree program had 44 students, of which half were horticulture students and a fourth were turfgrass students.

An important aspect of our undergraduate education in horticulture comes outside the classroom. In addition to the local activities of the UK Horticulture Club and field trips as part of course laboratories, students have excellent off-campus learning experiences. Here are the highlights of such opportunities in 2010:

- Students toured California gardens, natural areas, and nursery/landscape businesses. The tour was led by Robert Geneve and Win Dunwell.
- Micah Stevens placed second in the International Plant Propagator's Society student competition for the southern region and published the results of his undergraduate research on adventitious root formation in poplar (*Populus*) intermodal stem cuttings grown *in vitro* in the *Combined Proceedings* of the International Plant Propagator's Society. His research was also presented as a poster presentation at the International Horticulture Congress in Portugal.
- Students accompanied faculty to the following regional/national/international meetings: the Kentucky Landscape Industries Conference, the Mid-States Horticultural Expo, 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 master's graduates are being employed in the industry, the Cooperative Extension Service, secondary and postsecondary education, and governmental agencies. Last year, there were nine graduate students in these degree programs conducting research directly related to the Kentucky nursery and landscape industry. Graduate students are active participants in the UK nursery and landscape research program and contribute significantly to our ability to address problems and opportunities important to the Kentucky nursery and landscape industry.

Amy Fulcher completed her Ph.D. and presented one paper at the Southern Nursery Association research conference and two papers at the International Horticultural Congress.

National Nursery Survey for *Phytophthora Ramorum* in Kentucky, 2010

Julie Beale and Sara Long, Department of Plant Pathology; Janet Lensing, Katie Kittrell, and John Obrycki, Department of Entomology

Nature of the Work

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, causes the widespread death of many oak and tanoak species. Other hosts of this pathogen include camellia, rhododendron, viburnum, lilac, and mountain laurel. Regulations and quarantines have been established to limit the spread of *P. ramorum*, but concerns remain about potential movement in contaminated nursery stock. Methods of long-distance spread of the pathogen include moving of plants, plant parts, soil, and water. *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 37^0 and 82^0 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.

The National Nursery Survey for *P. ramorum* in Kentucky was continued through the 2010 growing season. This survey is 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 and Plant Health Inspection Service (APHIS). It has been conducted every year since 2004. Procedures for collecting and testing followed protocols established by USDA-APHIS Plant Protection and Quarantine (PPQ). This year, samples consisted of leaves showing symptoms in or around commercial nurseries and on rhododendron leaves used as "baits" in irrigation ditches, ponds, or other bodies of water in or around the nursery. The water-baiting technique has been used in forest settings, but this is the first year it has been used in the nursery survey in Kentucky. A total of 204 samples were collected as a part of the survey. One hundred seventy-four foliage samples with symptoms suggestive of general *Phytophthora* infection were collected from 40 commercial nurseries, and 30 samples from water baiting were collected at 15 of those same nurseries. Nurseries surveyed were located across the state in 25 counties: Boone, Boyle, Breathitt, Bullitt, Calloway, Clark, Daviess, Fayette, Franklin, Graves, Grayson, Henderson, Hopkins, Jefferson, Jessamine, Kenton, Laurel, Marshall, McCracken, Mercer, Muhlenberg, Nelson, Shelby, Union, and Whitley. All samples collected were double-bagged and sent to the UK Plant Disease Diagnostic Laboratory (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 samples at the Lexington PDDL. 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).

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 2010.

Plant Species	Number of Samples	ELISA positive- *Phytophthora* sp.	PCR positive- *P. ramorum*
Rhododendron	89	31	0
Viburnum	59	3	0
Pieris	18	4	0
Kalmia	4	1	0
Camellia	4	0	0
Water Bait (rhododendron leaves)	30	23	0
Total	204	62	0

Results

Of the 174 plant samples collected, 39 tested positive for infection by *Phytophthora* species; of the 30 water-baited samples, 23 tested positive for infection by *Phytophthora* species, bringing the total number of positive samples to 62. Extracted DNA from these 62 samples was sent to USDA-APHIS approved testing laboratories 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.

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Real-Time PCR Detection of *Xylella fastidiosa* is Independent of Sample Storage Time and Temperature

Bernadette F. Amsden, Paul Vincelli, and John R. Hartman, Department of Plant Pathology

Nature of the Work

The xylem-limited bacterium *Xylella fastidiosa*, first associated with Pierce's disease of grapevines and alfalfa dwarf disease in 1973 (4) continues to be an economically important pathogen of several commercial crops. It also causes bacterial leaf scorch in urban shade trees such as sycamore, oaks, maples, mulberry, and elm (5). The usual course of action, in an effort to control the spread of this pathogen by insect vectors (9), is to prune out infected branches and vines or to rogue infected plants. Therefore, timely testing of suspect hosts is important.

Leaf samples showing symptoms are typically tested via ELISA and/or Taqman® PCR for the presence of *X. fastidiosa* several days after being collected. Assessing samples for *X. fastidiosa* by PCR requires several steps during which delays can, and often do, occur. These delays are often due to the distances separating the collection location and the assay lab. Samples may be delayed at their origin prior to shipping, or, for the sake of efficiency in the assay lab itself, in order to have several samples to test simultaneously. At each of these delays, samples are sometimes stored as desiccating twigs or branches or as leaves placed in plastic bags; also, they are sometimes either kept at room temperature on a bench or placed at 4° C. In our experience with these samples, ELISA scores ranging from negative to very strong positives often appear to be independent of the intensity of symptoms seen on the leaf margins. ELISA-positive samples with weak to moderate ELISA scores sometimes yield a weak positive reaction by PCR. Since PCR has become an accepted method of detection of *X. fastidiosa* due to its much greater detection sensitivity compared to ELISA (12), weak PCR-positive values in stored ELISA-positive samples suggested the possibility that sample storage conditions may have had detrimental effects on detection of *X. fastidiosa* by PCR.

The objectives of this study were (a) to investigate whether sample storage conditions and duration affected detectability of *X. fastidiosa* by real-time PCR and (b) to evaluate DNA extraction methods for use on host tissues infected by *X. fastidiosa* to determine the quickest method without impacting detectability of the bacterium.

Effects of Sample Storage Time and Temperature

Shoots from suspect trees or shrubs were collected and taken directly to the laboratory, where processing was begun on the day of collection. Excised petioles were surface-sterilized twice for 2 min in 1% sodium hypochlorite, twice for 2 min in 70% ethanol, rinsed twice for 1 min in two changes of sterile reverse-osmosis (RO) water, and allowed to dry.

In order to test sample handling/storage parameters, surface-sterilized petioles were arbitrarily allocated among two storage times (<24 h and 6 d) and four storage temperatures (room temperature [RT], 4°C, -20°C, or -80°C). Samples consisted of field-collected shoots of *Acer griseum, Acer platanoides, Acer saccharum, Chionanthus virginicus, Clematis* sp.*, Clethera* sp.*, Fraxinus americana, Gallum odoratum, Kerria* sp*, Morus alba, Platanus occidentalis, Quercus palustris, Quercus rubra, Quercus shumardii, Stewartia* sp.*, and Vitis vinifera.* Two data sets were available for this analysis: one consisting of 11 samples for which total sample DNA was quantified (see methods below), and three samples for which total sample DNA was unquantified; for the latter, all PCR reactions received a uniform volume of sample extract.

Surface-sterilized petioles were tested for the presence of *X. fastidiosa* by ELISA (AgDia® PathoScreen® Xf, cat# PSP34501, http://www.agdia.com/) within 24 hours of collection. Ten to 14 petioles (2007) or three petioles (2008 and 2009) per sample were ground in an AgDia® mesh sample bag along with a 10X volume (v/wt) of AgDia® ELISA general extraction buffer. Tissue was disrupted using a hammer to break petiole ends and then mashed with an AgDia® circular-bearing Tissue Homogenizer (cat# ACC00900) attached to a drill press to complete tissue disruption. One hundred µl of crude extract was added to the ELISA plate for antibody detection of the bacterium. The remaining crude extract was used for DNA extraction (hereafter referred to as "eDNA") using the DNeasy® Plant Mini Kit (Qiagen, http://www1.qiagen.com/, cat# 69104) as described below.

The PCR master mix consisted of (final concentrations, reaction volume=25 µl): 1X Epicentre® Biotechnologies FailSafe™ Probes Pre-mix #6 (cat# FSP51206); 500 nM each of primers XfF1 and XfR1 and 200 nM Taqman® probe XfP1 (11) with FAM and BHQ1 as the reporter dye and quencher, respectively; and 2.5 units of Failsafe™ Enzyme Blend (cat# FSE51100). For most samples, DNA was added as 10 ng extracted total DNA. For certain samples, DNA concentration was too low to achieve a 10-ng aliquot in the reaction tube; in those cases, the maximum allowable volume of 8 µl was added to the PCR reaction. Negative and positive controls were 2 µl of molecular-grade water and 2 µl of known *X. fastidiosa* genomic DNA (American Type Culture Collection # 35881D), respectively. For each sample, a parallel control was tested and consisted of a sample reaction spiked with 2 µl of known *X. fastidiosa* genomic DNA in order to test for PCR inhibition (12). Reactions were amplified on a SmartCycler® II thermocycler (Cepheid, http://www.cepheid.com) with the following thermocycling conditions: a 95° C hold for 1 min, followed by 40 cycles at 95° C for 1 sec and 60° C for 20 sec. In the parallel control, a failure to amplify was taken to be indicative of inhibition. For samples where PCR inhibition occurred, the sample was serially diluted tenfold until inhibition was overcome. Quantification of genomic DNA of *X. fastidiosa* in DNA extracts of samples were estimated against a standard curve of Ct vs. DNA concentration generated using known *X. fastidiosa* genomic DNA (ATCC #35881D). DNA concentrations were determined using Quant-It® dsDNA HS Assay Kit (cat# Q32851) from Invitrogen and the Invitrogen™ Qubit®

fluorometer (cat# 32857). Estimates of amounts of genomic DNA of *X. fastidiosa* were expressed on a basis of pg per ng of sample total DNA or pg per µl of sample total DNA.

Data from samples subjected to the temperature (four levels) and time (two levels) conditions described above were subjected to analysis of variance following a 4X2 factorial design within a randomized complete block design, where plant samples were considered blocks. Because missing data created an unbalanced design, Type II sums of squares were used to evaluate treatment effects (10).

Because the storage temperature X duration interaction was nonsignificant (P=0.96, Tables 1 and 2), evaluation of main effects was possible. Storage temperature had no effect (P>0.15) on the detectability of *X. fastidiosa* by PCR in petioles of shade trees and shrubs (Tables 1 and 2). Processing osamples within 24 hours did not result in improved detectability as compared to holding samples for six days. Indeed, in one of the two datasets (Table 1), detection was significantly better (P=0.059) after six days than 24 hours, although we postulate that this could be an anomalous result. In both datasets, variability was substantial, as reflected in high standard errors (Tables 1 and 2) and coefficients of variation of 111% and 126% in datasets 1 and 2, respectively. In any case, our data suggest that among-petiole variability, as reported in sampling studies of grape petioles for detection of *X. fastidiosa* (6), is at least as important a factor in detectability of *X. fastidiosa* as the sample handling parameters included in this study. This suggests that it would be advisable to pool small subsamples of several petioles before DNA extraction and PCR.

Evaluation of Methods for Preparing PCR Template

TE bacterial release: Following the method of Chen et al.(3), surface-sterilized, excised petioles (~100 mg per sample) were finely chopped, placed into a Mini-BeadBeater tube, flash-frozen in liquid nitrogen, and pulverized as described above. To this pulverized tissue was added 500 µl of sterile elution buffer taken from a Qiagen DNA extraction kit (a Tris/EDTA buffer, pH 9.0) (1) and allowed to soak at RT for 15 min, vortexed for 10 sec, and centrifuged for 10 sec at 24,000 x g. A series of tenfold dilutions was conducted using sterile RO water. A 5-µl aliquot of this extract was used directly in the PCR reaction.

For all TE bacterial release samples, in order to overcome PCR inhibition, dilutions ranging from 1/100 to 1/10,000 were necessary (Table 3). In spite of the ease of disrupting suspect tissue directly in TE buffer and using that supernatant directly in the PCR reaction, the broad range of dilutions required to overcome PCR inhibition renders this TE bacterial release method inefficient due to the number of times the PCR had to be repeated until there was no longer evidence of PCR inhibition. Furthermore, excessive dilution runs the risk of a false negative for samples with very low pathogen titers.

Evaluation of ELISA Buffer Extract as a Source of DNA for Extraction: After removing a 100-µl aliquot for ELISA testing, the remaining crude extract from the ELISA extraction was immediately transferred into one or two 1.5 ml microcentrifuge tubes and centrifuged at maximum speed for 15 min at RT in order to precipitate plant debris and any bacteria. After discarding the supernatant, each pellet was resuspended in 400 µl of AP1 Buffer from the Qiagen's DNeasy® Plant Mini Kit (cat# 69104) plus 4 µl RNase A by vortexing. DNA extraction was accomplished by following the DNeasy® protocol with the exception of incubation at 85° C for 5 min at step 8 of the procedure, instead of incubation at 65° C for 10 min. DNA was eluted with 100 µl AE elution buffer. After extraction, the DNA was stored at -20°C until testing was completed.

eDNA was extracted from 23 samples, eight of which were also processed using the QIAamp® Stool kit, permitting a direct comparison using a paired t-test (8). Qiagen's QIAamp®

Table 1. Mean concentration of *X. fastidiosa* genomic DNA obtained from plant samples stored at various times and temperatures, using 11 sample extracts having quantified total sample DNA.

Timing of DNA extraction	RT[a]	4°C	-20°C	-80°C
Within 24 h of collection	0.39 *(0.39)*[b]	1.1 *(0.39)*	0.52 *(0.38)*	0.44 *(0.38)*
Six days after collection	0.97 *(0.39)*	1.4 *(0.41)*	0.85 *(0.42)*	0.92 *(0.41)*

ANOVA source	df	MS[c]	*F*-value	*P*
Model	17	4.232	4.80	<0.0001
Plant sample (=blocking variable)	10	6.284	7.13	<0.0001
Temperature (RT, 4°, -20° & -80°C)	3	1.422	1.61	0.1956
Time (<24 h v. 6 d)	1	3.264	3.70	0.0590
Time X Temp	3	0.088	0.10	0.9598
Error	60	0.881	-	-

[a] RT: Ambient room temperature.
[b] Mean genomic DNA content of *X. fastidiosa* in pg/ng total sample DNA extract (italicized values are standard errors), determined using quantitative real-time PCR (11). Least-square means generated using SAS PROC GLM (10).
[c] Mean squares for treatment factors are Type II mean squares (10).

Table 2. Mean concentration of *X. fastidiosa* genomic DNA obtained from plant samples stored at various times and temperatures, using three sample extracts for which quantitation of total sample DNA was unavailable[a].

Timing of DNA extraction	RT[b]	4°C	-20°C	-80°C
Within 24 h of collection	16 *(56)*[c]	17 *(56)*	45 *(62)*	103 *(56)*
Six days after collection	29 *(59)*	10 *(62)*	78 *(56)*	96 *(62)*

ANOVA source	df	MS[d]	*F*-value	*P*
Model	9	12549	3.31	0.0326
Plant sample (=blocking variable)	2	40412	10.67	0.0027
Temperature (RT, 4°, -20° & -80°C)	3	8232	2.17	0.1487
Time (<24 h v. 6 d)	1	210.9	0.06	0.8178
Time X Temp	3	391.0	0.10	0.9564
Error	11	3787	-	-

[a] Uniform volumes of sample total DNA extract were added to PCR reactions.
[b] RT: Ambient room temperature.
[c] Mean genomic DNA content of *X. fastidiosa* in pg/ng total sample DNA extract (italicized values are standard errors), determined using quantitative real-time PCR (11). Least-square means generated using SAS PROC GLM (10).
[d] Mean squares for treatment factors are Type II mean squares (10).

DNA Stool Mini Kit (cat# 51504) was used (7) to extract total DNA from surface-sterilized subsamples of the samples also processed via eDNA/DNeasy® extraction. One hundred mg of finely chopped petiole (~1-2 mm) was placed into a Mini-BeadBeater 3110BX (BioSpec Products) tube without buffer, flash-frozen in liquid nitrogen, and pulverized at 2500 rpm at repeated 30-sec intervals, with flash-freezing between each beating. Immediately after pulverization, the DNA was extracted following kit instructions with the exception of elution in 100 µl volumes, and stored at -20°C until testing was completed.

Results

Our study validates the approach of Buzombo et al. (2), in that we found ELISA buffer extract provided amplifiable DNA template (Table 4). This is based on the observations that (a) a *t*-test indicated no significant difference ($P>0.1$) in the quantity of *X. fastidiosa* DNA recovered from the eight samples processed by both the eDNA/DNeasy® method and the QIAamp® Stool kit method (Table 4) and (b) no PCR inhibition was observed in any sample DNA obtained by the eDNA/DNeasy® method, including 15 samples extracted only by the eDNA technique (*data not shown*). Using ELISA-buffer extract for both ELISA and for DNA extraction for PCR tests speeded sample processing substantially over QIAamp® Stool kit DNA extraction alone, which require approximately one additional hour for completion. Furthermore, using the same host tissue fragments for both ELISA and PCR addresses discrepancies that may be caused by non-uniform distribution of the pathogen in the host (6).

In summary, this study shows that bacterial leaf scorch suspect samples may remain at ambient temperature for up to six days after collection without adversely affecting detectability of *X. fastidiosa*. It also verifies that the use of ELISA extract remaining from the antibody test can successfully be used as a source of bacterial DNA for PCR and reduces preparation time and effort.

Significance to the Nursery Industry

The results of this study have shown that it is not necessary to ship collected suspect samples overnight or under expensive chilled conditions in order to prevent loss of detection of the causal bacterium *Xylella fastidiosa*. In fact, it has been shown that detection is still possible if holding samples at ambient temperature for as long as 6 days after collection. Perhaps a longer time frame is possible, but it has not been tested.

Xylella has been shown to be unevenly distributed throughout infected petioles and from petiole to petiole within any given symptomatic sample. This study shows that utilizing the exact same tissue extract for both ELISA and the DNA extraction for subsequent PCR detection should result in more reliable determination of infectivity, which will provide more reliable diagnostic results.

Table 3. Dilutions of TE-released *X. fastidiosa* required to overcome PCR inhibition.

Host	Sample ID	Dilution needed to overcome inhibition[a]
Vitis vinifera	1685-09	1/100
Quercus sp	1702-09	1/10,000
Platanus occidentalis	1718-09	1/10,000
Stewartia sp	1744-09	1/100
Acer saccharum	1768-09	1/10,000
Quercus sp.	1770-09	1/10,000
Clethera sp.	1779-09	1/1000
Clematis sp.	1780-09	1/1000
Gallum odoratum	1781-09	1/1000
Kerria sp.	1782-09	1/1000
Kerria sp.	1783-09	1/1000
Kerria japonica, variegated	not numbered	1/1000

[a] Inhibition was considered to be overcome by dilution if the Ct value of the parallel control was greater than 0.

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Table 4. Evaluation of the suitability of using ELISA buffer sample extract as a source of DNA for PCR amplification.

Sample ID	Host plant	ELISA value[a]	Amount (pg) Xf[b] DNA per µl of "eDNA"[c]	Amount (pg) Xf DNA per ng total DNA extracted using QIAamp® Stool DNA kit
41BA09w[e]	*Acer griseum*	++	17.4	17.05
41BA09st[e]	*Acer griseum*	+++	58.1	16.47
76BA09 early[e]	*Quercus rubra*	nd	10.0	5.84
76BA09w[e]	*Quercus rubra*	+ weak	6.2	3.15
76BA09st[e]	*Quercus rubra*	+ weak	25.6	0
93BA09w[e]	*Acer platanoides*	Neg	0	0
106H09w[e]	*Chionanthus virginicus*	+ weak	0	0
106H09st[e]	*Chionanthus virginicus*	+ weak	0	0

[a] ELISA values are subjectively determined based on color reaction intensity.
[b] Xf = *Xylella fastidiosa.*
[c] ELISA extract was used as source of sample materials for DNA extraction using Qiagen DNeasy® Plant Kit.
[d] "-" - not tested.
[e] Samples used in *t*-test comparison of yields of eDNA vs. DNA extracted via the QIAamp® Stool Kit.

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Gleanings from a Five-State Pest Management Strategic Plan and Crop Profile

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Nature of the Work

Growers face many challenges to growing a healthy, profitable nursery crop. Pests can cause substantial losses to the nursery industry. For example, In North Carolina, the green industry reported annual losses of $91 million due to insects and diseases (2). A regional group of extension professionals formed in October 2008 to address nursery crop production needs through integrated pest management (IPM) programming. The group, the Southern Nursery IPM Working Group (SNIPM), represented five states: Georgia, Kentucky, North Carolina, South Carolina, and Tennessee. The initial goal of the working group was to acquire funding to develop a five-state nursery crop pest management strategic plan and crop profile andthen create these two documents, which could be used to define research and extension objectives.

So that the pest management strategic plan and crop profile would accurately reflect current needs of the nursery crop industry, growers (two per state) were invited to form a focus group with the extension professionals. Growers were selected to broadly represent each state's nursery industry. In advance of the meeting, growers identified their top insect, weed and disease problems.

A two-day facilitated sharing session and needs assessment took place with the focus group on July 30-31, 2009 in Mills River, NC. At the meeting, extension professionals presented overviews of the production characteristics and metrics for each state. Growers provided an overview of their nursery, common pest problems, and challenges to managing those problems. Growers again prioritized pests within each pest category (insect, disease, weed) as follows:

- *Insect pests*—For insect pests, growers ranked the previously identified pests using a ballot system. Specifically, each focus group member was issued 10 votes and was permitted to use them at his or her discretion to vote for insect pests based on difficulty to control and prevalence. All votes could be used on one pest or divided among several insect pests. Not all votes had to be cast.
- *Disease pests*—In order to rank diseases, the facilitator guided the focus group in a consensus-building process to rank the pests, greatest to least.
- *Weed pests*—To rank weeds, the facilitator guided the focus group in a process to review and modify, as needed, the pre-meeting weed rankings to reflect the group's current consensus.

Growers also identified specific emerging pests as well as issues influencing insect, disease, and weed control (such as contaminated irrigation water) and non-pest issues (e.g., water availability, water rights, etc). Finally, through facilitation and a consensus-building process, growers were asked to identify extension, research, and regulatory priorities for each pest category and overall priorities. These data were assimilated into a five-state pest management strategic plan and crop profile (1).

Results and Discussion

Focus groups developed final pest rankings for insects, diseases, and weeds (both container and field production) See Tables 1-4.

- *Insect pests*— Insects were ranked for both difficulty to control and prevalence. Borers (flatheaded and clearwing), granulate ambrosia beetle, mites, and scales accounted for 91% of the votes when difficult-to-control insects were ranked and 73% of the votes in the ranking by prevalence (Table 1).
- *Disease pests* —Diseases included leaf spots and mildew, bacterial and fungal blights, root rots, and cankers (Table 2). Root rots (*Phytophthora* and *Pythium*) were the most highly ranked disease problem.

Table 1. SNIPM focus group identification of arthropod pests in the Southeast based on grower-perceived difficulty to control and prevalence in field and container nursery production.

	Votes	
Arthropod	**Difficulty to Control[1]**	**Prevalence[2]**
Scales	26	20
Borers	17	17
Granulate ambrosia beetles	15	12
Mites	14	16
Root grubs/weevils	5	3
Caterpillars	1	1
Leafhoppers	1	7
Aphids	0	6
Japanese beetles	0	5
Flea/leaf beetles	0	2

[1] Number of votes cast, by insect. Greater number of votes indicates more focus group members identified this as a problem insect.
[2] Number of votes cast indicating how frequently focus group members encounter the pest.

- *Weed pests*—Ten weed species were identified as major nursery pests (Table 3). More weed species were listed for container production than for field production. Marestail [horseweed; *Conyza canadensis* (L.) Cronquist] was listed in field production specifically because of concern regarding glyphosate-resistant plants. An additional 12 species (weed, algae and liverwort) were identified as emerging or potential pests for nursery producers in the Southeast (Table 4).

Table 2. SNIPM focus group ranking of diseases in the Southeast by grower-perceived importance.

Disease	**Rank[1]**
Root rots (*Phytophthora* and *Pythium* spp.)	1
Fungal leaf spots	2
Powdery mildew	3
Downy mildew	4
Phomopsis	5
Black root rot	6
Botryosphaeria	7
Cedar rusts	8
Passalora needle blight, *Cercosporidium* needle blight, and *Cercospora* blight)	9
Fire blight	10

[1] Rank = 1 greatest importance, 10 lowest importance.

Based on the focus group discussion, 34 extension and research priorities were developed for insect, disease, and weed pests (Tables 5-10). Overall, extension, research, and regulatory priorities were often very specific but spanned a broader range of concepts than previously discussed by the focus group, sometimes including issues outside pest management (Tables 11-13).

A focus group of field and container nursery crop producers and extension professionals identified and prioritized major nursery pests. The focus group was also able to develop priorities for extension programming and applied research for five southeastern states. These priorities can be used to develop statewide or multi-state strategic plans, define research and extension objectives, and support grant proposals.

Table 3. SNIPM focus group ranking of container and field production weeds in the Southeast by grower-perceived importance.

Container Production		**Field Production**	
Weed Species	**Level of Importance (votes)[1]**	**Weed Species**	**Priority (votes)**
Spurge	9	Yellow Nutsedge	12
Oxalis/woodsorrel	7	Crabgrass	7
Bittercress	6	Marestail/ horseweed	7
Liverwort	5		
Groundsel	5		
Eclipta	4		
Annual bluegrass	2		

[1] Greater numbers of votes indicates more focus group members found this to be a problem weed.

Table 4. Emerging weeds, algae, and liverworts of concern in the southeastern United States.

Common name	**Scientific name**
Algae[1]	*Nostoc* spp.
American Burnweed	*Erechtites hieraciifolia*
Asiatic Hawksbeard	*Youngia japonica*
Benghal Dayflower	*Commelina benghalensis*
Cogongrass	*Imperata cynlindrica*
Dogfennel	*Eupatorium capillifolium*
Doveweed	*Murdannia nudiflora*
Liverwort	*Marchantia polymorpha*
Mulberryweed	*Fatoua villosa*
Longstalked phyllanthus, chamberbitter, gripeweed	*Phyllanthus tenellus* (longstalked phyllanthus), *P. urinaria*, (chamberbitter, gripeweed)
Ragweed Parthenium	*Parthenium hysterophorus*

[1] Species are listed alphabetically, not in order of priority or importance.

Table 5. Entomology extension priorities (unranked).

- Monitoring of the presence and populations of insects and establishment of action thresholds
- Grouping of scale insects and development of management guidelines for each group
- Emphasis on scouting and early detection to be able to act on thresholds
- Use of oils early, when thresholds are reached, to avoid using products that might be more expensive, more toxic, or both
- Emphasis on the importance of decreasing plant stress and using appropriate production practices to do so

Significance to the Industry

Pest problems can cause substantial lost revenue (dead or unhealthy/unmarketable plants) and increased inputs (labor, fuel, and pesticide) for ornamental plant producers. A focus group composed of industry and academic members identified and prioritized extension, research, and regulatory issues for the nursery crop industry. This information will help growers, land grant professionals, and government officials focus resources on the most relevant pests. Additionally, this information will allow regional comparisons of serious nursery crop pests and will allow for temporal comparisons of pertinent nursery crop pests.

Acknowledgments

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Table 6. Entomology research priorities (unranked).

- Mite management improvements
- Thresholds and products to use to avoid secondary pest outbreaks such as potato leafhopper applications that increase mite populations
- Use of water conditioner for pH
- Relationship of production practices to pest outbreaks—focus on insect complexes, not on an individual but focus on a plant to allow the consolidation of sprays
- Assessment of whether improved nutrition in the fall will reduce attacks by the flatheaded apple tree borer in field and container-grown plants. (Some growers use 25 ppm K or Mg nitrate late in summer to gradually slow the plants down.)
- Impact of timing in pruning
- Determination of correct surfactants and their rate to increase chemical efficacy
- Borer identification improvements in order to distinguish between various borers
- Determination of insect biology, host preference, and overwintering host preference and how production practices might affect both
- Development of products that control pests with minimal negative effects on natural enemies and pollinators
- Determination of possibilities for management of granulate ambrosia beetle after it enters trees
- Investigatation of pesticide efficacy, life history, timing of sprays, and carrying out of trials to show using life history and timing of sprays for Japanese maple scale, white peach scale.
- Development of thresholds for Japanese beetles

Table 7. Plant pathology extension priorities (unranked).

- Development of resources on cultural practices and chemical controls with efficacy tables that would include details such as curative/preventive activity and some state label restrictions

Table 8. Plant pathology research priorities (unranked).

- Evaluate the efficacy of products applied via chemigation

Table 9. Weed extension priorities (unranked).

- Improvement of management guidelines for hard-to-control weeds such as seasonal timing for postemergent (POST) weed control to manage perennial weed pests in nursery borders, field rows, and new (e.g., container and pot-in-pot) production areas
- Improvement of monitoring tools, protocols, and educational programs (e.g., improved guides for identifying "emerging weeds of concern")
- Improved decision-aids for selecting the most appropriate weed management options (e.g., economic thresholds, efficacy tables, resistance management protocols)
- Training that would lead to development of an overall integrated weed management plan for controlling weeds tailored to each specific production operation
- Education on avoiding crop damage from herbicides

Table 10. Weed research priorities (unranked).

- Biology and ecology of weeds in unique nursery ecosystems (e.g., environmental and climatic modeling for predicting certain weed seed germination; development and reproduction of common and newly introduced species)
- A systematic survey of the current state of weeds in nursery production systems across the southeastern United States
- Greater understanding of herbicide persistence and longevity of control relative to the need for re-applications or other supplemental management (e.g., pairing environmental/climatic models with knowledge of herbicide persistence and efficacy to better time both deployment and re-application of preemergent (PRE) herbicides)
- Assessment of effectiveness and utility of cultural, physical, and mechanical controls such as cover crops and living mulches, physical barriers (e.g., landscape fabric, geotextile, woolpack, hair and coir disks, and large bark chip topdressings)
- Accurate cost accounting of weed management systems including labor for hand-weeding; strategies for efficient resource utilization through use of IPM to decrease weed management costs
- Assessment of opportunities to achieve efficient weed control with reduced PRE and POST emergence herbicide use, particularly in crops nearing sale date
- Development of understanding and avoidance of crop injury from herbicide use in nurseries (e.g., long-term consequences of POST-emergence herbicide use such as glyphosate applications via Enviromist sprayer technology or environmental persistence such as herbicide residue effects on seedling germination and liner growth
- Phytotoxicity of both PRE and POST-emergence chemistries on the diverse ornamental crops with emphasis on new and expanding crop categories (e.g., perennials, ornamental grasses, tropical plants) being grown in the southeastern United States
- Development of new weed control technologies and herbicide formulations

Table 11. Overall extension priorities (unranked) of nursery producers and extension professionals in the southeastern United States.

- Encouragement of support and use of county extension personnel (serving the green industry) in the dissemination of information
- Utilization of multi-state collaboration of university/industry personnel to develop a regional web site/clearing house for compiling and disseminating pest/pest management information
- Emphasis on use of digital diagnosis through county offices
- Development of training and certification for scouting (expansion availability online and through distance education)
- Development and availability of efficacy tables to include re-entry intervals and grouping by mode of action
- Development of awareness regarding timing of pesticide applications to increase worker protection and effectiveness of chemicals

Table 12. Overall research priorities identified by nursery producers and extension professionals in the southeastern United States

- IPM profitability and viability for nursery crop production
- Identification of effective treatments for foliar nematodes
- Identification of plant phenological indicators of arthropod pest activity
- Investigation of how to manage arthropod pest complexes rather than individual species
- Development of whole systems approach to pest management
- Determination of cause and treatment of *Cryptomeria* tip disorder
- Development of more cost-effective management of fire ants
- Understanding of glyphosate damage in nursery crops: its symptoms, application technology
- Determination of physiological differences between container and field- grown plants with regard to pest susceptibility and pesticide treatments
- Development of systemic controls of borer and scale insects
- Identification of surfactant and penetrate use for insect control in trees
- Conducting of efficacy and cost analysis of generic pesticides
- Development of a controlled release preemergence herbicide
- Determination of appropriate timing of pest monitoring, scouting, and pesticide applications for weeds, arthropods, and diseases
- Testing of efficacy of efficacy of chemicals
- Investigation of biology of black root rot

Table 13. Overall regulatory priorities identified by nursery producers and Extension professionals in the southeastern United States

- Evaluation of the sustainability of oak production regarding Sudden Oak Death
- Resolution of questions on required quarantined treatments for fire ants and Japanese beetles
- Addressing use of hydrogen peroxide for water filters
- Addressing chlorine concerns (Department of Homeland Security)
- Addressing of numerous water issues (availability, quality, runoff, regulations, etc.)
- Identification of ornamental production as an agriculture industry

2010 Landscape Plant Disease Observations from the University of Kentucky Plant Disease Diagnostic Laboratory

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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 UK Research and Education Center in Princeton. Of the more than 4,000 plant specimens examined in 2010, 30% were landscape ornamentals (1). Of those, 16% were commercial samples from nursery or greenhouse production systems or from professional landscape companies.

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(s) involved. In addition, many specimens require special tests such as moist chamber incubation, culturing, enzyme-linked immunosorbent assay (ELISA), 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 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 programs, and plant health care workshops.

To assist county extension agents in dealing with plant disease issues, we also operate a web-based digital consulting sys-

tem. 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 digital consulting 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 2010, approximately 40% of digital consulting cases dealt with landscape and nursery plants.

The 2010 growing season was much drier overall than the previous year, making 2010 a less disease-conducive season in general than 2009. January precipitation was slightly below normal, while February through April was 4.3 inches below normal. Heavy rainfall in May was 3 inches above normal and rainfall through September was normal or slightly below normal. Western Kentucky received far less rainfall during the summer that other portions of the state and was 6-9 inches below normal in September, while central and Northern Kentucky were 3-6 inches below normal.

January and February temperatures were 3° and 6.9 °F below normal, respectively. Temperatures for April through August ran consistently 3°- 4.8° F above normal. Louisville had 82 days, Bowling Green 75 days, Paducah 74 days, Lexington 44 days, Cincinnati 34 days, and Jackson 22 days above 90 °F this summer. This was the second warmest year for Kentucky on record.

Landscape plant diseases ranged from root rots favored by wet soils during the previous summer (2009) and the spring of 2010 to canker and vascular diseases enhanced by stress from summer heat and drought in 2010. Many of the foliar diseases that typically infect during wet, cool weather at leaf emergence and expansion—e.g., anthracnose, apple scab—were less common than in many years. The following important or unusual diseases were observed:

Deciduous trees

Flowering pear and flowering crabapple fire blight (*Erwinia*)
Flowering cherry leaf spot (*Coccomyces*)
Flowering crabapple frogeye leaf spot (*Botryosphaeria*)
Flowering crabapple scab (*Venturia*)
Flowering plum and flowering cherry black knot (*Apiosporina*)
Flowering plum pockets (*Taphrina*)
Serviceberry cedar/quince rust (*Gymnosporangium*)
Blackgum and willow cankers (*Botryosphaeria*)
Ash, maple, and oak bacterial leaf scorch (*Xylella*)
Maple tuliptree and catalpa wilt (*Verticillium*)
Oak anthracnose (*Apiognomonia*), often on white oak with jumping oak gall
Willow leaf spot (*Cercospora*)
Dutch elm disease (*Ophiostoma*)
Oak, flowering plum, and sassafrass root rot (*Phytophthora*)

Needle Evergreens

Juniper twig blights (*Kabatina, Phomopsis*)
Juniper cedar/apple rust (*Gymnosporangium*)
Pine needle spot/blight (*Dothistroma, Mycosphaerella*)
Pine needle rust (*Coleosporium*)
Pine tip blight (*Sphaeropsis*)
Spruce needle cast/blight (*Rhizosphaera, Stigmina*)
Arborvitae, fir, juniper, pine, spruce, and taxus root rot (*Phytophthora*)

Shrubs

Azalea leaf/flower gall (*Exobasidium*)
Boxwood canker (*Pseudonectria*)
Cherrylaurel bacterial leaf spot (*Xanthomonas*) and fungal leaf spot (*Cercospora*)
Cherrylaurel, forsythia, rhododendron, and viburnum root rot (*Phytophthora*)
Holly black root rot (*Thielaviopsis*)
Hydrangea fungal leaf spot (*Cercospora*)
Photinia and hawthorn leaf spot (*Entomosporium*)
Rhododendron and lilac canker (*Botryosphaeria*)
Rose rosette (virus)
Herbaceous Annuals and Perennials
Begonia crown rot (*Sclerotinia*)
Calibrachoa crown rot (*Sclerotinia*) and virus infection (tobacco mosaic virus)
Chrysanthemum root/crown rot (*Pythium*) and wilt (*Fusarium*)
European Ginger [*Asarum europaeum*] black root rot (*Thielaviopsis*)
Hollyhock rust (*Puccinia*)
Liriope crown rot (*Phytophthora*)
Petunia root/crown rots (*Rhizoctonia*, *Pythium*, *Phytophthora*)
Sedum crown rot (*Phytophthora*)
Snapdragon virus (impatiens necrotic spot virus)

Significance to the Industry

Plant diseases play a significant role in production and maintenance of landscape plants in Kentucky. The first step in appropriate pest management in the landscape and nursery industry is an accurate diagnosis of the problem. The UK Plant Disease Diagnostic Laboratory assists the landscape industry of Kentucky in this effort. To serve their clients effectively, landscape industry professionals such as arborists, nursery operators, and landscape installation and maintenance organizations need to be aware of recent plant disease history and the implications for landscape maintenance. This report is a synopsis of information about plant disease provided for landscape professionals.

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Annualized Perennials for Kentucky: Report on 2009-2010 Selections

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Nature of the Work

The term "annualized perennials" refers to herbaceous perennial plants that can be produced from seed or cutting to a flowering product within a single growing season. Widespread interest in annualized perennial production around the country has spurred plant breeders to develop many new cultivars that can be produced in this manner. Breeders have successfully produced annualized cultivars in genera that normally require vernalization to flower and/or exhibit extended juvenility periods (Cameron, et al., 2007). While this creates opportunities for growers, it also leads to confusion. For example, Runkle and Heins (2006) tested five cultivars of *Achillea filipendulina* and found that one of the cultivars required vernalization to bloom, while the other four did not. So simply recommending *A. filipendulina* for annualized perennial production is not sufficient. There are thousands of perennial cultivars on the market, and new ones are introduced each year, so there is a continuing need for cultivar trialing to determine suitability for annualized production. Many of the newly developed annualized perennials can be grown on a similar production schedule with popular annual bedding plants yet fetch a higher price. The wholesale price of quart-sized (equivalent to 4.5-inch pot) perennials has increased from $1.48 in 2002 to $2.27 in 2007 versus $0.73 to $0.78 for 4-to-5 inch potted annual bedding plants (USDA, 2003 and 2007). The longevity of perennial plants in the garden is the main reason that gardeners value these plants and are willing to pay more for them than annual varieties (Wilkins and Anderson, 2007). So, it is critical that plants marketed to Kentucky gardeners and landscapers as perennials do in fact persist in the landscape.

In the spring of 2009 seeds were sown of 50 varieties on annualized perennials in 98-cell plug trays. When the seedlings were rooted into the cells they were transplanted into 1-quart (4.5 inch) pots. The plants were grown to market ready stage, defined as the plant being fully rooted into the container and large enough to appear proportional to the container. Data were collected on the number of weeks from seed to rooted plug and transplant to market-ready plant in a 1-quart container.

Nine plants of each variety were transplanted into landscape beds on May 15, 2009. The beds were tilled, amended with composted horse manure, and tilled a second time in early spring 2009. A 3-inch layer of hardwood mulch was spread over all beds. The management of the trial plots was designed to simulate conditions in a low-maintenance commercial landscape or home garden situation. Overhead irrigation was used during establishment. Once the plants were deemed established, they were reliant upon natural rainfall for water. Data were collected monthly (May to October 2009) on appearance and flowering. The plants were rated for appearance on a 0-5 scale (0-dead; 1-poor; 2-marginal; 3-acceptable; 4-good, 5-excellent). A variety was considered to be in flower if any open flowers were present at the time of data collection. In April of 2010, the percentage winter survival was documented. Monthly ratings were continued from May to October of 2010.

Results and Discussion

Production time needed and the landscape performance of the 50 selections included in the trial varied widely (Tables 1 and 2). Some of the plants that required the least greenhouse production time failed to perform in the landscape and vice versa. These results illustrate the challenges growers face in selecting plants that are easy for them to grow and sell but also perform well for their customers. For example, both varieties of *Geum coccinium* ('Cooky' and 'Koi') quickly produced a marketable plant but succumbed to disease in the landscape. Variety 'Cooky' was more resistant, persisting into 2010, but finally did succumb to fungal disease. Both *Rhizoctonia* sp. and *Pythium* sp. were identified in the dead root tissue. Conversely, the two varieties of *Liatris spicata* ('Floristan White' and 'Floristan Violet') required four weeks of additional greenhouse production time to produce a marketable 1-quart plant compared to the *Geum coccinuem* varieties, but they performed very well in the landscape. Some varieties that show potential for both quick and profitable production for growers and good landscape performance include *Solidago canadensis* 'Golden Baby', *Achillea millifolium* 'Colorado', *Kniphofia uvaria* 'Flamenco', *Sedum selskianum* 'Spirit', *Salvia x superba* 'Dwarf Blue Queen', and *Penstemon digitalis* 'Mystica'. Some varieties that are clearly not suited for annualized perennial production in Kentucky include: *Prunella grandiflora* 'Bella Series', *Helenium autumnale* 'Helena Series', and *Geum coccinium* 'Koi' and 'Cooky'.

In addition to issues with plant performance, some selections produced very few flowers in the first year. While technically this is first year flowering, the plants were not in full bloom so the floral display would not be sufficient to market the plant as a blooming plant. Some examples plants with this problem are *Eryngium planum* 'Blue Glitter', 'White Glitter', and 'Blue Hobbit' and *Physostegia virginiana* 'Rose Queen'. The month-by-month performance data for each variety as well as photographs are available online (Schnelle and Cassidy, 2009). The highly variable results of this trial clearly indicate the need for ongoing trialing of potential annualized perennials both in the greenhouse and landscape.

Significance to the Industry

The market share and value for herbaceous perennials is on the rise. From 2002 to 2007 perennial sales have increased by an average of 6.5% per year, while sales of annual potted plants have held steady. Sales of annual flats have steadily declined over this period (USDA 2003; USDA 2007). There are 486 farms in Kentucky producing floriculture crops, of which 432 produce bedding/garden plants (USDA, 2007). At the state level, USDA statistics do not differentiate between annual and perennial bedding/garden plants. It is my observation that the majority of Kentucky bedding plant growers currently produce all or mostly

annual bedding plants due to the popular conception that perennials are more difficult to produce. The information generated by this ongoing project will demonstrate to Kentucky's growers that perennial plants can be easily and quickly produced if the proper varieties are selected.

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Table 1. The greenhouse production time in weeks needed to produce a 98-cell plug from seed sowing, the time needed to produce a marketable plant in a 1-quart container from a 98-cell size plug, and the total production time required from seed to marketable plant.

Supplier	Plant Name (Genus species 'Variety')	Production Time (weeks)		
		Sow to plug	Plug to quart	Total
Benary	*Achillea millifolium* 'Colorado'	5	7	12
	Achillea ptarmica 'Nobelessa'	5	5	10
	Achillea tomentosa 'Aurea'	6	8	14
	Achillea tomentosa 'Goldie'	6	8	14
	Armeria maritima 'Morning Star Deep Rose'	6	8	14
	Armeria maritima 'Morning Star White'	6	8	14
Johnny's	*Artemisia absinthium*	4	3	8
Jelitto	*Asclepias incarnata*	7	8	14
Benary	*Asclepias incarnata* 'Ice Ballet'	8	7	14
	Asclepias tuberosa	7	8	14
	Campanula carpatica 'Clips Blue'	9	7	16
	Centaurea montana	5	9	14
	Corespsis grandiflora 'Sunray'	6	8	14
	Coreopsis rosea	6	8	14
	Dianthus gratianopolitanus 'Flavora Rose Shades'	6	8	14
	Echinops ritro	direct sow	14	14
	Eryngium planum 'Blue Glitter'	5	9	14
	Eryngium planum 'Blue Hobbit'	6	8	14
	Eryngium planum 'White Glitter'	6	9	14
Jelitto	*Gaillardia aristata* 'Arizona Sun'	5	9	14
Benary	*Gaillardia pulchella* 'Sundance'	5	7	12
	Geum coccinium 'Cooky'	7	5	12
	Geum coccinium 'Koi'	6	6	12
Jelitto	*Helenium autumnale*	8	3	11
	Helenium autumnale 'Helena Gold'	8	3	11
Benary	*Helenium autumnale* 'Helena Red Shades'	7	4	11
	Hypericum polyphyllum 'Grandiflorum'	7	8	14
	Kniphofia uvaria 'Flamenco'	8	7	14
	Lavandula angustifolia 'Vicenza Blue'	8	7	14
	Lavandula angustifolia 'Hidcote Blue	6	11	17
	Lavandula angustifolia 'Munstead"	6	11	17
Jelitto	*Liatris spicata* 'Floristan Violet'	9	7	16
Benary	*Liatris spicata* 'Floristan White'	9	7	16
	Oenothera macrocarpa	5	9	14
	Penstemon barbatus 'Rhondo'	6	8	14
	Penstemon digitalis 'Mystica'	6	8	14
	Physostegia virginiana 'Crystal Peaks White'	6	8	14
	Physostegia virginiana 'Rose Queen'	7	8	14
	Prunella grandiflora 'Bella Blue'	6	8	14
	Prunella grandiflora 'Bella Deep Rose'	6	8	14
Jelitto	*Rudbeckia fulgida* 'Goldsturm'	10	5	14
Benary	*Salvia x superba* 'Adora Blue'	6	8	14
	Salvia x superba 'Dwarf Blue Queen'	6	9	14
	Salvia x superba 'Rose Queen'	5	9	14
	Scabiosa japonica var. *alpina* 'Ritz Blue'	6	8	14
	Sedum acre	6	8	14
	Sedum forsterianum 'Oracle'	6	8	14
	Sedum reflexum	6	8	14
	Sedum selskianum 'Spirit'	7	8	14
	Sedum spurium 'Voodoo'	6	8	14
	Solidago canadensis 'Golden Baby'	7	4	11

Table 2. The 2009 and 2010 landscape performance including the average of the May through October monthly appearance ratings on a 0-5 scale (0-dead; 1-poor; 2-marginal; 3-acceptable; 4-good, 5-excellent); the percent of plants surviving the winter; and the number of months in flower between May and October in 2009 and 2010.

		Landscape Performance				
		2009		Percent	2010	
Supplier	Plant Name (Genus species 'Variety')	Average Rating	Months in Flower	Winter Survival	Average Rating	Months in Flower
Benary	*Achillea millifolium* 'Colorado'	4.2	4	100	3.2	4
	Achillea ptarmica 'Nobelessa'	3.8	4	100	2.7	3
	Achillea tomentosa 'Aurea'	3.4	4	50	1.8	2
	Achillea tomentosa 'Goldie'	3.4	4	75	0.8	2
	Armeria maritima 'Morning Star Deep Rose'	4.4	4	100	2.8	4
	Armeria maritima 'Morning Star White'	4.4	4	100	3.2	4
Johnny's	*Artemisia absinthium*	4.6	0	100	4.5	2
Jelitto	*Asclepias incarnata*	3.8	1	100	2.5	1
Benary	*Asclepias incarnata* 'Ice Ballet'	3.6	1	100	1.8	1
	Asclepias tuberosa	3.6	1	50	1.5	1
	Campanula carpatica 'Clips Blue'	4.4	4	100	2.7	4
	Centaurea montana	4	3	100+	3.3	4
	Corespsis grandiflora 'Sunray'	4.2	4	75	2.7	3
	Coreopsis rosea	3.8	3	100+	3.0	3
	Dianthus gratianopolitanus 'Flavora Rose Shades'	3.8	5	100	3.3	5
	Echinops ritro	4.4	3	100	3.3	3
	Eryngium planum 'Blue Glitter'	3.6	2	75	3.0	2
	Eryngium planum 'Blue Hobbit'	3	2	30	0.8	2
	Eryngium planum 'White Glitter'	3.4	2	30	1.7	2
Jelitto	*Gaillardia aristata* 'Arizona Sun'	4.2	5	50	2.2	5
Benary	*Gaillardia pulchella* 'Sundance'	4	5	0	0	0
	Geum coccinium 'Cooky'	3.6	3	50	1.0	1
	Geum coccinium 'Koi'	3.4	4	0	0	0
Jelitto	*Helenium autumnale*	3.6	3	50	1.8	2
	Helenium autumnale 'Helena Gold'	3.6	3	10	0.7	1
Benary	*Helenium autumnale* 'Helena Red Shades'	3.4	3	10	1.0	1
	Hypericum polyphyllum 'Grandiflorum'	4	2	100	3.5	3
	Kniphofia uvaria 'Flamenco'	4.4	3	100	3.8	3
	Lavandula angustifolia 'Vicenza Blue'	4.2	5	0	2.5	5
	Lavandula angustifolia 'Hidcote Blue	4	5	50	3.7	5
	Lavandula angustifolia 'Munstead"	4.2	3	30	3.5	4
Jelitto	*Liatris spicata* 'Floristan Violet'	3.8	2	100	3.2	3
Benary	*Liatris spicata* 'Floristan White'	3.6	3	100	3.2	3
	Oenothera macrocarpa	4	2	50	3.7	3
	Penstemon barbatus 'Rhondo'	4	2	30	0.8	1
	Penstemon digitalis 'Mystica'	4	1	100	3.7	2
	Physostegia virginiana 'Crystal Peaks White'	4	3	75	2.7	3
	Physostegia virginiana 'Rose Queen'	4	1	100++	3.2	3
	Prunella grandiflora 'Bella Blue'	2.2	4	0	0	0
	Prunella grandiflora 'Bella Deep Rose'	3	3	0	0	0
Jelitto	*Rudbeckia fulgida* 'Goldsturm'	4.4	1	100	3.3	2
Benary	*Salvia x superba* 'Adora Blue'	4	5	100+	4.2	5
	Salvia x superba 'Dwarf Blue Queen'	3.6	5	100	4.0	5
	Salvia x superba 'Rose Queen'	3.8	4	100	4.0	5
	Scabiosa japonica var. *alpina* 'Ritz Blue'	3.8	5	50	2.2	5
	Sedum acre	4.2	0	100	2.2	0
	Sedum forsterianum 'Oracle'	3.4	0	100	1.3	0
	Sedum reflexum	4.2	2	100	3.7	0
	Sedum selskianum 'Spirit'	4.2	2	100	4.3	3
	Sedum spurium 'Voodoo'	3.6	0	100	1.8	1
	Solidago canadensis 'Golden Baby'	4	4	100	3.3	4

Natural Season, Container-Grown Garden Mum Production Demonstration

Steve Berberich, Department of Horticulture

Nature of the Work

On-farm commercial demonstrations for growing potted natural-season garden mums were conducted in Spencer and Anderson County in 2010. The growers marketed the majority of these plants at wholesale produce auctions and farmers markets. On-farm demonstrations are conducted to help new and existing growers understand and apply technologies of profitable production systems. The purpose of these garden mum plots is to demonstrate cultural practices necessary for successful outdoor fall flower production using drip irrigation and appropriate fertilizer injectors.

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.

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 of water from both plots was determined to be acceptable for production of container-grown plants. However, calcium and magnesium needed to be supplemented for both growers.

An outdoor irrigation pad 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 12 garden mum cultivars, *Chrysanthemum* x *morifolium* 'Alexis White,' 'Cheryl Pink,' 'Glenda Red,' 'Hanna Orange,' 'Okra Yellow,' 'Camina,' 'Cesaro,' 'Conaco,' 'Gold Finch,' 'Izola Orange,' 'Novare Yellow,' and 'Padre Lemon' were received in 50-cell trays. The first week of June 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 June 15, the plants were drenched with Banrot fungicide (Scotts Company LLC, Marysville, Ohio 43041) at label rate as a preventive 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 200 ppm N for Week 1 and 2, 400 ppm N for Week 3 through 6, and 300 ppm N for Week 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 lb per 100 gallons water and biweekly applications of magnesium sulfate at 1 lb 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 appropriate concentration of fertilizer salts. Media samples were sent to the laboratory for analysis the second week of each month.

Results and Discussion

The weather conditions during the latter part of the 2010 growing season were unusually warm and dry. Higher insect pressure was observed particularly for plots near fields. High temperatures caused heat-delayed flowering in many cultivars. Additionally, many plants were larger than normal because of longer vegetative period. However, this crop was still successful for the growers/cooperators, and both of them intend to continue production next year.

Table 1. Production budget from on-farm demonstrations of natural-season, container grown garden mums in 2010.

	Spencer Co. (500 plants)	Anderson Co. (300 plants)
Sales		
12-inch	3,779.00	3,376.50
Total Sales	$3,779.00	$3,376.50
Expenses—Variable		
Liners	244.71	146.82
12-inch container (Nursery Supplies C1200S)	275.00	165.00
Media (2.8 cu. ft. Metro Mix 540 Coir)	660.00	396.00
Fertilizer	74.24	44.54
Total Variable Expenses	$1,253.95	$752.36
Expenses—Fixed (amortized over 5 years)		
Woven ground cover	37.50	22.50
Fertilizer injector (Chemilizer 11 GPM)	41.00	41.00
Misc. PVC fitting, filter, regulator, etc.	30.00	30.00
Irrigation supplies (lines, emitters, spray stakes, etc.)	50.00	30.00
Backpack sprayer	19.00	19.00
pH/EC meter	28.00	28.00
Total Fixed Expenses	$205.50	$170.50
Total Expenses	$1,459.45	$922.86
Profit (total sales – total expenses)	$2,319.55	$2,453.64
Profit per plant (profit ÷ total plants)	$4.64	$8.18
Labor (hours)		
Preparation of irrigation pad (amortized over 5 years)	5.80	3.48
Production	112.00	67.20
Total labor	117.80	70.68
Return per hour (profit ÷ total labor)	$19.70	$34.71

The average price for the Spencer County plot was $7.56; for the Anderson County plot, it was $11.25. Price differences were due primarily to different marketing channels. 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 costs typically associated with garden mum production (Table 1).

Product Trial: RootTrapper®-in-Pot Insert

Carey Grable, Virginia Travis, June Johnston, and Winston Dunwell, Department of Horticulture

Nature of the Work

Container production represents a large section of the nursery stock grown in western Kentucky, with Pot-in-Pot (PnP) representing a large portion of those containers. Two of the major issues facing growers using PnP production are root circling and root escape, both of which can prove costly for growers. Circling roots produce lower quality plants and have the potential to produce girdling roots in tree production. Root escape can prove even more costly when escaped roots become large and prevent the removal of the liner pot from the socket pot. When this occurs, growers are often left with little choice but to remove the socket pot and replace it with a new one. Traditionally, root circling and root escape are controlled by the use of copper-treated containers. The roots are pruned by the copper when they reach the sidewall and are forced to branch laterally.

The RootTrapper®-in-Pot insert made by the RootMaker Company was designed to address both root circling and root escape. In the PnP facilities at the UK Research and Education Center in Princeton, 76 Shummard oak (*Quercus shumardii*) liners were containerized, half in standard #15 plastic liner pots and half in the RootTrapper®-in-Pot insert. The liners were grown from seed by a local propagator using RootTrapper 5-gallon bags. The liners were potted in a pure pine bark mix and were topdressed with a 15-9-12 slow-release fertilizer.

Results and Discussion

The liners started at an average caliper of 0.8 inch caliper and will be grown to an approximate caliper of 2 inches. The trees will then be evaluated on increase in caliper, level of root escape, and root circling. After the first season of growth, there was no significant difference in the caliper of the standard containers and the bag inserts. During the next season, when the average caliper approaches 2 inches, the containers will be evaluated on the level of root circling and root escape. Roots that have escaped their containers will be counted and evaluated on size.

Table 1. Beginning calipers and growth by October 25.

Average Starting Caliper*	0.781
Average Caliper 10-25-10	1.351
Average Bag Caliper 10-25-10	1.382
Average Standard Cont. Caliper 10-25-10	1.321
Average Bag Caliper Increase	0.600
Average Standard Cont. Caliper Increase	0.539

* Caliper was measured as the diameter of the trunk in inches at 6 inches above ground level.

Significance to the Industry

these liners have the potential to produce a higher quality plant and prevent loss of time and money caused by root escape. This product may aid growers with pre-established pot-in-pot setups that have annual problems with both root escape and circling.

A Preliminary Comparison in Landscape Establishment of Three Pin Oak Production Methods

Carey Grable and Winston Dunwell, Department of Horticulture

Nature of the Work

There are several tree production methods in use in the western Kentucky area, and each of these methods provides its growers and consumers with distinct benefits. Field production, container production, and root-pruning fabric container production provide slightly different products, and there is much debate on which produces the best tree. This project was designed as a preamble to a planned project to show the comparative root morphology and establishment rates of trees grown in these three production systems.

In this experiment, finished pin oaks (*Quercus palustris*) were purchased from three different growers. Each grower used a different production method to grow these trees to a caliper of approximately 2 inches (Table 2). The production methods used were field-grown balled and burlapped (BnB), #15 smooth-walled plastic container, and in-ground knit fabric bag. These three production methods represent the majority of trees grown in western Kentucky. To compare how well trees established with these methods, they were planted in a plot that emulated the average home landscape soil. The trees were

measured for caliper at planting and again six months later. The need for staking was evaluated as well by comparing how well unstaked trees remained upright. The trees were planted in holes dug by a 24-inch auger and widened as needed. The walls of the holes were scored to allow root penetration (Watson & Himelick, 1997). After planting, the trees were watered with approximately 10 gallons twice a week.

Results and Discussion

After planting, the trees were left unstaked. Two weeks after planting, an intense rain hit the plot. After this rain, 90% of the BnB trees were still upright. The standard container and bag- grown trees both showed 80% of the trees moved (Table 1). These results show the advantage of the weight of a field-grown tree. The soil in the root ball acts as an anchor to hold the tree in place. In terms of caliper increase, For containers, the average calipher increase was 3.6%; for bags, it was 10.4%; and for BnB, it was 14.7% (Table 2).

As these trees were grown by three different growers, we cannot hold this experiment as a true morphology experiment. It does, however, show potential differences between the trees that are available for purchase in the western Kentucky area. The poor performance of the plastic container trees can be partially attributed to the trees being very root-bound and therefore of lesser quality than those from the other production systems. As these trees were at or slightly above a 2-inch caliper, there was a large amount of root circling. While it does affect the results of this comparison, these were the only pin oaks of this size available in the area. As a counterpoint, the container trees were the cheapest of the trees purchased for this experiment, at $45 per tree. The bag tree prices roughly in the middle at $75 per tree, and the BnB trees were the most expensive, at $95 per tree. These trees will continue to be evaluated next year to see how they compare the second year after planting. This experiment provides a starting point for the planned experiment referred to earlier that will compare the effects of these production systems on trees from the same genetic source.

Significance to the Industry

Studies on comparative establishment between different production methods help ensure satisfaction of the end consumer with trees' performance after planting.

Literature Cited

1. Watson, Gary W., and E. B. Himelick. 1997. Planting Trees and Shrubs. International Society of Arboriculture, Savoy, IL.

Table 1. Tree movement after a heavy rain.

	Container	Bag	BnB
Leaning	7	4	1
Near Ground	1	4	0
No Change	2	2	9

Table 2. Initial calipers and growth by October 25, 2010.

	Avg. Initial Caliper (in)	Avg. Oct 25 Caliper (in)	Avg. Increase (in)	Avg. Gain (%)
Container	2.3192	2.402	0.084	3.569
Bag	1.9988	2.2055	0.207	10.366
BnB	2.2478	2.5737	0.326	14.664

Differences in Pour-through Results from Two Plant Species and a No-plant Control

Winston Dunwell, Carey Grable, Dwight Wolfe, and Dewayne Ingram, Department of Horticulture

Nature of the Work

In western Kentucky, regardless of the longevity stated for a slow-release fertilizer, we find that there are few or no soluble salt readings from PT taken in midsummer following spring application. Dan Struve (5) stated that the plant root system would be filling the pot by that time and would be more efficient at removing fertilizer from the soil solution. Previous attempts to retrieve all fertilizer prills to test for fertilizer remaining in midsummer when the PT results with low soluble salts occurred have not been successful. Including a container with no plant might give us an indication of whether there was still fertilizer being released to the soil solution.

On April 23, 2010, 15 plants each of *Pterostyrax hispida* and *Indigofera heterantha* were transplanted from 3-gallon containers (Nursery Supplies, C300) to 7-gallon containers (WhiteRidge, LLC, 2358 l). The media was aged pine bark with no amendments. Fifteen 7-gallon containers filled with media without a plant were used as the no-plant control. Containers were set in TopHat™ Container Stabilizers to avoid blow- over and fertilizer loss. Irrigation was provided via a single Agridor 4463 sprayer per container. Water was applied at 0900 and 1400 for 20 minutes each time. Osmocote Plus 15-9-12 5-6 month was applied at 3.5 ounces per pot on June 9, 2010. The three treatments were allocated to the 45 containers in a generalized randomized block design with three treatments per row and three rows (blocks).

PT soluble salt reading and pH were recorded every two weeks from June 14, 2010 to October 4, 2010 by the Pour-Through-Extraction method (3). An additional irrigation emitter was added to the *Indigofera heterantha*, July 2, 2010 to ensure the amount of water leaching from a 500 ml application 30 minutes following an irrigation event was the equivalent to that of the no-plant and *Pterostyrax hispida* (1).

Results and Discussion

Leachate salts averaged 441 µS/m for the no-plant control, 294 µS/m for the *Pterostyrax hispida,* and 202 µS/m for *Indigofera heterantha* over duration of experiment and were significantly different from each other (Table 1). The peak level of soluble salts in the leachate for all treatments was one month after application, July 12, 2010. At that time the salt levels averaged 1099 µS/m for the no-plant control, 610 µS/m for the *Pterostyrax hispida,* and 204 µS/m for the *Indigofera heterantha*. At the September 21, 2010 extraction the readings indicated that the fertilizer was less than the range 200 to 500 µS/m (7), which is considered adequate for growth.

Over the course of the study the pH of the leachate initially declined before leveling out in the range of 6.5- 6.9 (Figure 2). The pH levels inversely reflected the level of soluble salts in the leachate. The no-plant treatment pH was significantly lower that the *Pterostyrax hispida* and *Indigofera heterantha* for the duration. Measuring leachate pH was discontinued following the September 3 readings.

Significance to the Industry

This research was performed to determine if midseason low pour-through (PT) soluble salt readings are an indication that plant growth is a factor or that all the fertilizer has been released. The plant root system may expand to fill the pot and lead to higher fertilizer utilization efficiency. The data show that the soluble salt level of the leachate from the no-plant container followed the same pattern as the leachate from containers with plants. The five-to-six-month controlled release fertilizer (CRT) no longer provided adequate levels of fertilizer after 13 weeks in western Kentucky. If additional growth is desirable, additional fertilizer would need to be applied.

Indigofera heterantha is in a genus recognized for drought tolerance (2,4), but observations indicate that in a container production system, it is a heavy water user.

Figure 1. Soluble salts in PT leachate from *Pterostyrax hispida, Indigofera heterantha,* and no-plant containers for two-week sampling dates. Mean intervals are + or – ½ of the least significant difference at the 0.05 probability level.

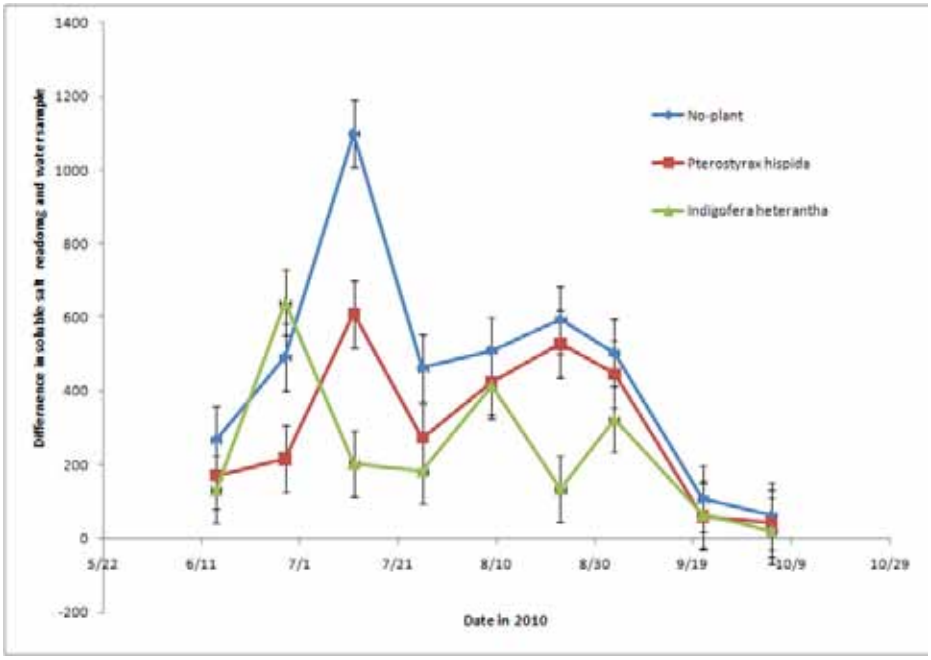

Figure 2. pH of the PT leachate from *Pterostyrax hispida, Indigofera heterantha,* and no-plant containers for two-week sampling dates. Mean intervals are + or – ½ of the least significant difference at the 0.05 probability level.

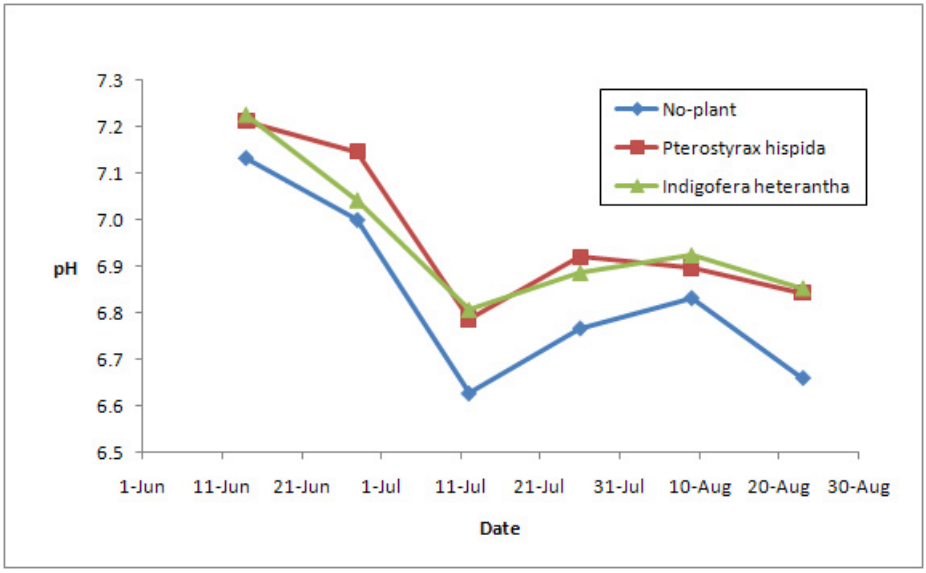

Table 1. Average soluble salt reading over the experiment.

Treatment	Soluble Salt	Number of Readings
No-plant	441 a[1]	135
Pterostyrax hispida	294 b	134
Indigofera heterantha	202 c	133
LSD (0.05)	51	na

[1] Means with the same letter are not significantly different.

Literature Cited

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Characteristics of Kentucky's Nursery and Greenhouse Industries

Dewayne L. Ingram, Winston Dunwell, Department of Horticulture, University of Kentucky;
Alan Hodges, Department of Food and Resource Economics, University of Florida[2]

Nature of the Work

The purpose of this research was to characterize the Kentucky's nursery and greenhouse industry in relation to the national and regional industry by gleaning information from the Green Industry Research Consortium's 2008 and 2003 national survey data. The Green Industry Research Consortium, Multi-state Regional Project S-1021 of the Southern Region's agricultural experiment stations, conducts a survey of the U.S. nursery and greenhouse industries every five years. The University of Kentucky's Agricultural Experiment Station is a member institution in the consortium, represented by Dewayne Ingram.

The most recent survey was conducted in 2009 in all 50 states, reflecting 2008 data. Alan Hodges, Charles Hall, and Marco Palma took the lead on this survey and published the results in the Southern Cooperative Series Bulletin #411, *Trade Flows and Marketing Practices within the U.S. Nursery Industry, 2008* (available at http://www.greenindustryresearch.org) (2). The Kentucky data have been compiled from SCS Bulletin #411, and additional computations have been made from the original data for this report. Kentucky's nursery and greenhouse industry firms were identified through the state's licensing and certification program. Questionnaires were mailed to 165 of the 352 commercial firms on that list. Later, through telephone calls and other avenues, it was determined that the validated business population was 238. The 2008 data were compared to the 2003 data (1) for selected characteristics.

Survey data were augmented by information obtained from the experiences of the authors and from conversations with nursery owners. Information is presented relative to employment, plant types sold, production types, markets and marketing channels, sales methods and marketing practices, purchases of propagation materials, advertising expenditures, integrated pest management practices, water sources and irrigation methods, as well as the economic impact of the Kentucky nursery and greenhouse industries.

Results and Discussion

Kentucky's nursery and greenhouse industry has grown at a rate of 8 to 10% per year for most years between 2000 and 2008, with the most significant U.S. industry growth in the 1980s and 1990s and the most rapid growth of Kentucky's industry since 2000. U.S. sales of nursery and greenhouse crops were more than $27 billion in 2008, and Kentucky's sales were more than $147 million. These sales data do not include firms engaged strictly in providing landscape installation and maintenance services.

The majority of Kentucky firms responding to the survey had both wholesale and retail sales, with 35% of total sales being wholesale. Seventy percent of the firms responding sold in wholesale markets, and 70% had retail sales. The ratio of wholesale to retail sales in Kentucky was lower than in states in the region with a larger nursery and greenhouse industry. For example, 88% of Tennessee and 87% of North Carolina total annual sales were to the wholesale market.

The average annual sales reported by Kentucky respondents was $617,000 per firm and the national average was $1.7 million. Sixty-three percent of firms had annual sales of less than $250,000, 10% had sales of $1-2 million, and 7% had sales of $2-10 million. These numbers are similar to national data, in which over 50% of respondents had less than $250,000 in annual sales and 17% had sales of $1 million or greater.

One-half of Kentucky respondents have established their firms since the year 2000. Thirteen percent were established in the 1990s, and 23% in the 1980s or 1970s. In contrast, only 10% of Tennessee respondents' firms have been started since 2000. Nationally, the highest growth rate in terms of number of firms was in the 1980s and 1990s. Generally, Kentucky has experienced the greatest entry into the industry since the turn of the century, lagging somewhat the timing of the U.S. growth trajectory. The timing of the growth trajectory of the Kentucky nursery and greenhouse industry coincides with state investments (Kentucky Agricultural Development Fund) in research, extension, marketing assistance, and advertising cost-share programs through the Kentucky Horticulture Council.

The projected total employment (permanent and temporary) for Kentucky was 2,095 in 2008. Approximately one-third of the Kentucky nursery and greenhouse industry's employees were permanent employees. As with sales data, these employment data do not include firms engaged strictly in providing landscape installation and maintenance services.

The average number of employees of responding Kentucky firms was 3.8 permanent employees and 5.0 temporary employees. On the average, respondents reported reducing their permanent employees by 9% and decreased temporary employees by 17% over the five years 2004-2008. On the average, respondents had increased their permanent employees by 11% and had increased temporary employees by 14% over the previous five-year period, 1999-2003. Nationally, there was no change in number of employees per firm between 2003 and 2008 surveys.

Approximately 12% of total sales by Kentucky survey respondents were deciduous shade or flowering trees in 2008. The percent of total sales accounted for by deciduous shrubs, evergreen trees, and broadleaf evergreens were also down slightly in this five-year period. Plant types showing an increase in percentage of total sales included roses, herbaceous perennials, bedding plants, and vines/ground covers. Bedding plants, both flowering annuals and vegetable, fruit, and herb transplants, represented 8.6% of sales in 2003 and 17.5% in 2008. Given that overall sales increased dramatically in that five-year period, a doubling of the percent of sales from bedding plants is even more impressive. This growth is likely from the expansion of larger greenhouse operations as well as an increased number of smaller growers adding "color" to their product mix. Likewise, roses were 1.2% of sales in 2003 but 12.7% in 2008. New continuous bloom, low-maintenance landscape roses such as the Knock Out® rose surely contributed to that increase. Herbaceous perennials increased from 6.6% of sales in 2003 to 12.2% in 2008.

Containerized plants comprised 57% of total sales in 2008, compared to 39% in 2003. This increase is consistent with the reported increases in that five-year period for bedding plants, roses, herbaceous perennials, and other plants that are primarily grown in containers. Balled and burlapped plants averaged 12.8% of survey respondents' sales in 2008, down from 49% in 2003. The percent of total plant sales as bare-root plants increased to 24.7% in 2008 from less than 1% in 2003. These findings regarding plants sold and production methods are consistent from our observations in terms of the range of individual producers; however, they differ somewhat from our assessment of a relatively small number of large nursery operations that account for a significant portion of the production and may not have responded to the survey. For these nurseries, a significant portion of their sales come from field-produced trees.

Seventy-seven percent of respondents' total annual sales were to landscape firms in 2008, up slightly from 2003. The percentage of total sales to mass merchandisers doubled from 4% in 2003 to 8.2% in 2008. The percentage of total sales to home centers (0.4%) in 2008 was similar to those in 2003. The percentage of total sales to single-location garden centers (2.2%), multiple-location garden centers (0.4%), and re-wholesalers (10.9%) were down slightly from 2003. More than 80% of plants grown in Kentucky were sold in the Appalachian region, and 19% were sold in the Midwest region in 2008, percentages similar to those of 2003. The percentage of plants grown in Kentucky by survey respondents that were sold in Kentucky increased from 74% in 2003 to 79% in 2008. These data are consistent with a survey of intentions of landscape plant buyers in Kentucky, Ohio, Tennessee, and Indiana in 2004, in which it was noted that buyers in the other states expected to purchase less than 10% of their plants from Kentucky (3).

More than 80% of total sales of Kentucky respondents in 2008 were through in-person orders. That is almost double the national and Appalachian region averages. Less than 10% of total sales were from trade show orders, telephone orders, or mail orders, and Internet sales accounted for less than 1% of total sales in 2008. A similar trend was noted in 2003, except that a smaller percentage of sales (9.7%) was from telephone orders in 2008. Firms in the Appalachian region (39.7%) and nationally (43.3%) averaged at least four times the percentage of sales made by telephone compared to Kentucky. Almost two-thirds of 2008 sales for Kentucky respondents were to repeat customers, compared to 79.8% and 80.55% for the Appalachian region and national averages, respectively. Twenty-three percent of sales were through negotiated sales, i.e. sales in which price or terms were discussed and/or adjusted upon negotiation between buyer and seller. About six percent of Kentucky growers reported forward contracted sales, i.e., sales in which price and quantity were agreed upon in advance. Those with whom growers engaged in forward contracts were other producers and cooperatives. Also, about seven percent of total sales were for brokerage of finished plants purchased from other growers and immediately resold.

Kentucky survey respondents averaged spending 6.2% of their total annual sales in advertising, compared to 7.8% in the Appalachian region and 4.6% nationally. This represented a significant increase in advertising spending by Kentucky respondents since the 2003 survey, at which time they spent an average of 2.5% of total annual sales on advertising. In 2008, respondents reported that almost 50% of their advertising expenditures were for catalogs (print and CDs). Twenty-three percent of advertising expenditures were in radio/television, up from 6% in 2003. Trade show expenses constituted almost 12% of advertising expenditures in 2008. In both 2003 and 2008, trade show participation with an exhibit or without an exhibit was 1.4 per year. Nationally, growers attended an average of 2.3 trade shows annually with an exhibit and 1.8 shows without an exhibit. Yellow Pages advertising accounted for 36% of expenditures in 2003 but only 9% in 2008. The decreased use of Yellow Pages advertising in Kentucky follows the national trend and may relate to wholesale nurseries utilizing Internet sites such as the plant availability guide on the Kentucky Department of Agriculture web site. Many nurseries have developed their own web pages, which include up-to-date inventory information.

The increased expenditures for advertising from 2003 to 2008 could be due to the use of advertising cost-share funds available through a Kentucky Horticulture Council grant from the Kentucky Agricultural Development Fund. Participation greatly increased from 2002 through 2007, when over $514,000

was invested into grass-roots projects in all segments of horticulture across the Commonwealth. In 2005 alone, over $165,000 was invested and matched with $174,817 producer dollars. The advertising cost-share program helped fund such advertising strategies as market signage, advertising (print and radio), brochures, web sites, and point-of-purchase, and it helped producers learn how to plan their own marketing campaigns as well as feature the Kentucky Proud logo in all of the advertising. Participation in the Kentucky Proud Program increased from 200 businesses in 2004 to nearly 1,100 in early 2008. These data were provided by the Kentucky Department of Agriculture's Marketing and Value-added Division, which administered the advertising cost-share program for the Kentucky Horticulture Council.

More than 60% of Kentucky respondents in 2008 used water from municipal sources, and 60% of growers applied irrigation water via overhead sprinklers. A third of the growers used water from natural surface water, and 16.6% used water from wells. In contrast, wells (46%) and natural surface waters (43%) were the dominant sources of water for nursery irrigation in the Appalachian region. A third of the Kentucky respondents used drip irrigation.

Several integrated pest management strategies were widely practiced by survey respondents. The majority used removal of infested plants, cultivation and hand weeding, and spot treatment with pesticides. Other practices important to respondents included alternating pesticides to avoid chemical resistance, elevating or spacing plants for air circulation, adjusting pesticide application to protect beneficial insects, identifying beneficial insects, inspecting incoming stock, mulching, managing irrigation to reduce pests, ventilating greenhouses, adjusting fertilization rates, and use of pest-resistant varieties. Educational workshops offered in 2008 and 2009 introduced a pest control strategy for reducing by one-half the pesticides applied. Growers who attended these workshops reported in a follow-up questionnaire that they already had reduced their pesticide use by half due in 2010 or planned to do so due to this program.

Significance to the Industry

The nursery and greenhouse industry is a significant portion of Kentucky's horticulture industry and important to the state's agricultural economy. Industry leaders can utilize this information when working with other agricultural leaders and state government. The characteristics of the industry can be used not only by those looking at the larger scale of the agricultural economy, but tjeu can help individual nursery and greenhouse owners compare their activities to state and national averages.

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National Elm Trial: Kentucky Data, 2010

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Nature of the Work

The National Elm Trial was established to evaluate landscape-suitable elm cultivars for disease and insect tolerance and for horticultural characteristics at 15 locations nationwide 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 in April 2007. Plots were located south and east of the UK sports complex across from the The Arboretum entrance 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 (Figure 1), 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 and watered during dry periods during the first three years. 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*

Table 1. Size of elms, 2010.

Cultivar number and name from list above	Increase from 2009		
	Avg. trunk diameter (in), dbh*	Avg. height (ft)	Avg. crown width (ft)
1. JFS Bieberich	2.23 (0.48)	15.9 (2.3)	6.8 (1.4)
2. Emer II Allee	1.23 (0.87)	14.5 (3.2)	11.7 (2.3)
3. Frontier	1.84 (0.50)	14.3 (2.0)	7.7 (1.4)
4. Homestead	2.54 (0.52)	16.2 (2.6)	8.7 (0.9)
5. Morton Glossy	2.60 (0.73)	15.3 (2.8)	8.4 (2.5)
6. Morton Plainsman	2.40 (0.48)	14.0 (1.8)	10.3 (2.9)
7. Morton Red Tip	3.78 (1.28)	15.0 (2.0)	9.5 (1.2)
8. Morton Stalwart	3.10 (0.83)	16.2 (2.5)	8.6 (1.8)
9. Morton Accolade	2.56 (0.68)	14.6 (2.0)	8.2 (1.3)
10. New Horizon	3.52 (1.40)	16.9 (3.1)	8.7 (1.6)
11. Patriot	2.83 (0.78)	19.3 (3.8)	9.3 (1.8)
12. Pioneer	2.15 (0.45)	13.0 (1.0)	7.5 (0.9)
13. Prospector	2.50 (0.58)	12.8 (1.6)	7.6 (1.0)
14. Valley Forge	2.90 (0.92)	17.0 (3.3)	12.2 (4.2)
15. Princeton	3.08 (1.04)	20.0 (3.3)	6.8 (2.0)
16. Jefferson	1.50 (0.53)	13.5 (3.1)	5.4 (1.6)
17. New Harmony	2.20 (0.86)	17.7 (4.0)	5.1 (0.7)
18. Athena	1.43 (0.38)	10.0 (2.5)	4.9 (0.8)
19. Everclear	1.20 (0.43)	12.4 (3.6)	3.4 (0.8)
20. Prairie Expedition	1.55 (0.60)	10.6 (2.3)	5.9 (1.9)

*Indicating that trunk diameter taken at 4.5 ft.

Figure 1. View of part of the National Elm Trial plots in Kentucky showing the double row of different elm cultivars in front of the UK sports complex. Due to summer drought and lateness of the season when this picture was taken (November 9), most of the trees had lost their leaves.

Figure 2. This elm cultivar, 'New Horizon', had retained its leaves and was developing a slightly yellow fall color as of November 9. This tree, in its sixth year after transplanting, is over 15 feet tall and has about a 3.5 inch trunk diameter.

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 2010 the plots were provided with adequate rainfall through July but then suffered through a very hot and dry period from August through October. On July 29, 2010 tree trunk diameters were measured with a caliper, and tree height and width were determined (Figure 2). 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 2010 there have been no incidences of bacterial leaf scorch, elm yellows, or Dutch elm disease. The elms did not produce much fall color this year with the exception of one cultivar (Figure 3).

Significance to the 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 insects such as Japanese beetles, elm leaf miners, and other pests will benefit arborists and the landscape maintenance and nursery industries.

Figure 3. Leaves of the cultivar 'Emer II' Allee elm have developed a red-bronze fall color.

Update of Industry Support for the UK Nursery and Landscape Program

The UK Nursery/Landscape Fund provides an avenue for companies and individuals to invest financial resources to support research and educational activities of the University of Kentucky to benefit the industry. The majority of UK Nursery/Landscape Fund contributions are used for student labor and specialized materials and equipment. These investments have allowed us to initiate new research and to collect more in-depth data than possible before.

Fifteen individuals and companies have contributed or pledged at least $10,000 each 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 the 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, (270) 365-7541, ext. 209; or the UK College of Agriculture Development Office at (859) 257-7200.

UK Nursery and Landscape Fund and Endowment Fellows

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Wallitsch Nursery

Richard and Shirley Ammon
Ammon Landscape Inc.

**deceased*

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100 Club ($100 or more)
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Kentucky Nursery & Landscape Association

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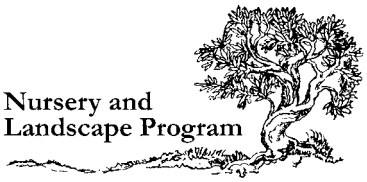

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