AGRICULTURAL EXPERIMENT STATION
UNIVERSITY OF KENTUCKY COLLEGE OF AGRICULTURE, FOOD AND ENVIRONMENT, LEXINGTON, KY, 40546

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UK UNIVERSITY OF KENTUCKY College of Agriculture, Food and Environment

Nursery and Landscape Program 2011 Research Report

UKAg RESEARCH University of Kentucky • Lexington, Kentucky 40546

About the Cover

Feather reed grass, *Calamagrostis* × *acutiflora* 'Karl Foerster' is an ornamental grass that won the 2001 Perennial Plant of the Year and Kentucky's Theodore Klein Plant Award for 2012. It is highly regarded in the United States and worldwide. It has become common in our landscapes because it has a tidy appearance, stands upright, blooms reasonably early for the species, and holds its blooms through to winter. When the blooms turn their tan color against the green foliage, it creates a beautiful effect. It prefers sun or part-shade exposure in a moist soil, but it has been seen growing well in a variety of soils. In shade it can be thin and slow to create an ornamental clump. 'Karl Foerster' is a hybrid cross between *C. arundinacea* and *C. epigejos*. It looks good in the pot in the nursery or retail yard where it will bloom and can be planted as a slowly spreading clump specimen, in a container or a mass planting. Allan Armitage says "Plants grow tightly together and should be grouped for best effect." To see mass plantings of the feather reed grass, *Calamagrostis* × *acutiflora* 'Karl Foerster,' visit Ball Seed Company's Plant Evaluation Gardens in Chicago or at www.ballhort.com/GardensAtBall/Map. The image was taken at Ball Seed Company.

In late winter or early spring at the University of Kentucky Research and Education Center at Princeton, the 4-6 foot stems are cut down to 6-8 inches. They have been cut as early as Thanksgiving so the stems could be used for arrangements or decorations. If not cut down in winter, new growth in the spring may be damaged.

A sharp heavy spade can be used to divide the clumps that in older plants are quite woody. A small amount of slow-release fertilizer is recommended.

The seeds of 'Karl Foerster' are sterile—good news when considering grasses.

Grasses tend to be especially well-adapted to rain-garden environments and 'Karl Foerster' is no exception. The Missouri Botanical Garden Plant Finder specifically says of the grass: "Suggested Use: Rain Garden."

Hoffman Nursery, a grass specialty nursery, says the grass was named in honor of the late great nurseryman Karl Foerster (1874-1970). Mr. Foerster was responsible for introducing this grass as well as many other acclaimed plants during his distinguished career in horticulture.

UK Nursery and Landscape Program

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Contents

National Elm Trial-Kentucky Data, 2010

Nicole Ward and Ed Dixon, Plant Pathology Department; Dan Potter, Department of Entomology; Jerry Hart, Plant Pathology Department-Grounds; and William Fountain, Department of Horticulture

Nature of 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 sports complex across from the UK Arboretum entrance along Alumni Drive (North 38°, 1 min.; West 84°, 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. Cultivars listed below were replicated five times and arranged in a randomized complete block design. Trees were staked, mulched, and watered during dry periods through the first three years of the study, only. Minimal pruning continues in established plantings.

The seventeen 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*

Individual trees were evaluated for Dutch elm disease symptoms during July and October. Trunk diameters were measured and tree height and width were determined in July 2011. Japanese beetle damage and scale insect infestations were assessed by entomologist collaborators and these results are reported elsewhere.

Table 1. Elm size and change in growth.

Cultivar number and name	Average height (increase from 2010)	Average crown width (increase from 2010)	Average trunk diameter (increase from 2010)
	feet		*inches at dbh**
1. 'JFS Bieberich'	18.0 (2.1)	7.5 (0.8)	2.70 (0.48)
2. 'Emer II' Allee	16.3 (1.8)	14.3 (2.7)	3.20 (1.00)
3. 'Frontier'	16.4 (2.1)	9.0 (1.3)	2.20 (0.36)
4. 'Homestead'	19.6 (3.4)	10.5 (1.8)	3.38 (0.84)
5. 'Morton Glossy'	16.7 (1.5)	9.8 (1.4)	3.15 (0.55)
6. 'Morton Plainsman'	15.5 (1.5)	11.8 (1.5)	2.85 (0.45)
7. 'Morton Red Tip'	17.8 (2.8)	11.3 (1.8)	4.26 (0.48)
8. 'Morton Stalwart'	17.3 (1.0)	10.5 (2.3)	3.30 (0.26)
9. 'Morton' Accolade	15.8 (1.2)	10.6 (2.4)	3.10 (0.54)
10. 'New Horizon'	18.2 (1.3)	10.4 (1.7)	4.30 (0.78)
13. 'Prospector'	14.5 (1.8)	9.8 (2.7)	3.00 (0.50)
14. 'Valley Forge'	20.4 (3.4)	14.9 (2.7)	3.50 (0.60)
15. 'Princeton'	23.0 (3.0)	7.8 (1.0)	3.64 (0.56)
16. 'Jefferson'	17.3 (2.8)	7.0 (1.3)	2.10 (0.47)
17. 'New Harmony'	19.5 (1.7)	6.4 (1.3)	2.94 (0.54)
18. 'Athena Classic'	10.3 (0.7)	6.2 (1.5)	1.73 (0.30)
20. 'Prarie Expedition'	12.5 (1.9)	7.9 (2.0)	1.90 (0.35)

*Trunk diameter taken at 4.5 ft, on July 22, 2011.

Table 2. Fall color and growth habit.

Cultivar number and name	Fall color[1]	Shape
1. 'JFS Bieberich' Emerald Sunshine'	Green-yellow	Upright oval
2. 'Emer II' Allee	Yellow to red	Round
3. 'Frontier'	Burgundy	Oval
4. 'Homestead'	Green-yellow	Oval-round
5. 'Morton Glossy' Triumph	Yellow to brown	Upright oval
6. 'Morton Plainsman' Vanguard	Yellow gold	Vase
7. 'Morton Red Tip' Danada Charm	Yellow to brown	Vase
8. 'Morton Stalwart' Commendation	Yellow	Round
9. 'Morton' Accolade	Yellow-brown	Round
10. 'New Horizon'	Green-yellow	Upright oval
13. 'Prospector'	Green-yellow	Vase-oval
14. 'Valley Forge'	Yellow-gold	Round-oval
15. 'Princeton'	Yellow	Oval
16. 'Jefferson'	Yellow	Upright vase
17. 'New Harmony'	Yellow	Upright oval
18. 'Athena Classic'	Yellow	Oval
20. 'Prarie Expedition'	Yellow	Vase

[1] Fall color evaluated October 12, 2011.

Results and Discussion

Dutch elm disease was not detected in 2011. No disease resistance ratings were documented. Growth habits and landscape qualities are presented in Table 1. All elm cultivars increased in height and/or trunk diameter. Table 2 includes descriptions of fall color and tree shape.

In 2011, a total of 12 trees were lost to environmental stresses, decline, and secondary disease. Cultivars 'Everclear,' 'Patriot,' and 'Pioneer' were reduced by two or three trees each. There are insufficient numbers of these cultivars to conduct proper evaluations, so they were eliminated from reports.

Significance to Industry

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

2011 Landscape Plant Disease Observations from the University of Kentucky Plant Disease Diagnostic Laboratory

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

Nature of Work

Plant disease diagnosis is an ongoing educational and research activity of the UK Department of Plant Pathology. The department maintains two branches of the Plant Disease Diagnostic Laboratory (PDDL), one on the Lexington campus and one at the Research and Education Center in Princeton. Two full-time diagnosticians and a full-time diagnostic assistant are employed in the PDDL. In June, Dr. John Hartman retired from the UK Department of Plant Pathology after 40 years of service, during which his expertise in diseases of ornamentals benefited commercial producers, landscape professionals and homeowners throughout the Commonwealth. Dr. Nicole Ward joined the department in August as Extension Plant Pathologist focusing on diseases of ornamental and fruit crops.

More than 3,300 plant specimens were examined between January 1 and November 1 in 2011. Of those samples, 44% were landscape ornamental plants (1), with 28% submitted from commercial nursery or greenhouse production systems, or from professional landscape companies.

Plant disease diagnosis involves a great deal of research into the possible causes of plant problems and utilizes various techniques to identify pathogens. Most visual diagnoses require microscopy. Occasionally, specimens may require special tests such as moist chamber incubation, isolation on culture media, enzyme-linked immunosorbent assay (ELISA), nematode extraction, or soil pH and soluble salts tests. The laboratory also uses polymerase-chain-reaction (PCR) testing which, although more expensive than methods mentioned above, allows more precise and accurate diagnoses.

Computer-based laboratory records are maintained for use in plant disease surveys, identification of new disease outbreaks, and formulation of educational programs. Information from the laboratory also forms the basis for timely alerts of landscape disease problems through the *Kentucky Pest News* newsletter, radio and television programs, and plant health care workshops.

In order to assist County Extension Agents with plant disease diagnosis and management, the PDDL operates a web-based digital consulting system. Submitted digital images allow more open communication between agents and diagnosticians in the determination of more sufficient/ appropriate physical samples. The digital consulting system is especially useful in providing assistance with landscape tree and shrub diseases and disorders as whole plants are often difficult to submit to the laboratory. In 2011, 54% of digital consulting requests involved landscape and nursery plants.

Weather during the 2011 growing season in Kentucky was variable. February 2011 was the first month to have above normal precipitation since November 2010, and by the first half of March, abundant rainfall effectively ended all drought conditions across the Commonwealth. April 2011 was the wettest April recorded; above average precipitation was recorded in May and June as well. Temperatures were above average between July and early September, with July 2011 being tied for the fifth warmest July on record. During this period, soils became dry in much of the state, but pockets of abundant rainfall occurred through the summer. Fall months were generally rainy.

Early season rains and cool temperatures were favorable for the development of a number of foliar diseases such as anthracnose on various shade trees. High humidity throughout the summer promoted fungal leaf spots caused by species of *Cercospora* and related fungi on a number of landscape hosts. Needle cast/blights on spruce were extremely common. These needle disease occurrences may be traced to favorable conditions for infections in early 2010, as the two most common needle disease pathogens in Kentucky have life cycles that may be greater than 12 months. In general, diagnoses of root rots—particularly those caused by oomycete pathogens--were slightly fewer than in the previous two years.

The following important or unusual diseases were observed:

Deciduous trees

Beech, blackgum and redbud canker (*Botryosphaeria*)
Flowering cherry fungal leaf spot (*Coccomyces*) and bacterial leaf spot (*Xanthomonas*)
Flowering crabapple scab (*Venturia*)
Dogwood anthracnose (*Discula*) and spot anthracnose (*Elsinoe*)
Ash, beech, elm, maple, oak and tuliptree anthracnose (various fungi)
Oak bacterial leaf scorch (*Xylella*)

Linden spot anthracnose (*Elsinoe*)
Honeylocust, pecan, redbud, willow and yellowwood leaf spot (*Cercospora*)
Walnut leaf spot (*Phloeospora*)

Needle Evergreens

Arborvitae twig blights (*Botrytis, Pestalotia*)
Leyland cypress canker (*Seiridium*)
Pine needle spot/blight (*Dothistroma, Mycosphaerella*)
Pine tip blight (*Sphaeropsis*)
Spruce needle cast/blight (*Rhizosphaera, Stigmina*)
Arborvitae, juniper, pine, spruce and taxus root rot (*Phytophthora*)

Shrubs

Boxwood canker (*Pseudonectria*)
Cherrylaurel bacterial leaf spot (*Xanthomonas*)
Crapemyrtle leaf spot (*Cercospora*)
Euonymus stem blight (*Sclerotinia*)
Hawthorn cedar-quince rust (*Gymnosporangium*)
Holly black root rot (*Thielaviopsis*)
Hydrangea fungal leaf spot (*Cercospora*) and bacterial leaf spot (*Xanthomonas*)
Rhododendron canker (*Botryosphaeria*) and stem blight (*Phomopsis*)
Rose rosette (virus)
Azalea, cherrylaurel, forsythia and rhododendron root rot (*Phytophthora*)

Herbaceous Annuals and Perennials

Catharanthus black root rot (*Thielaviopsis*)
Chrysanthemum root/crown rot (*Pythium*; *Rhizoctonia*)
Chrysanthemum web blight (*Rhizoctonia*)
Geranium bacterial blight (*Xanthomonas*)
Impatiens leaf spot (*Alternaria*)
Hollyhock rust (*Puccinia*)
Hosta southern blight (*Sclerotium*)
Liriope crown rot (*Phytophthora*)
Mandevilla southern [bacterial] wilt (*Ralstonia*)
Peony stem blights (*Botrytis*, *Phytophthora*, and *Sclerotinia*)
Petunia black root rot (*Thielaviopsis*)
Petunia root/crown rot (*Pythium*)
Zinnia leaf spot (*Alternaria*)

Significance to Industry

Plant diseases play a significant role in production and maintenance of nursery and landscape plants in Kentucky. The first step in effective pest management is accurate diagnosis of the disease problems. The PDDL assists the nursery and landscape industry of Kentucky in this effort. In order to serve their clients effectively, industry professionals, such as arborists, nursery operators, and landscape installation and maintenance organizations, should be aware of recent plant disease history and the implications of these diseases for future production or landscape maintenance. This synopsis of plant disease occurrences is provided to assist nursery and landscape professionals with that task.

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Nursery Survey for Phytophthora Ramorum in Kentucky, 2011

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

Background

Phytophthora ramorum, the cause of Ramorum blight and sudden oak death, continues to be a problem on the west coast 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 for this pathogen include: camellia, rhododendron, viburnum, mountain laurel and many others. A complete host list can be found at: http://www.aphis.usda.gov/plant_health/plant_pest_info/pram/. Symptoms of *P. ramorum* infection on these hosts vary depending on the species and weather conditions, but include leaf spotting, leaf tip necrosis and twig dieback. Regulations and quarantines have been established to limit the spread of this pathogen, but concerns still remain about potential movement in contaminated nursery stock. Methods of long distance spread of the pathogen include moving plants, plant parts, soil and water. The Appalachian region is considered to be a high risk area for the establishment of *P. ramorum* because several of the native plant species in the region are identified as hosts and appropriate weather conditions occur often.

Nature of the Work

The nursery survey for *P. ramorum* in Kentucky was continued through the 2011 growing season as part of the Cooperative Agricultural Pest Survey (CAPS) program. This survey, a collaborative effort between the Department of Plant Pathology and the Office of the State Entomologist (Department of Entomology) at the University of Kentucky, has been ongoing each year since 2004 and utilizes protocols for collecting and testing established by the USDA-APHIS-PPQ. A total of 121 samples with foliar symptoms suggestive of general *Phytophthora* infection were collected from nurseries and home gardens in ten counties: Boone, Boyle, Campbell, Fayette, Franklin, Henderson, Jefferson, Kenton, Laurel and Lee. These samples were double bagged and sent to the Plant Disease Diagnostic Laboratory (PDDL) in Lexington for testing. An immunological test, enzyme-linked immunosorbent assay (ELISA), was used at the Lexington PDDL as an initial screen of all samples collected. This assay detects the presence of proteins typical of several plant pathogens in the genus *Phytophthora*, including *P. ramo-*

rum. DNA was then extracted from samples testing positive via ELISA for general *Phytophthora* infection. Extracted DNA samples were sent to USDA-APHIS approved testing laboratories for further identification via polymerase chain reaction (PCR).

Results

Of the 121 total samples collected throughout the state, 60 tested ELISA positive for infection by *Phytophthora* species. Although this is a much higher percentage of positive samples than in past nursery surveys, wet weather during sample collection in late spring /early summer was very conducive to the development of foliar disease caused by various *Phytophthora* species. Extracted DNA from the 60 ELISA positive samples was sent to USDA-APHIS approved testing laboratories for species identification through PCR. The *P. ramorum* PCR test for each of these samples was negative. *Phytophthora ramorum* was NOT found in the state of Kentucky this growing season. Results are summarized in Table 1.

Table 1. Number and type of plants sampled and results of ELISA assays for Phytophthora in general and PCR for Phytophthora ramorum during the nursery survey for Phytophthora ramorum in Kentucky in 2011.

Plant Species	Number of Samples	ELISA positive *Phytophthora* sp.	PCR positive *P. ramorum*
Rhododendron	70	41	0
Pieris	27	17	0
Viburnum	18	2	0
Camellia	4	0	0
Kalmia (Mt. Laurel)	1	0	0
Azalea	1	0	0
Total	121	60	0

Pest Scouting Program for Nurseries across Kentucky

Sarah J. Vanek, Horticulture

Nature of the Work

Kentucky nursery crop producers, retailers, and landscapers continually fight insect pests and diseases on their plants. Management of these pests is essential because many can seriously injure or kill nursery crops. Furthermore, the end consumer often rejects even minimal levels of plant damage. An essential step in effectively managing these problems is routine scouting and insect trapping to identify existing infestations and proper treatment timing.

In June 2011, a nursery scout from University of Kentucky began weekly scouting at four nurseries in different counties of central Kentucky. Scouting efforts focused on numerous common nursery and landscape pests of trees and shrubs. Specific plants were inspected for known pests at certain times during the season, depending on the estimated dates of each pest's emergence or initial activity. Observations of other insect pests or diseases were also noted. In many cases, diseased samples were submitted to the University of Kentucky Plant Disease Diagnostic Lab for identification. Weekly scouting was continued during June and July, and scouting visits were reduced to approximately two visits at each nursery during August and September.

In addition to plant inspections, monitoring traps were used to detect activity of three wood-boring insects: granulate ambrosia beetle (*Xylosandrus crassiusculus*) and two clearwing moths, peachtree borer (*Synanthedon exitiosa*) and lesser peachtree borer (*Synanthedon pictipes*). At each nursery, one trap was used for granulate ambrosia beetle, two traps were used for peachtree borer, and two were used to monitor lesser peachtree borer. Lures used for the respective borers were Ethanol-Ultra High Release (Great Lakes IPM, Inc., Vestaburg, MI), Clearwing Borer Complex, and Lesser Peachtree Borer (Scentry Biologicals, Inc., Billings, MT).

The majority of traps were established in early June, and a few were not established until late June due to a temporary shortage of lures. Traps were monitored and replaced during each nursery visit, and lures were replaced approximately every four weeks. Peachtree borer and lesser peachtree borer traps were removed in August, and granulate ambrosia beetle traps were removed in September.

Results were shared and discussed with participants during on-site visits and telephone and email communication. New observations of pest activity, along with information about pest biology and management, were distributed to other members of the nursery industry through an email listserv. The locations of pest infestations remained confidential to prevent unfair stigmatization of participating nurseries.

Results and Discussion

Multiple insect, mite, and disease pests were identified at each location. Insect pests included hawthorn lace bug, oak lace bug, potato leafhopper, calico scale, cottony maple scale, flatheaded apple tree borer, Japanese beetle, bagworm, fall webworm, green-striped mapleworm, pink-striped oakworm, and magnolia serpentine leafminer. Mite pests included honeylocust spider mite, maple spider mite, and two-spotted spider mite. Diseases included anthracnose, cedar-quince rust, fire blight, Phloeospora leaf spot, and powdery mildew. Herbicide damage and indications of other abiotic diseases were also noted and shared with the grower.

Trapping was successful in showing growers the general abundance of each of the three pests. Pest activity varied amongst the four locations. For example, traps at one nursery collected a total of 75 peachtree borers during one week, while, traps at another nursery only collected 13 during the same period. Similarly, traps at one nursery captured 66 lesser peachtree borers in one week, while only 14 were collected at a second nursery.

Treatment guidelines for clearwing borers recommend that preventive sprays be applied 10–14 days after the first capture of male moths and again six weeks later if moths are still active (2). Traps used in this program captured the initial flight activity of peachtree borer. This provided growers with the optimal dates for both the first and second treatment applications. Trapping also showed that the moths were still active at the scheduled time of the second treatment.

Traps were established after the initial flight of lesser peachtree borer. However, by following the estimated dates of the moths' first flight, effective treatment dates could still be estimated (2). Trap results verified that moths were still active at the second scheduled treatment date. These results showed that the second treatment was warranted.

Flight activity of granulate ambrosia beetle in Kentucky has not yet been thoroughly studied. In Indiana, the beetle's flight typically begins in April, reaches its peak in May, and continues at low levels throughout the summer (1). In some years, a second, smaller peak occurs any time from late June through September.

Monitoring for granulate ambrosia beetle during this period did not reveal a distinct second peak common amongst the four locations. Trap counts remained low (< 8 beetles) at three of the four nurseries, with weekly averages of 1.4, 2.0, and 3.0 beetles. However, there was a greater amount of activity at the fourth nursery during late June through July. The greatest number captured in one week was 20 beetles during late June.

Significance to the Industry

Scouting and monitoring play essential roles in successful pest management programs. However, many nursery businesses have cut back their workforce in response to the economic recession. Consequently, scouting activities are also being heavily reduced or nearly eliminated in many Kentucky nurseries.

Through this program, participating nursery managers, as well as other related professionals across the state, learned about current pest emergences and proper treatment timing. Participating nursery managers also became more closely aware of the pests that were currently present at their nurseries. Positive feedback from multiple nursery producers illustrates that the scouting program assists producers in identifying and treating pest problems at the optimal time.

Acknowledgement

I would like to acknowledge Taylor Cavanaugh as the primary contributor in the scouting activities. I am grateful to the participants who volunteered their nurseries for scouting efforts and agreed to allow scouting results to be shared with the greater nursery community.

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Natural Season Container-Grown Garden Mum Production Demonstration

Steve Berberich, Horticulture

Introduction

On-farm commercial demonstrations for growing potted, natural-season garden mums were conducted in Harrison, Kenton, Owen, and Robertson counties in 2011. The growers marketed the majority of the plants through on-farm sales and farmers markets. On-farm demonstrations were conducted to help new and existing growers understand and apply technologies of profitable production systems. The purpose of these plots was to demonstrate cultural practices necessary for successful outdoor fall flower production.

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

Materials and Methods

In preparation for the demonstration, irrigation water was analyzed at the University of Kentucky Regulatory Services laboratory and the fertigation program was formulated. The water from all of the plots was determined to be acceptable for production of container-grown plants. However, calcium and magnesium were included in the fertility program for several growers.

An outdoor container-production 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. A 1:100 ratio, water-operated, proportional fertilizer injector (Chemilizer HN55, Hydro Systems Company, Cincinnati, OH 45244), along with appropriate filters, regulators, and valves, was installed.

Liners of 12 garden-mum cultivars, *Chrysanthemum* x *morifolium* 'Hanna Orange,' 'Gold Finch Yellow,' 'Izola Orange,' 'Carpino Purple,' 'Padre Lemon,' 'Cesaro,' 'Belgo Lilac,' 'Viviana Yellow,' 'Brandi,' 'Raquel,' 'Ashley,' and 'Jazzy Ursala' were received in 50 cell trays. The first week of June, the Harrison and Owen county growers transferred liners to 12-inch mum pans (Nursery Supplies, Inc. Classic 1200S) in SunGro Metro-Mix 560 Coir (SunGro Horticulture Distribution Inc., Bellevue, WA 98008). The third week of June, the Kenton County grower transferred liners to 9-inch mum pans (Nursery Supplies, Inc. C550) and the Robertson County grower transferred liners to 8-inch pans (Nursery Supplies, Inc. C330), both in SunGro Metro-Mix 560 Coir. Two weeks after potting, all four plots were treated with Banrot fungicide drench (Scotts Company LLC, Marysville, OH 43041) at label rate as a preventative treatment for root rot diseases.

The primary fertilizer used for the continuous liquid feed program was 20-10-20 Peat-Lite Special (Scotts Company LLC, Marysville, Ohio 43041). The plants were fertigated as needed throughout the growing season. The fertilizer concentration was 200 ppm N for week one and two, 350 ppm N for week three through six, and 300 ppm N for week six through ten. 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 1pound per 100 gallons water and bi-weekly applications of magnesium sulfate at 1 pound per 100 gallons of water. The 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 garden mum flower initiation period of the 2011 growing season were unusually warm, particularly night temperatures. Flowering of many cultivars was delayed two to three weeks by the high temperatures; consequently, many plants were larger than normal because of the longer vegetative period. Additionally, higher insect pressure was observed in plots near unmown fields. However, this was still a successful crop for the growers/cooperators and all intend to continue production next year.

Table 1. Costs and returns for on-farm demonstration of container-grown, natural-season garden mums.

Inputs	Harrison (250 plants) 12-inch pot	Kenton (250 plants) 9-inch pot	Owen (250 plants) 12-inch pot	Robertson (250 plants) 8-inch pot
Liners	120.25	120.25	120.25	120.25
Pots	125.00	96.00	125.00	94.00
Potting media	375.00	187.50	375.00	166.67
Fertilizer	114.00	85.50	114.00	79.80
Woven ground cover[1]	15.20	15.20	15.20	15.20
Fertilizer injector[1]	41.00	41.00	41.00	41.00
Misc. filter, regulator, etc.[1]	20.00	20.00	20.00	20.00
Irrigation lines, emitters, spray stakes[1]	26.66	26.66	26.66	26.66
Labor[2]	0	0	432.00	0
Total expenses	837.11	592.11	1269.11	563.58
Income	2100.00	2170.00	2332.00	1093.50
Net income	1262.89	1577.89	1062.89	529.92
Dollar return/dollar input	2.51	3.66	1.84	1.94

1 Amortized over five years.
2 Does not include unpaid family labor.

The average price varied considerably depending on market and geographic location in the state. 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 than might normally be available. Although production costs may vary considerably from grower to grower, a new grower can use the costs listed below as an estimate of those typically associated with garden mum production (Table 1).

Long Residual Controlled-Release Fertilizer Pour-through Results from Two Plant Species and a No-Plant Control

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

Significance to Industry

This research was performed to determine if using controlled-release fertilizer (CRF) of high longevity, 12-14 month, would overcome mid-season low pour-through (PT) soluble salt readings that occur when 5-6 month CRF no longer provides adequate levels of fertilizer after 13 weeks in Western Kentucky (2). 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 12-14 month CRF provided adequate levels of fertilizer from the June application to October as indicated by PT soluble salt levels.

Nature of Work

Utilizing the pour-through (PT) method (3) to evaluate soluble salt levels that indicate fertilizer availability, has typically revealed that soluble salt levels in mid-summer following a spring CRF application were less than recommended (2). Previous work attempting to retrieve all fertilizer prills to test for fertilizer remaining in mid-summer when the low soluble salts PT results occurred has 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 but not depleted by the plant.

April 20, 2011, fifteen plants each of *Nyssa sylvatica* 'Fire Master' and *Cotoneaster* x 'Hessei' were transplanted from RootTrapper® II RTII 8 bags and 3 gallon containers (Nursery Supplies, C300) respectively to 7-gallon containers (WhiteRidge, LLC, 2358 l). The substrate 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 three cycles of 12 minutes each (250ml/min) at 1020, 1400, 1700. Osmocote Plus 15-9-12, 12-14 month formulation, was applied June 28, 2011 at the medium rate of 7.5 oz for a 7-gallon container. The three treatments were allocated to the 45 containers in a generalized randomized block design with three treatments per row and three rows (blocks).

Soluble salts and pH were recorded approximately every two weeks from June 6, 2011 to October 24, 2011 by the pour-through extraction method (3,7). The PT was performed 30 minutes following irrigation except on September 26, 2011 when the pour-through was done without irrigation following a 1.88 inch (5) overnight rain. The leachate soluble salts and pH were read with a Hanna HI9811 pH/EC/TDS Meter.

Results and Discussion

Leachate salts showed a stable release rate (Figure 1.) averaging 294 µS/m for the no-plant control, 316 µS/m for the *Nyssa sylvatica* 'Fire Master' and 272 µS/m for the *Cotoneaster* x 'Hessei' over the duration of experiment and were not significantly different from each other (Table 1.). The soluble salts in the leachate for the September 26, 2011 non-irrigated PT spiked for the *N. sylvatica* 'Fire Master' and the *C.* x 'Hessei' while the No-plant container PT was significantly different from the *N. sylvatica* 'Fire Master' and the *C.* x 'Hessei' and was not significantly different from the September 12, 2011 PT. The salt level was in the 200 to 500 µS/m range considered adequate for growth (2,7,8) and was maintained from the June application date to the last PT in October. The levels of fertility in October are high enough for growth and may result in reduced cold

Table 1. Average soluble salt reading over the experiment.

Treatment	Soluble Salt	Number of Readings
No-plant	294 a[1]	176
Nyssa sylvatica 'Fire Master'	316 a	176
Cotoneaster x 'Hessei'	272a	177
Lsd (0.05)	47	na

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

Table 2. Average pH reading over the experiment.

Treatment	Soluble Salt	Number of Readings
No-plant	6.91a[1]	176
Nyssa sylvatica 'Fire Master'	6.91a	176
Cotoneaster x 'Hessei'	6.85b	177
Lsd (0.05)	0.05	N/A

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

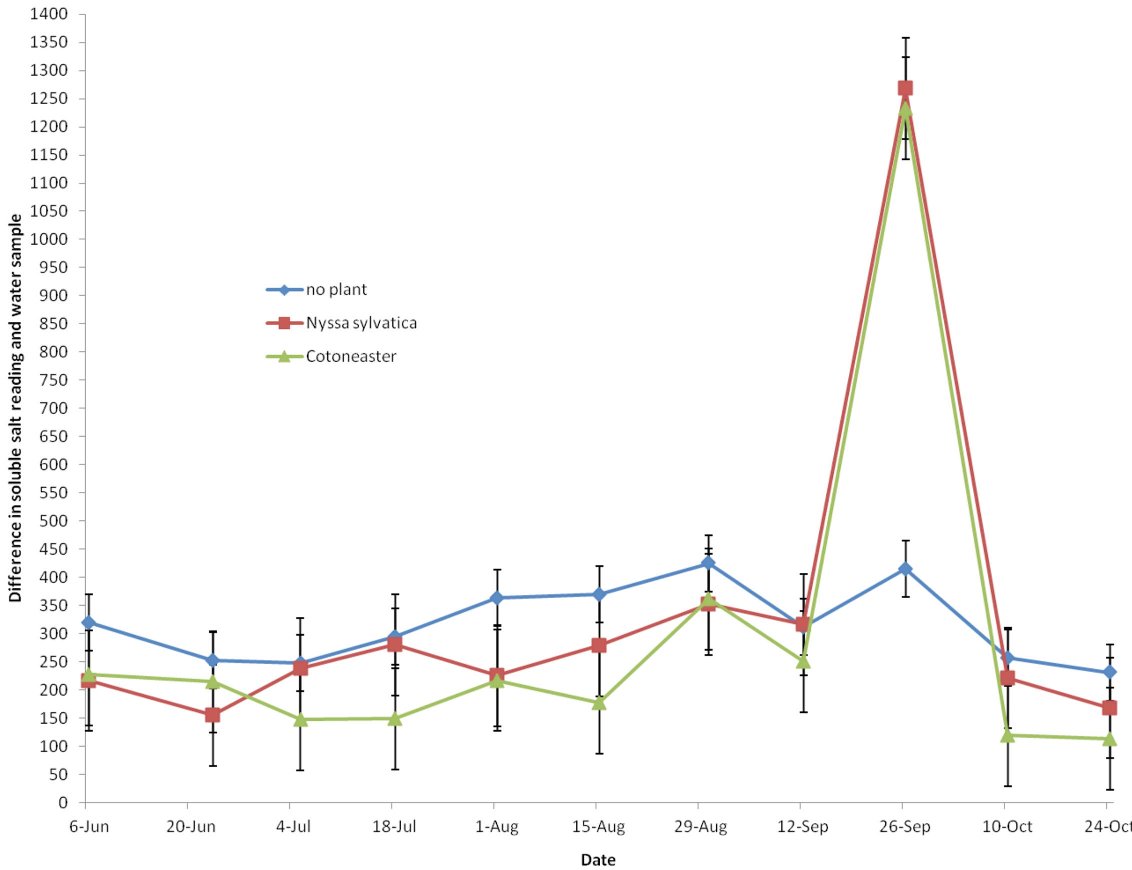

Figure 1. Soluble salts in PT leachate from Nyssa sylvatica 'Fire Master', Cotoneaster x 'Hessei' and no-plant containers for two-week sampling intervals. Mean intervals are + or – half the least significant difference at the 0.05 probability level.

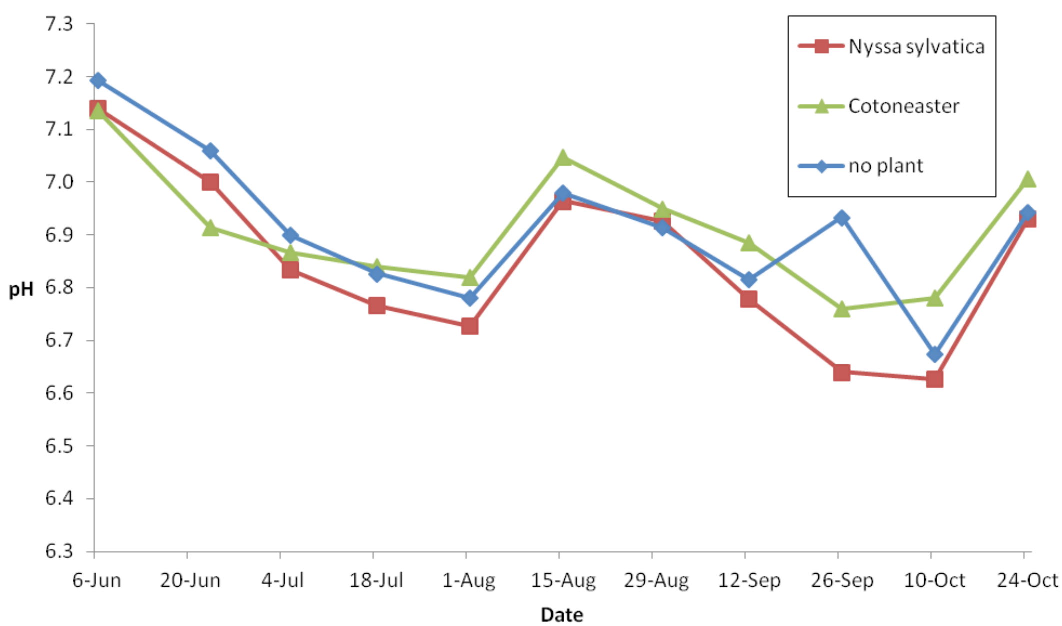

Figure 2. pH of the PT leachate from Nyssa sylvatica 'Fire Master', Cotoneaster x 'Hessei' and no-plant containers for two week-sampling intervals.

hardiness leading to potential winter injury (4,6). A no-plant treatment did not contribute information for evaluating nutrient availability that is not gained by performing PT on containers with plants.

The spike in leachate soluble salts for *Nyssa sylvatica* 'Fire Master' and *Cotoneaster* x 'Hessei' on September 26, 2011 was due a lack of pre-PT leaching of soluble salts. The evening rainfall triggered elimination of the irrigation event prior to the PT. It is speculated that the lack of a significant soluble salts spike in the no-plant container reflects the lack of plant depletion of water leading to a concentration of soluble salts.

The average leachate pH readings over the course of the experiment for *Cotoneaster* x 'Hessei' were significantly different from the No-plant and *Nyssa sylvatica* 'Fire Master' Leachate pH (Table 2), but the readings were not consistently different from date to date. The pH of pour-through leachate declined over time (Figure 2).

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Life Cycle Assessment as a Tool for Estimating the Carbon Footprint of Nursery Production Systems

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Nature of Work

Consumers are becoming more concerned about the impact of their purchases and activities on the environment. Special interest groups and marketers are heightening their awareness through news stories and advertisement. Terms such as "sustainability," "green," and "reduced carbon footprint" are being used in conversations and promotions. Indeed consumers have increasingly higher expectations for products and services that are more sustainable in terms of economics, natural resources and global warming potential, as well as the health and safety of producers and consumers. Consumers have been shown to be willing to pay a premium for plants in more "sustainable" containers, but the premium differed with type of sustainable containers (5). A consumer survey found that there was a higher demand for locally-grown landscape plants than for plants labeled as certified organic. Biodegradable and compostable pots were more desirable to surveyed customers than recycled pots.

Unfortunately, there are few standards being utilized in the claims of some products and services, and the terms being used are often loosely defined. One tool for quantifying the environmental impact of a product or service that has been accepted in the scientific community is Life Cycle Assessment (LCA). International standards for assessing various environmental impacts have become increasingly important as international trade exploded in recent decades (2,4).

Life Cycle Assessment is a systematic process accounting for diverse environmental impacts of interrelated input components and processes of a product or practice during its complete life cycle, cradle-to-grave (1). A carbon footprint (the total amount of greenhouse gas emissions caused by an organization, event, product or service) is the most common focus of LCAs analyzing system components and their interactions. The carbon footprint of a product or activity is expressed in kg CO_2 equivalent emitted (CO_2e). Other questions that could be addressed by LCA might be a product's water footprint (the water used, both directly and indirectly, by an organization, event, product or service), toxicity potential (releases that are toxic to humans and/or the environment, both acute and chronic) or some other environmental impact measure.

A project has been initiated using LCA to examine the three primary life phases (production, use phase and post-life phase) of a 2-inch caliper red maple relative to their impact on the carbon footprint (Global Warming Potential (GWP); kg CO_2e) of the final product. Production protocols for field production of shade trees differ significantly between nurseries, even within a state or region. In order to define a generally representative model system for this study, interviews were conducted with nursery managers in Kentucky and Tennessee with experience in producing field-grown *Acer rubrum* 'October Glory.' In this model system, 6-ft liners would be produced from cuttings in one nursery and transported to another nursery for finishing in the field. Liner production would involve rooting cuttings in a ground bed in May and transplanting to the field the following May before being harvested in November or December. Liners would be dug bare root in the fall, overwintered in a barn and trucked to the field nursery in April. The field block at the second nursery would have previously remained fallow with a sudex cover crop for one growing season that was plowed under in the fall. Two-inch caliper trees would be harvested in the fall of the fourth year, after approximately 44 months in the field.

In as much as possible, each input material, all equipment use and transportation were inventoried for the system and the investment of greenhouse gas emissions in each was determined relative to a single red maple tree. Equipment time required per operation over a defined area with a known population of trees was documented. Determining the GWP of inputs is a difficult step in developing a LCA for horticultural products because the complete information is simply not available for a unique set of inputs. The assumptions made and justifications for those assumptions are critical to the reliability of a LCA, however, space does not allow a complete description of those in this progress report.

Results and Discussion

Preliminary results are being shared with the understanding that is a progress report and the final results may differ somewhat from data presented here. There is a danger in putting a great deal of credence in the calculated carbon footprint of any product or service as a finite number. However, these calculations can be used to compare the carbon footprints of common products. Implied cradle-to-grave calculated carbon footprints have been reported in the Wall Street Journal as 54 kg CO_2e for a pair of winter boots and 3.4 kg CO_2e for a gallon jug of milk (http://online.wsj.com/article/SB122304950601802565.html). Including carbon sequestration during one year of liner production and the final four years of field production, the carbon footprint of the tree in this study was estimated to be 4 to 6 kg CO_2e. CO_2e emissions from input materials, equipment use, overhead, product transport and transplanting totaled 20 to 22 kg CO_2e /tree and the CO_2 sequestered during production was 15 to 16 kg CO_2e /tree.

Fuel and electricity consumption from cutting-to-landscape contributed approximately 85% of the carbon footprint of the red maple tree, before accounting for carbon sequestration during production. Diesel use in transporting and transplanting the tree alone accounted for 35% of CO_2e emissions associate with the product.

An important element of LCA is the ability to query the model relative to the impact of alternative input materials or processes. In the current model, simply substituting urea for ammonium nitrate as the source of N fertilization during field production would reduce the CO_2e investment by 0.646 kg CO_2e / tree and decrease the carbon footprint by 13%.

The CO_2 sequestered was estimated for the 60-year life of the red maple in a suburban landscape using published methods (3). A weighted impact of this sequestered carbon, as calculated following international standards (4), revealed that the positive impact of the tree in the landscape on potential global warming was over 100 times the potential negative impact from production. This does not include any indirect effect of energy saving, oxygen generation or micro-climate modification due to shading, wind reduction, etc. in structures graced by strategically placed trees or additional carbon investment in tree maintenance.

Significance to the Industry

Information generated using LCA will allow nursery managers to make informed decisions about the various elements of their operations. Consumers can be informed about the relative GWP of system components, such as transportation, and make informed purchasing decisions driven by environmental concerns. Data generated from such analyses can also document the dramatically positive impact of landscape plant production on potential climate change.

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Use of Plantable Containers for Ground Cover Plant Production and Establishment in the Landscape–Preliminary Results

Dewayne L. Ingram and Susmitha S. Nambuthiri, Department of Horticulture

Nature of Work

The demand for ground cover plants for use in Kentucky landscapes is increasing. The two primary reasons for this increased demand is the need to reduce inputs required to maintain larger areas of the landscape and the visual appeal of masses of these low-growing plants in small to medium-sized areas of the landscape. Turfgrass requires significant management during the growing season and can be difficult to maintain under trees due to shading and competition for available water. However, there are diverse plants that can be used as ground covers that offer lower maintenance and higher performance under various soil, moisture and light conditions.

The landscape industry is truly a "green" industry. However, hundreds of plastic pots scattered across a client's landscape that must be collected and disposed of or recycled detract from that image. To be recycled, containers usually are cleaned, stacked and transported and recycling services are not available in many areas. To be re-used the containers must be transported to the nursery where they are cleaned before use. If plantable containers can be utilized efficiently in a ground cover production / marketing system, it would allow landscapers to differentiate themselves in the market as offering more eco-friendly products and services.

An increasing number of bio-degradable and plantable containers are becoming available in sizes appropriate for ground cover production. These containers are made from paper, straw, wood fibers, peat, coir fiber, rice hulls and bio-plastics and commonly range in size from 2 to 6 inches in diameter. Preformed flats accommodating several plants in each flat are also available, although design modifications and composition could increase their utility for ground cover production, transport and installation. Production container design must also address the ease of maintenance on job sites and/or in the retail environment. Several horticultural supply companies have recently or will soon be releasing new products aimed at these criteria.

A preliminary study was conducted in 2011 at the UK Horticulture Research Farm in Lexington, KY to help set parameters for more extensive experiments in 2012 related to ground cover production. The objective was to evaluate selected ground cover plant performance in plantable containers during production and after transplanting into the landscape. *Sedum hybridum* 'Immergrunchen' and *Sedum spuricum* 'Red Carpet Stonecrop' plugs from 72-count flats (approx. 1.5-inch diameter cells) were supplied by Midwest Groundcovers Inc. Plants were transplanted into one of three containers in mid-April: standard 3-inch round plastic containers in 10-count flats, 3.5-inch (90mm) Ellepots® in 10-count flats, or 3.25-inch (80mm) Soil Wrap® in 12-count flats. *Liriope muscari* 'Big Blue' bibs were obtained from Classic Groundcovers, Inc. and transplanted into the above containers in addition to 3-inch Rice Hull NetPot® containers in 10-count flats. Each species was transplanted to two flats of each container tested. Plants were fertigated once with 200 ppm N from Peters Excel 21-5-20 and topdressed with 3.5g of Osmocote Plus 15-9-12 in early May and moved to a 24ft x 50ft quonset-type greenhouse with clear plastic cover, side ventilation and no ends.

On July 5, 2011, the sedum cultivars were transplanted into a field plot that had been cleaned and tilled. Plants were transplanted on 1-ft centers in a triangular arrangement in two blocks per species. The plots were mulched with pine bark and watered by hand as needed. The liriope were transplanted to a field plot on September 1, 2011. The liriope plants were dug on November 8, 2011 and the roots extending from the original container were harvested, washed and oven dried before being weighed.

Figure 1. Sedum hybridum 'Immergrunchen' (left) and Sedum spuricum 'Red Carpet Stonecrop' (right) upon transplanting to the landscape on July 5, 2011.

Figure 2. Sedum hybridum 'Immergrunchen'(top) and Sedum spuricum 'Red Carpet Stonecrop' (bottom) approached complete coverage of the planted area 14 weeks after transplanting into the field.

Plant growth and ground coverage was analyzed using SigmaScan Pro 5.0 image analysis software (SPSS Science, Chicago) from digital images taken monthly from the same height and using a fixed focal length (1). SigmaScan Pro 5.0 in the Trace Mode was used to analyze images to measure individual plant growth and ground coverage over time. Accuracy of the method was assessed each time using the known area of a frame that was used to border each plot. Final images were taken on October 25, 2011 as later it became difficult to measure individual plant growth because of high overlapping plant canopies.

Results and Discussion

The two sedum cultivars were estimated to be marketable 8 weeks (first week of July) after transplanting into the test containers (Figure 1.) It was estimated that within another month, the separation of these plants when removing from the flats would have been problematic. Two more months of production time was required before the liriope was ready for transplanting. The Soil Wrap® containers were breaking down after 12 weeks of production.

The growth index (width in two direction, divided by 2) of the sedum averaged 19.5 at transplanting into the field and had not been affected by production container. Using the monthly image analysis of the sedum field plots, it was observed that the two sedum cultivars grew at a similar rate but the smaller-leafed *S. spuricum* 'Red Carpet Stonecrop' appeared to cover the area more slowly. By October 24, 14 weeks after transplanting to the field, the plants of both cultivars were intertwined and approaching complete coverage of the planted area (Figure 2).

Liriope were judged not to be marketable until the end of August, approximately three months in production. The container type had no significant impact on plant growth. By mid-June, the liriope averaged two off-shoots per plant and over 4.6 off-shoots by mid-August. At harvest from the field plot in November (two months after transplanting), the mean dry weight of roots extending from the original container

Figure 3. Liriope muscari 'Big Blue' after transplanted in the landscape for two months. Production container treatments, from left to right: standard plastic container, Soil Wrap®, Ellepots®, and Rice Hull NetPot®. (November 10, 2011)

substrate was 7g, the mean number of off-shoots arising from below the soil surface was 5.6. There was no significant effect of the production containers on the parameters measured after harvesting from the field plot (Figure 3).

From the preliminary results from this one-year study, there does not appear to be any negative impact of these plantable containers on the growth of sedum and liriope during the production period or during establishment into the landscape. Sedum is a candidate for rapid turnover systems for ground cover plant production. The production period of liriope grown from bibs will be longer than sedum in this system.

Significance to the Industry

Plantable containers (3 to 3.25-inch diameter) had no impact on the growth of sedum and liriope in spring months of 2011. Information generated in this short study will be utilized in designing a more extensive experiment in 2012 as production system protocols for rapid production of ground cover plants for immediate landscape installation are studied. At this point, nursery managers should select among the containers studied based on cost differential and market implications relative to reduced plastic wastes and customer perceptions and expectations.

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Acknowledgements

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Operation Pollinator: Expanding Potential Markets for Kentucky-Grown Flowering Plants

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Nature of the Work

Pollinating insects are an integral part of natural ecosystems, home lawns and gardens, agricultural production, and nursery systems, and are absolutely necessary for all plants which require animal-mediated pollination. Bumblebees comprise a large proportion of those pollinating insects. Over the last 40 years, a 70% decline in bumblebee populations has been documented; this loss is speculated to be primarily caused by habitat loss (Operation Pollinator).

Until recently, most American golf courses have been "green deserts" for pollinators: wide swathes of rich green turf unmarked by herbage, shrubs, or flowering plants which, while pleasant for the human eye, are wastelands for pollinating insects. However, a current trend in the golf industry involves restoring golf course landscapes to more naturalized states. This trend has been encouraged by the Audubon Cooperative Sanctuary Program and the Xerces Society, and consists of allowing out of play areas of golf courses to grow native plants without interference. These areas serve both as aesthetic additions to golf courses and as refuges for native birds and pollinators.

Operation Pollinator is a project that was developed in the United Kingdom in early 2010 in order to increase available pollen and nectar-rich habitats for pollinators on golf courses by growing wildflowers in out of play areas. This project was designed by the Sports Turf Research Institute (STRI), funded by Syngenta, and has been very successful in the United Kingdom. While initially proposed as a project specifically for golf courses, Operation Pollinator could also be implemented in schools, parks, and backyard habitats by individuals and Master Gardeners. The goals of this research are 1) to evaluate various wildflower seed mixes adapted to the US transitional climatic zone for cost and ease of establishment on golf courses and to provide guidelines for use by superintendents, 2) to evaluate attractiveness to those mixes and individual wildflower species to bumblebees, butterflies, and other native pollinators, and 3) to provide settings for educational pollinator conservation workshops targeting golf superintendents, other land managers, and the public.

Present Status of Project

We have collaborated with Applewood Seed Company, Sharon Bale (Horticulture), and Syngenta turf scientists to develop a simple bee-specific wildflower seed mix, a complex bee-specific wildflower seed mix, and a butterfly-specific wildflower seed mix. All of the selected wildflower species are native to Kentucky, most are perennial, and the remainder are hardy self-seeding annuals. We have established plots to compare the three wildflower mixes and a control on five golf courses in the Lexington, KY area and one on Spindletop, the university research farm. Plots were prepared for seeding and seeded using a modified protocol from the original Operation Pollinator sites in Great Britain (Fig. 1 and 2). The planting process was completed by September 13, 2011, sites should be ready for initial evaluations in Summer 2012, though not all plants may be well established at that point, and the final evaluations will occur in Summer 2013.

Next Growing Season

Establishment of the wildflower mixes will be evaluated by floral density sampling. Ten quadrats will be randomly distributed throughout each plot, and within each quadrat every species of flowering plant will be identified and counted. The

Figure 1. Vegetation was cut, Fusilade II herbicide was applied, and the soil surface was scarified prior to seed application.

Figure 2. After site preparation, plots were divided into four quadrats and a wildflower seed/vermiculite mix was applied.

proportion of the quadrat occupied by the plant in bloom will also be estimated, and which species bloom in the first and second years of the trial will be recorded.

The pollinator populations will be evaluated using visual observations, vacuum sampling, and hand sampling. Visual observations will be conducted while wildflowers are in bloom and during consistent times of the day, for two ten-minute periods every 3-4 weeks during blooming periods. Vacuum sampling will be conducted immediately after observation periods using a modified leaf blower over a transect the length of the plot during a one minute interval. Arthropods will be hand sorted and all bees and butterflies will be pinned and identified to family and species based on keys and reference specimens in the UK Insect Collection. Species diversity/richness indices and abundance of particular types of pollinator will be compared between the wildflower mixes.

Educational workshops will be conducted at the site at the UK Turfgrass Research Center during the annual UK Turfgrass Field Day and other meetings. Signage and an educational brochure with color photos of signature pollinators will be developed for distribution at the cooperating golf courses (and others as well).

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Biodegradable Pots and Sensor-Based Irrigation Practices in Ornamental Crop Production Systems

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Nature of the Work

Of the estimated 542 million pounds of plastic used in agriculture annually, 320 million pounds (59%) is attributed to nursery containers (Garthe and Kowal, 1993). The dependence on petroleum industry for plastic production and the disposal of plastic containers lead to negative environmental impacts. Alternatives to plastic pots made from biodegradable natural resources are gaining momentum. Green industry stakeholders have identified production practices which reduce plastic and water use as major focus areas to increase sustainability. Less information is currently available regarding the environmental impact on biodegradable containers and plant growth and vigor in these containers.

Container nursery production depends on irrigation considering the small volume of growing media and its low water holding capacity. Water resources are becoming scarce and their use is becoming competitive. Substrate moisture sensors help growers to monitor substrate water content and to schedule irrigation cycles to meet plant demand. Sensor based management of water resources conserves water and increases water use efficiency by reducing overwatering to a minimum and also by responding to plant water demand. Irrigating based on daily water use (DWU) is a better way to improve water use efficiency. Substrate moisture sensors are used to measure how much water was removed through evaporation and transpiration in each day and replace that volume of water.

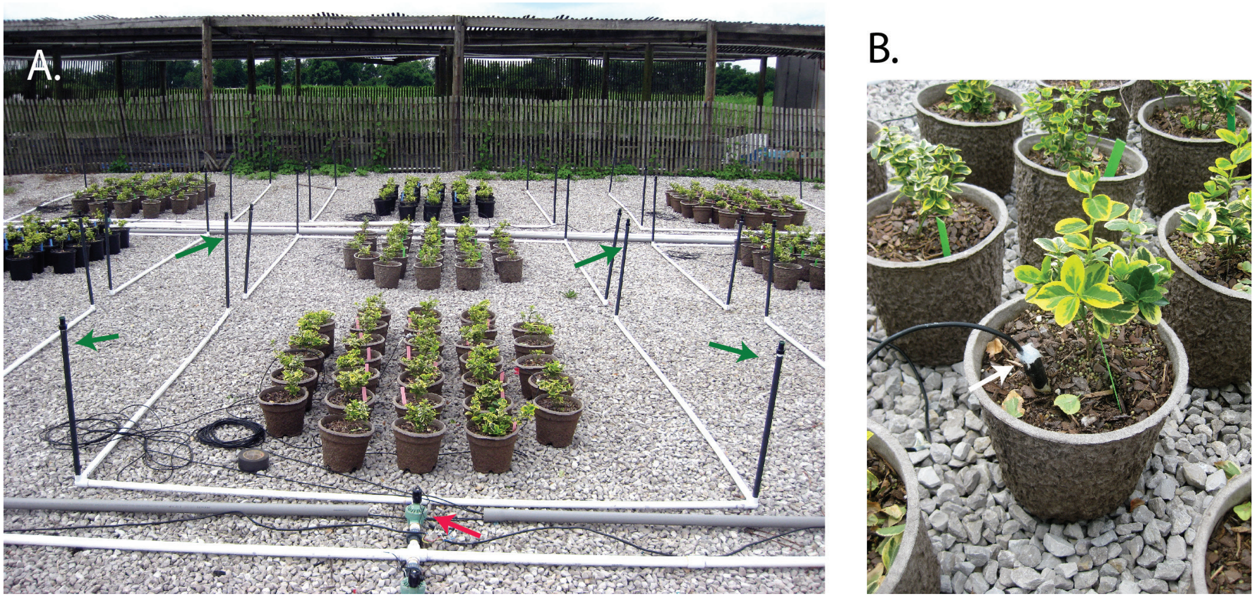

Figure 1. (A.) Container irrigation design showing the solenoid (red arrow) and the four irrigation risers in each corner of the plot (green arrows). (B.) A single one-gallon container with the irrigation sensor inserted into the substrate (white arrow).

The overall objective of this project is to evaluate the use of biodegradable nursery containers over a range of Northern and Southern growing environments. In the present study, water use was evaluated for two biodegradable and one standard plastic 1-gal containers.

The study was conducted at the University of Kentucky Horticulture Research Farm in Lexington and is part of a larger cooperative study with locations at Michigan, Illinois, West Virginia, Mississippi, and Texas under the USDA-SCRI program. The experiment set up was the same in all of the locations. Weather data was recorded by a weather station located at the farm. In May 2011, four-inch liners of Gold splash (*Euonymus fortunei*) were planted into one gallon containers. Container substrate consisted of 85% pine bark: 15% peatmoss (vol:vol). Plants were fertilized after transplanting with 8 g per container of a 19.0N–2.2P–7.5K controlled release fertilizer with micronutrients (HFI Topdress Special; Harrell's Inc.). Soluble salt levels (EC) and pH of leachate were recorded monthly using the pour-through extraction method.

The three types of one gallon containers included Kord Fiber Grow Pots (ITML Horticultural Products, Middlefield, OH), Western Pulp (Western Pulp Products, Jacksonville, TX), and Nursery Supplies PF400 black plastic (Nursery Supplies, Chambersberg, PA) container. The biopots were made from recycled paper and cardboard. Container treatments were replicated three times and the experiment was arranged in a completely randomized design. Irrigation zones were 10 square feet with 15 plants per replicate and guard plants (16 plants per treatment replicate) were placed around the outside of each treatment replicate to minimize edge effects.

Irrigation in each treatment replicate was controlled by a solenoid valve (The Toro Co., Riverside, CA). Irrigation was applied through four overlapping Toro 570 Shrub Spray Sprinklers (The Toro Co., Riverside, CA) per irrigation zone (Figure 1). Emitters were mounted on 1.3 cm diameter risers at a height of 66 cm. Volumetric water content was be measured using Echo-5 moisture sensors (Decagon, IL) inserted into two containers per irrigation zone. Irrigation was scheduled to apply 100% DWU (Warsaw et al., 2009) every day. The irrigation applications were scheduled with a SDM 16 AC/DC controller. Substrate moisture data acquisition and control was monitored using Campbell CR1000 data loggers.

Results and Discussion

Substrate volumetric water content (in mVolts) during July 18th 2011 to Aug 3rd 2011 shows a typical two-week water usage pattern that was repeated throughout the growing season (Figure 2). The substrate water content varied from 560 mV (approximately 48 % volumetric water content) to 430 mV (approximately 27 % volumetric water content). Irrigation applied over this typical two-week period was highest for the PF400 plastic pots (15.7 liters per plot) compared to 12.5 and 10.4 liters per plot for the Western Pulp and Kord Fiber Grow pots, respectively. The greater water usage observed in the plastic containers was most likely associated with higher evapotranspiration caused by the higher substrate temperature in these containers compared to the fiber biopots. Black plastic containers can have higher substrate temperatures due to a greater absorption of solar radiation by the black plastic surface combined with decreased side-wall heat loss (Ingram, 1981). Ruter (1999), noted that fiber biopots remained cooler than plastic container partly due to evaporative cooling through the side-walls and air exchange throughout the depth of the container, which may also have contributed to the decreased water requirement of biopots compared to the black plastic containers.

Significance to the Industry

This multistate study could provide valuable initial inputs useful to the container industry, nursery growers and consumers about the performance of these plastic alternatives under diverse environments. Management plans for the efficient use of water resources in the nursery industry could be developed from the study. The economic and environmental impacts of implementing sustainable production practices in nursery operations will be assessed to develop a national program that increases sustainability through grower education and marketing sustainably produced plants to the public.

Acknowledgements

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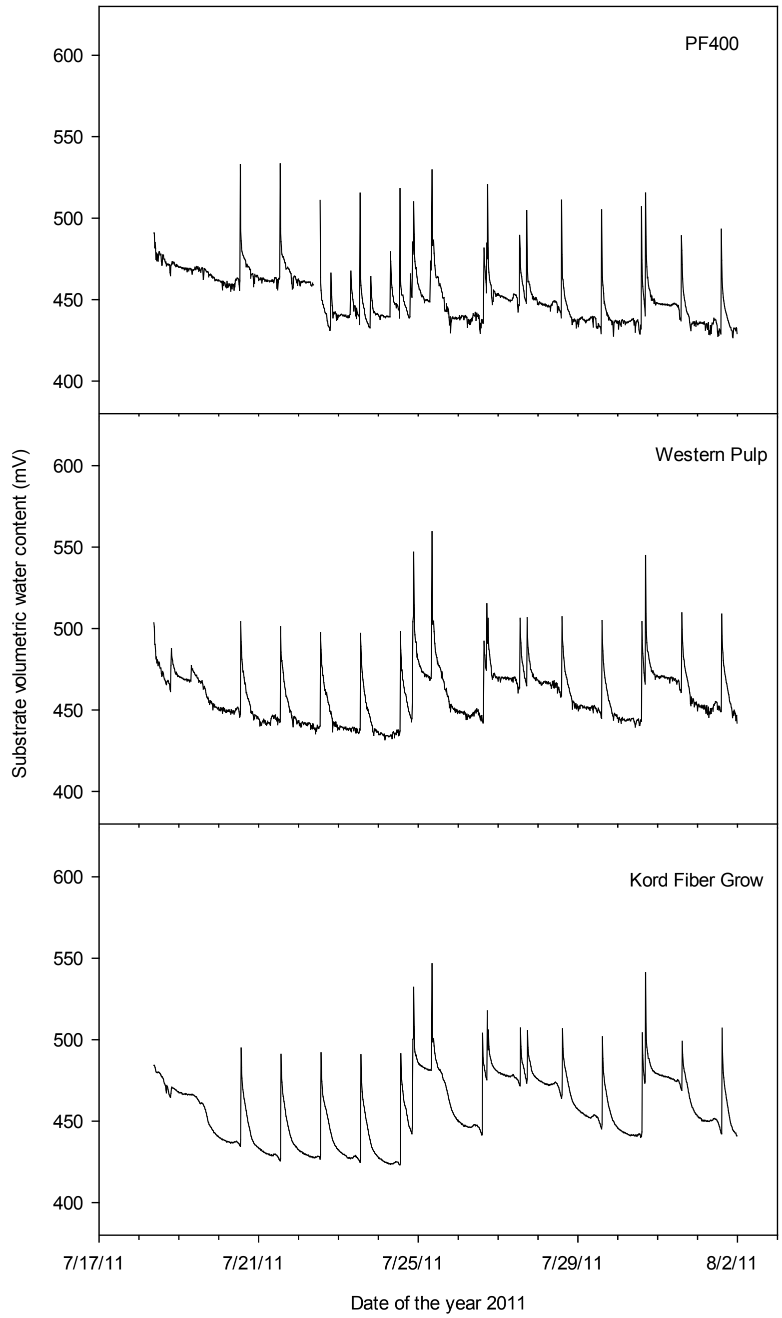

Figure 2. Substrate volumetric water content in PF400 black plastic, Western Pulp, and Kord Fiber Grow Pot containers irrigated using a daily water use replacement program July 18-Aug 2, 2011.

Tracking Fertilizer Levels in 'Green Mountain' Boxwood by use of the Pour-through Technique

Carey Grable, Department of Horticulture

Nature of Work

Few things are as important to nursery production as proper fertilization. A quality plant product is considered healthy, showing no signs of nutrient deficiency or stress. This often leads growers to reapply fertilizer when they assume their slow release fertilizer has run out. This can be a viable method to ensure that plants are properly supplied with the required nutrients, but the grower should be informed of the current fertilizer levels before taking this step. In this study, the longevity of a 5-6 month slow release fertilizer is analyzed in a western Kentucky nursery by using the pour-through technique.

The pour-through technique has been the industry standard for nutrient and pH monitoring for several years. Originally developed by Virginia Tech for use with greenhouse crops, this method has been adapted by the nursery industry for container grown crops. When using this technique, a grower should choose a representative sample from a block of containers. This means that all areas of the block of plants should be represented (Figure 1). This helps to account for environmental factors such as changes in irrigation and light levels, which may affect the observed readings. Traditionally with this technique, five steps are taken. To begin, the containers are irrigated, usually for the same length of time as their regular irrigation. Next, the containers are allowed to drain for half an hour (2). This allows pH and EC levels in the container time to stabilize. After the containers have drained, they are placed in collection trays. While clear plastic trays will work, they are less durable and are prone to cracking. This will cause a loss of some or all collected leachate. While more expensive, thicker plastic trays (like those used with ornamental pots) have more durability and will last longer for repeated use. After the containers are placed in the trays, enough irrigation water is poured on to cause roughly 50 ml of leachate to flow into the collection trays (3). This amount will vary with container size and plant. A rough estimation of how much irrigation water to use can be found using the following rule of thumb: 100 ml for every gallon, plus 50 ml. So a 7-gallon container would need roughly 750 ml of irrigation water poured on to cause 50 ml of leachate to come out. The final step is to take your readings. It is important to remember to take a reading of the irrigation water used as this is used during data interpretation.

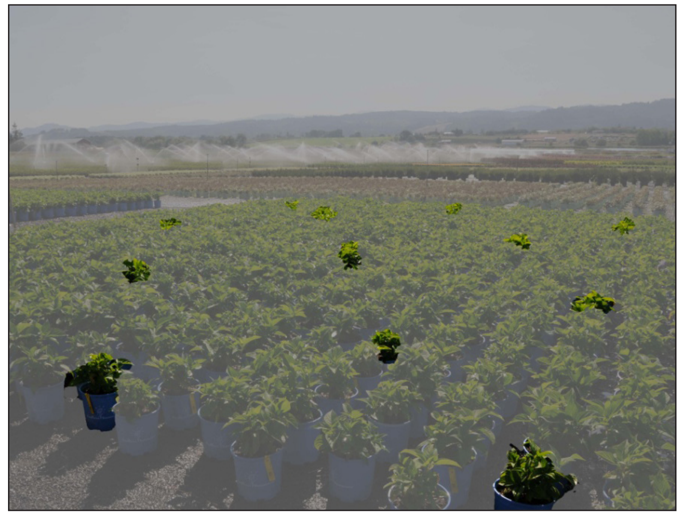

Figure 1. Selecting a representative sample in a block of containers.

In this study, ten 7-gallon 'Green Mountain' Boxwood (*Buxus* × *'Green Mountain'*) were used to monitor a block of plants. This block was irrigated with overhead irrigation pulled from a retention pond. These plants had not yet been fertilized for the year before this study was conducted. The pH and EC levels were read every two weeks during the course of this study. After two readings, the containers were top-dressed with 5-6 month 15-9-12 slow release fertilizer. Pour through readings were then taken until EC levels fell under levels recommended for periods of active growth (Table 1).

Table 1. Desired levels for pH and EC in container production.*

Analysis	Desirable levels: Solution only or CRF and solution	Desirable levels: CRF fertilizer only
pH	4.5 to 6.5	4.5 to 6.5
Electrical conductivity, µS/cm	800 to 1500	500 to 1000

*Adapted from Best Management Practices: Guide for Producing Nursery Crops (4).

Table 2. Average pH, soluble salts, and observed temperatures of 'Green Mountain' Boxwood from June 16 to October 20.

Date	Average pH	Average Soluble Salts (µS/cm)	Temperature (F)
16-Jun	5.92	-17	92
30-Jun	5.88	-8	88
14-Jul	5.91	974.28	91
28-Jul	5.67	1003.33	94
11-Aug	6.23	1075	83
25-Aug	5.94	1123	88
23-Sep	5.9	999	71
6-Oct	5.8	735.55	84
20-Oct	5.96	460	57

Results and Discussion

Before fertilizer application, the numbers indicate that the sample containers were feeding from the salts in the irrigation water. This was found by subtracting the observed irrigation water EC from the leachate EC. Fertilizer was applied after the readings taken on June 30. Two weeks later, EC levels were found to have risen to the high end of the desired range of 500 to 1000 µS/cm (Table 2). Over consecutive readings, EC levels were found to hover just above the desired level range (Figure 2). When EC levels are found to be higher than the desired range, there are a couple of steps a grower can take. First is to reduce the fertilization rate. After topdressing with a slow release fertilizer, this may not be a feasible option. The second option is to increase irrigation. This flushes more salts from the container and thus lowers EC levels (1). The observed pH levels in this study remained in the range of desired pH for active growing season (Figure 3, Table 1).

In this study, the EC levels were found to be below recommended levels for active growth on October 20. With their initial fertilizer application date of June 30, this is a life span of 111 days. At just under 4 months, this study finds results in line with the product label. At 90° F, this slow release granular fertilizer is rated to last 3-4 months. While advertised as 5-6 month fertilizer, this product's longevity is affected by temperature. The observed temperature during the course of this study averaged roughly 86°F.

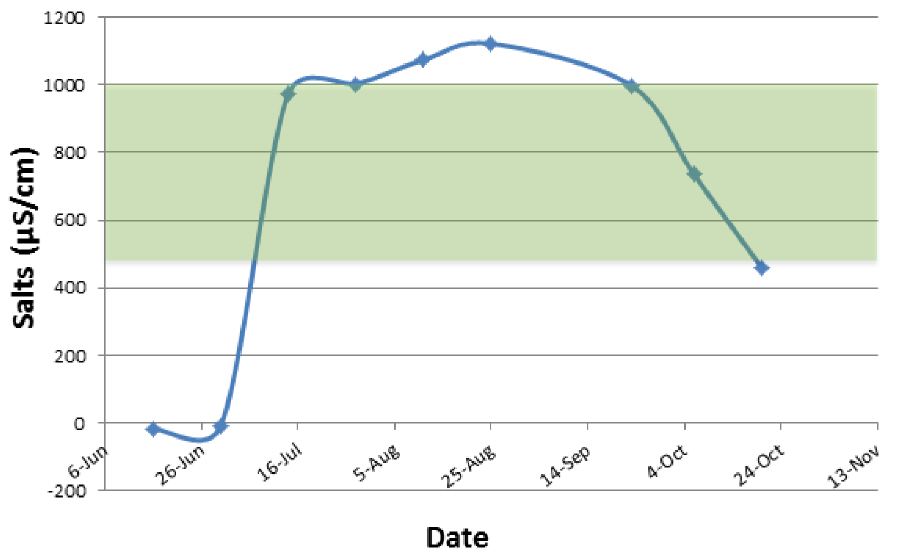

Figure 2. Soluble salt release in 'Green Mountain' Boxwood. Shaded area indicates desired range for periods of active growth.

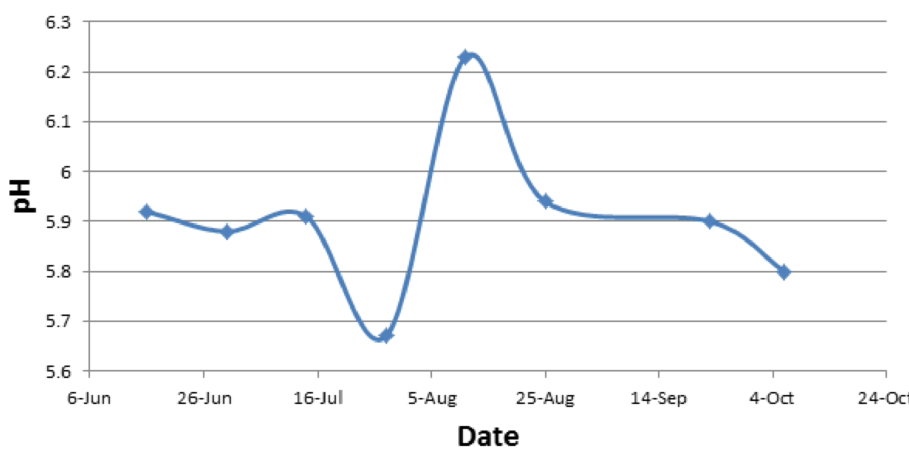

Figure 3. pH Levels of 'Green Mountain' Boxwood.

Significance to Industry

This study demonstrates how the pour through method of soluble salts and pH monitoring can be used to help adjust fertilizer application timing and amount. When using a slow release fertilizer similar to that used in this study, this technique can allow a grower to know whether reapplication is required. This can also help growers to develop more efficient fertilization strategies. If a grower notices that his slow release fertilizer is consistently running out, they may consider moving to a longer lasting product. The pour through technique is also quite important for those running fertigation as it allows the grower to be sure that their injection system is properly calibrated.

In the past, pH/EC/TDS combination meters were expensive pieces of equipment. Now, however, they are affordable enough for the smallest of nursery operations. In this study, the Hanna® Instruments 9811-5N pH/EC/TDS meter was used. This meter is an example of an all-in-one style meter that uses a single probe to take both pH and EC readings. With the reduction of price on this and other meters, the pour-through technique becomes an even more procedure for monitoring container pH and soluble salt levels.

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Product Trial: RootTrapper®-in-Pot Insert

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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, preventing 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 (4). This method, however, might be considered less than ideal as the concept of sustainability becomes more important.

The RootTrapper®-in-Pot insert made by the RootMaker® Company was designed to address several of the issues with pot-in-pot including root escape and root circling (7). In the UKREC PnP facilities, 76 Shummard Oak (*Quercus shumardii*) liners were containerized, half in Nursery Supplies® GL6900 #15 standard plastic liner pots and half in the RTIP15ER RootTrapper®-in-Pot insert. The liners were grown from seed by a local propagator using RootTrapper 5 gallon bags. This particular model of the insert is open-sided to assist in fabric removal at planting (Figure 1). Two sides of the containers have overlapping layers of the fabric designed to provide an easy tearing surface for removal from the root ball. The liners were potted in a pure pine bark mix and were top-dressed with a 15-9-12 slow release fertilizer. No copper treatment or any other root control methods were used on any of the containers, nor were the containers rotated.

Figure 1. The open-sided RootTrapper®-in-pot Insert is designed to make removing the container easier.

Table 1. Average calipers, root ball ratings, and escaped root count of standard plastic containers and RootTrapper-in-pot inserts.

	Plastic Container	RootTrapper
Average Starting Caliper (Inches)	0.782	0.782
Average Finished Caliper (Inches)	1.855	1.959
Average Caliper Gain (Inches)	1.069	1.175
Average Root Ball Quality	2.568	3.676
Average Number of Escaped Roots	9.342	6.763

Once the trees reached an average caliper of roughly 2 inches, they were evaluated for levels of root escape, root circling, and increase in trunk caliper. Roots above the root hair size escaping the containers were counted and calipers of roots escaping through the socket pot were taken. After the containers were removed, they were judged on a quality scale of one to five, with one being a poor quality root ball and a five being a high quality root ball.

Results and Discussion

The liners started at an average caliper of 0.8 inch caliper and were grown to an approximate caliper of 2 inches (Table 1). The trees were then 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. However, after a second season of growth, the fabric containers showed roughly a tenth of an inch more growth with an average caliper of 1.959 inches while the standard plastic containers averaged a caliper of 1.855 inches. Other studies have found similar results with fabric containers showing faster caliper growth (1).

While the fabric containers did have root escape, the escaped roots were slightly fewer in number. The bags averaged 6.7 roots escaped per container while the standard plastic containers averaged 9.3. With the open-sided model of this product, there was

Figure 2. Root escape through the side opening on the RootTrapper®-in-pot insert.

a chance for an opening to form when the bags were placed in the socket container. When they are placed in the socket pot, the fabric can slide down and the overlapping layers can be pushed apart. This creates an opening for roots to escape (Figure 2). For this reason, fewer roots may be expected to escape when using the closed sided fabric bags.

Fifteen total trees were observed to have roots escaping through the drain holes in the socket pots. Ten of these trees were standard plastic containers with an average root caliper of 0.60 inches. The remaining five trees were fabric containers with an average root caliper of 0.63 inches. Calipers were measured for the largest escaping root at the interior side of the socket pot drain holes.

Root circling was found to be reduced in all fabric containers. A rating scale was developed to measure the level of circling control observed in this study (Figure 3). Root balls were rated between 1 to 5, with 1 being the lowest score and 5 the highest. Using this rating scale, the fabric containers were found to have an average rating of 3.68 while the standard plastic containers averaged a score of 2.57. Fabric container scores ranged from 2 to 5 while standard plastic container scores ranged from 1 to 4.

Significance to the Industry

Root morphology is highly important to plant establishment in the landscape. Smaller, juvenile roots are the site of water and nutrient uptake while more mature roots are often hardened off (5). This makes plant production methods that discourage larger roots in favor of a more course root system desirable for growers who wish to produce a product that will establish well in the landscape. Results from this study certainly seemed to suggest that this product encourages a courser root system with smaller overall roots.

Circling roots have the ability to affect the long term survival of a tree. Circling roots can begin to girdle a tree as its trunk becomes large enough to block the proper formation of the Xylem (3). In the long term, a girdled tree would be expected to decline (6). Therefore, methods of production that help prevent this circling may contribute to the long-term survival of the plants being produced. This product was observed to reduce circling overall with an average root ball quality rating of 3.68 over the standard plastic container's score of 2.57.

Production methods with the potential to help eliminate some of the issues commonly faced in container production are continually being improved upon. While fabric containers have been around for a long time, their design has changed significantly since their inception. With this particular product, the white layer on the exterior has the potential to help prevent root lose to extreme temperatures faced when the containers are removed from the pot-in-pot socket. Surface temperatures may be reduced enough to prevent the roots from reaching a temperature at which they may become damaged.

Another feature introduced with this particular product was the overlapping open sides as opposed to standard closed sides. This feature was designed to make the removal of the fabric from the root surface easier and to allow growers to reuse the bag by not cutting it off. However, in this study, the fabric was still quite

Figure 3. Root ball rating scale, 1 to 5. A root ball rated at one displayed large circling roots covering most of its surface. A two has half large circling roots and half small circling roots. A three has mostly small circling roots covering the entire root ball. A four has few circling roots. A five has no root circling.

difficult to remove from the root ball. Removal was observed to take a significant amount of time when trying to preserve the bag. Fabric removal was hastened by tearing the container at the seams, though this did prevent reuse. A cooperator in this study also reported similar difficulty in bag removal.

This open-sided feature also made proper instillation highly important as allowing the bags to slide down at all created openings for escaping roots. These open sides also made it necessary to pot the liners up directly in the socket pots. With the open sides, the root ball will fall apart without the support of the socket pot until the liner has completely rooted in. It is worth noting that this product does come in a normal closed-sided version as well that may eliminate some of these issues.

Financially, these containers are cheaper in cost than the Nursery Supplies® GL6900 to which it was compared in this study. This product was purchased for $4.95 per unit, while the average cost of the GL6900 is $8.64. This reduction in cost could be compounded if the containers were to be reused. As noted before, however, preserving the bag at removal was found to be difficult and time consuming.

Overall, this product does address the issues it was designed to fix, while creating a few new ones of its own. Root ball quality was better overall with a notable reduction in root circling over that of the traditional plastic container. Root escape was reduced, but it may be found to be reduced more when using the closed sided version of this product. The open sided feature of this product does create extra steps at potting as well as increased opportunity for root escape.

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Plant Growth Regulators for Size Control of Tomato, Eggplant, and Cucumber Transplants for the Retail Garden Center Market

Rebecca Schnelle and Victoria Anderson

Nature of Work

Many bedding plant growers include vegetable transplants in their spring product line. These vigorous species can often grow too large for their containers in a very short time. Overgrown transplants fare poorly through shipping and in the retail environment. For years there have been no Plant Growth Regulators (PGRs) labeled for size control of vegetable transplants. In 2008, a supplemental label for Uniconazole (Sumagic formulation; Valent USA Corporation, Walnut Creek, CA), a gibberellins biosynthesis inhibitor, was released to allow foliar sprays on select vegetable species including tomato and eggplant. Other products including N-(phenylmethyl)-1H-purine-6-amine, commonly referred to as N6-benzyladenine (Configure formulation; Fine Americas, Walnut Creek, CA), and Dikegulac Sodium (Augeo formulation; OHP, Inc., Mainland, PA) are being investigated for use on vegetable transplants to control size as well as to enhance branching. Enhanced branching has the potential to produce a more attractive transplant for the retail garden center market. Augeo and Configure are not currently labeled for use on vegetable transplants; however, the manufacturers have expressed interest in pursuing such labels. Augeo is considered a 'chemical pinching' agent; it breaks the apical dominance and produces lateral branching by disrupting the integrity of the cell walls in the apical meristem. Configure, a synthetic cytokinin, is intended to control height while stimulating lateral branching of treated plants.

There are several non-chemical methods to control transplant height include negative DIF (night temperatures higher than daytime temperatures), mechanical brushing, limiting phosphorous, and light quality manipulation (Duman and Duzyaman, 2003; Garner and Bjorkman, 1997; Johjima et al., 1992; Li, et al., 2000; Rideout and Overstreet, 2003). However, each of these methods requires significant labor input, precise greenhouse temperature control, or investment in materials. Many greenhouse growers do not have access to the necessary funds or infrastructure to successfully implement these methods. These methods may also have undesirable side effects. Obviously limiting phosphorous may lead to deficiency, producing a weaker plant. Mechanical brushing can potentially cause a reduction in total number and weight of fruits in certain cultivars of tomato (Johjima et al., 1992). Chemical height control agents can be applied with any type of sprayer and in some cases tank mixed with other chemicals thus requiring very little additional labor. Research has shown that Uniconazole applications to tomato transplants do not have negative side effects on fruit timing, fruit set, fruit size, or fruit flavor characteristics (Schnelle and Ruberg, 2010; Wang and Gregg, 1990; Zandastra, et al., 2006). There has been very little research on the efficacy of PGR applications for control size of cucumber and eggplant transplants.

Seeds of Cucumber 'Salad Crop,' Eggplant 'Black Beauty,' and Tomato 'Early Girl,' were sown in on 2 Aug. 2011 in 36-cell trays filled with a growing medium consisting of 6.5 sphagnum peat : 2 perlite : 1.5 vermiculite (v/v) (Fafard #2 medium; Conrad Fafard Inc., Agawam, MA). All plants received clear water for the first week followed by constant liquid feed of 15N-2.2P-8K at 150 mg·L^{-1} N (Peters 15-5-15; The Scotts Company, LLC., Marysville, OH).

Sumagic, Augeo, or Configure were applied as foliar sprays using a hand sprayer at a rate of 2 L·m^{-2} except one treatment in which sumagic was applied as a medium surface spray one day after sowing. As designated by the treatments outlined in table 1, the PGR sprays were applied at specific concentrations and development stages. Sprays were applied at the following development stages: cotyledon expansion, 1-2 true leaves expanded, 3-4 true leaves expanded, at the cotyledon stage and repeated 7 days later, or at the cotyledon stage then repeated both 7 and 14 days later. Sumagic was applied at 2.5, 5, or 10 mg·L^{-1}, Configure was applied at 300, 600, or 1200 mg·L^{-1}, and Augeo was applied at 200, 400, or 800 mg·L^{-1}.

Plant height for tomato and eggplant and stem length for cucumber was recorded for all plants at the market ready stage of development. Cucumber transplants were deemed market ready at the 3-4 true leaf stage (26 Aug.). Tomato and Eggplant transplants were deemed market ready at the 7-8 true leaf stage; 30 Aug., and 6 Sept., respectively. Branching was not observed in any treatments so branching data were not collected.

Results and Discussion

Plant response to the PGR applications was highly varied. Applications of Augeo resulted in plants as much as 72% larger than the untreated control plants while Sumagic applications produced plants as much as 76% smaller than the untreated control plants (Table 1). In no treatment was enhanced branching observed. In the ornamental plant market, plants that are about 30% shorter than untreated plants are generally considered well controlled. This level of height suppression usually results in an attractive plant that will resume normal growth in a reasonable amount of time for the end consumer. Plants that are over 50% shorter than a control plant may appear stunted and take longer than expected to resume normal growth.

All Sumagic applications to the tomato seedlings resulted in plants shorter than the untreated control at the market ready stage. Treated plants were 21% to 76% shorter than the untreated control plants. A single sumagic spray of 2.5 mg·L^{-1} at the cotyledon or 1-2 true leaf stages resulted in plants 38% or 43% shorter, respectively, than the control plants. Sprays at 5 or 10 mg·L^{-1} at these stages resulted in plants 55% to 64% shorter than the controls. Later applications resulted in less height suppression, but these plants may take longer to resume a normal growth rate (Table 1). This data is consistent with previous studies (Schnelle, 2009; Schnelle and Ruberg, 2010). These consistent results indicate that Sumagic can be effectively used to produce high quality retail tomato transplants. Augeo and Configure applications resulted in plants 11% taller to 21% shorter than control plants (Table 1). There was significant phytoxicity associated with Augeo applications as well. Given the lack of height control and absence of enhanced branching along with the negative side effects, these two products are not suitable for use on tomato transplants.

Sumagic applications to cucumber seedlings resulted in plants with 6% longer to 61% shorter stems than the untreated control plants. At 2.5 mg·L^{-1}, the size control achieved was variable, in fact the pre-germination media spray and spray at the cotyledon stage resulted in plants with longer stems. It is common for low concentrations of gibberellins inhibitors to stimulate stem elongation. At 5 mg·L^{-1}, the size control ranged from plants 31% to 52% smaller than the controls, indicating that this concentration is more suitable for cucumber (Table 1). However, additional research will be necessary to confirm this conclusion. The treatments with all concentrations of Augeo and at all stages of development resulted plants that were larger than the control plants. The Configure applications produced plants that were predominately not significantly different from the control group. Configure and Augeo are likely not suitable for use on cucumber.

The eggplant seedling growth was highly variable leading to difficulty in accessing the efficacy of the PGR applications. The standard deviation within treatments ranged from 31% to 66% of the mean. Additional research will be necessary to elucidate the efficacy of PGRs for height control of eggplant transplants.

Significance to Industry

This along with previous studies has shown that Sumagic is effective and safe for height control of tomato transplants. In fact, a number of Kentucky bedding plant growers have successfully adopted its use for their retail vegetable transplants including tomatoes and peppers already and more have expressed interest. Sumagic has the potential to improve quality of field bound tomato transplants as well. However, vegetable growers in general are not as familiar with PGRs as bedding plant growers so it will take more time and demonstrations to achieve widespread acceptance of Sumagic for field tomato transplants. At this time the Sumagic label does not include cucumber. Many growers report struggling to control the vigorous growth of cucurbit transplants including cucumber. With more research, it would be possible to add these plants to the label providing growers with a very useful tool. Augeo and Configure do not show the same promise and will likely not be labeled for use on vegetable transplants.

Table 1. Average heights of Tomato 'Early Girl,' Eggplant 'Black Beauty,' and Cucumber 'Salad Crop' plants sown on Aug. 2 at the market ready stage (Aug. 30, Sept. 6, and Aug. 26, respectively) following foliar sprays with either Sumagic (uniconazole), Augeo (dikegulac-sodium), or Configure (N6-benzyladenine) at the designated concentrations and development stages.

Product	Conc. ($mg \cdot L^{-1}$)	Development stage at spray	Height at market ready stage (cm)		
			Tomato	Eggplant	Cucumber
Control	-	-	35.5 abc[z]	13 abcde	20.4 fgh
Sumagic	2.5	Pre-germination	28.8 de	19.6 a	29.4 bcd
	5	Pre-germination	16 ghij	18.2 abc	14.1 jklm
	10	Pre-germination	14.6 hijk	8.2 ef	15.1 ijkl
	2.5	cotyledon	21.9 fg	15 abcde	21.6 efg
	5	cotyledon	13.7 ijk	4.8 f	10.4 lmno
	10	cotyledon	11.2 jk	14.3 abcde	8.0 nop
	2.5	1-2 leaves	20.3 fgh	16.4 abc	12.6 klmn
	5	1-2 leaves	12.7 ijk	15 abcde	9.9 mnop
	10	1-2 leaves	12.9 ijk	13.9 abcde	9.5 mnop
	2.5	3-4 leaves	26.2 ef	16.4 abc	-[y]
	5	3-4 leaves	28.4 de	12.1 cde	-
	10	3-4 leaves	24.8 ef	15.1 abcde	-
	2.5	cotyledon and 7 days later	17.5 ghi	12.3 bcde	5.6 op
	5	cotyledon and 7 days later	8.7 k	8.6 def	5.2 p
	2.5	cotyledon, 7, and 14 days later	17.2 ghi	13.1 abcde	5.9 op
Augeo	200	cotyledon	28 de	15.5 abcd	35 a
	400	cotyledon	37.4 ab	11.5 cdef	25.8 cde
	800	cotyledon	32.8 bcd	12.1 cde	26.5 cde
	200	1-2 leaves	39.3 a	16 abc	30.6 abc
	400	1-2 leaves	33.5 abcd	19.3 ab	28.8 bcd
	800	1-2 leaves	32.6 bcd	15.3 abcd	33.2 ab
	200	3-4 leaves	30.5 cde	12.1 cde	-
	400	3-4 leaves	29.3 de	15.8 abcde	-
	800	3-4 leaves	33.5 abcd	14.7 abcde	-
Configure	300	cotyledon	32.8 bcd	14.6 abcde	24.6 def
	600	cotyledon	37.7 ab	16.1 abc	22.4 efg
	1200	cotyledon	33.9 abcd	13.3 abcde	15.5 hijkl
	300	1-2 leaves	30.7 cde	13.5 abcde	20 fghi
	600	1-2 leaves	28.2 de	14.7 abcde	21.7 efg
	1200	1-2 leaves	29.6 cde	17.8 abc	13.9 jklm
	300	3-4 leaves	33 bcd	11.5 cdef	-
	600	3-4 leaves	29.1 de	15.7 abc	-
	1200	3-4 leaves	29.7 cde	15.5 abcd	-

[z] Within-column means followed by different letters are significantly different by Tukey's Studentized Range test at $P \leq 0.05$

[y] Cucumber transplants were deemed market ready at the three- to four-leaf stage.

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