CONTAINER-GROWN PLANT PRODUCTION

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Section Editor and Moderator

Twenty-eight students competed In the Bryson L. James Student Research Competition and twenty-nine research projects were presented in poster form, which were displayed for review during the SNA Research Conference and Trade Show, this year. Their research is presented in the topical sections which follow and are designated as Student or Poster papers.

Effects of Mycorrhizal Fungi and Phosphorus on Drought Resistance of Containerized Neem Trees (*Azadirachta indica*)

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Nature of Work: The neem tree (*Azadirachta indica*) is of ornamental, reforestation, medicinal and biomass value in India, Myanmar, Southeast Asia, and Africa. The compound azadirachtin is extracted from neem seeds and is commercially used as an insecticide for controlling insect pests (National Research Council, 1992). Oil extracted from the neems seeds can control plant fungal diseases, such as powdery mildew and rust (Becker, 1994).

The survival of neem trees under drought conditions - which is a common phenomenon of many sites where it is planted, may depend on vesicular-mycorrhizal fungi (VAM). Little information is known about naturally occurring VAM associations in neems. The benefits of VAM on growth enhancement, improvement of nutrient uptake, and diminishing abiotic stresses have been reported in a wide range of host plants from annual crops to woody perennials (Smith and Gianinazzi, 1988). Neem is commonly propagated by seed and grown in nurseries for 3-5 months before it is transplanted to productions sites (Benge, 1989). Preinouculation of neem seedlings with efficient VAM fungi would potentially enhance growth, reduce transplants shock and increase rate of survival and growth after transplanting, as reported in the production of other woody plant species (Strong and Davies, 1982: Graham, 1986; Davies and Call, 1990).

The objectives of this research were to determine: the effect of drought on growth, nutrient uptake, gas exchange, water relations, water use efficiency, and changes in leaf carbon isotope discrimination in VAM and Non-VAM neem trees of similar size and tissue P concentration. The possible roles of VAM association on a change in root to shoot ratio, osmotic adjustment, and soil aggregate formation that may be associated with increased water uptake and turgor maintenance and improved drought resistance were characterized.

Results and Discussion: Rooted cuttings of the neem tree (*Azadirachta indica* A. Juss) were grown for 65 days at 4 levels of soil phosphorus (P) supply: 0, 15, 30, and 60 mg $P.kg^{-1}$ soil (0, .00024, .00048, .00096 $oz.lb^{-1}$). Half of the plants were inoculated with the vesicular arbuscular mycorrhizal (VAM) fungus *Glomus intraradices* at transplanting. VAM and Non-VAM plants of comparable size and tissue nutrition responded to drought similarly. As a function of soil P supply, however, VAM compensated for low P supply, allowing VAM plant to have comparable growth, tissue P, and other physiological parameter as Non-VAM plants - which received higher P supply. Drought decreased growth, leaf area, transpiration, photosynthesis, stomatal conductance, leaf water potential and turgor, but had less effect on relative water content and osmotic potential. Neem tree leaves had low osmotic potential even under nonstressed conditions. Osmotic adjustment did not occur, but the relatively low osmotic potential allowed turgor maintenance at peak stress. Plant water relations and photosynthesis of stressed plants recovered to the level of non-stressed plant after rehydration, while stomatal conductance and transpiration partially recovered.

Significance to Industry: The nursery industry stands to benefit from naturally occurring mycorrhizal symbionts that potentially help reduce fertility and irrigation needs and reduce pesticide usage during production. VAM enhanced growth and photosynthetic rate at the two lowest soil P levels. Increased A was attributed to increased stomatal conductance and greater leaf P concentrations. The benefits of VAM symbiosis are of interest for a low input-sustainable agricultural system both at the nursery production stage and field production stage. Preinoculation of neem trees during the nursery production stage will enhance plant growth at lower fertilizer supply, which can reduce production costs and minimize the amount of fertilizer in runoff water and environmental pollution. This has application to woody plant commercial nursery production systems in the US .

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Composted Cotton Gin Trash as Substrate Amendment for Greenhouse Production

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Nature of Work: Growing substrate for ornamental production normally consist of at least two different materials to acquire the desired performance. Organic components, such as, peat moss and softwood and hardwood bark are becoming increasingly expensive making the search for alternatives more feasible. Composted cotton gin trash is a plentiful source in many areas of this country and is a major economic problem of disposal for cotton ginners and producers. Not only is the majority of this potentially valuable resource not being utilized, current mean of disposal is costly. Four common methods are used to dispose of cotton gin thrash: incineration, spreading on soil, feeding to livestock, or solid waste disposal at government approved sites. A solution to this problem would greatly benefit the cotton industry (3). Inorganic arsenic was used in cotton production from the late 1800's until the middle 1960's. Calcium arsenate was the major arsenical used in cotton production. In the middle 1960's, there was a change from use of inorganic arsenical herbicides to organic arsenical chemicals. Two common arsenic compounds used in cotton production are monosodium methane arsenate (MSMA) and disodium methane arsenate (DSMA) (1). Composted cotton gin thrash has been shown to be a valuable substrate amendment for adding nutrients and improving the water holding capacity, thus, improving plant growth (2).

Salvia coccinea, Carharanthus roseus, Tagetes erecta, and *Euphoris pulcherrima* were grown in a greenhouse with eight substrates. Substrate components included pine bark, sharp sand, sphagnum peat, and composted cotton gin thrash. A standard substrate consisting of a 5:1:1 volume per volume ratio of pine bark, sphagnum peat, and sharp sand, respectively was used for comparison . The sphagnum peat portion of the standard substrate was replaced with composted cotton gin trash, at 10, 20, 30, 40 and 50 percent by volume, for five of the eight treatments. Sunshine #1 and Baccto are commonly used commercial substrates and were included in this study.

Substrates used are listed in Table 1. Ammonium nitrate was applied with each irriagation at 200 ppm N until bedding plants were harvested. Fertilizer, 200 ppm N from calcium nitrate was applied to the poinsettia with each irrigation. After four weeks, fertilizer rate changed to 300 ppm ding plants as indicated in root appearance (Table 2).

Significance to Industry: Alternatives to existing growing substrates must evaluated to assist the producer in finding efficient alternatives while providing a means of recycling waste products. Such information will assist the producer with production decisions involving media substrate alternatives.

Table 1. Shoot appearance of greenhouse crops as influenced by growth substrate.

Substrate	Vincax	Marigold	Salvia	Poinsettia
Sunshine #1	6.08 c	3.58 d	4.92	3.91 d
Baccto	7.75 b	5.08 c	4.08 d	7.00 a
Standard	5.83 c	5.42 c	5.00 c	3.25 d
10 %	7.25 b	5.50 c	7.08 b	4.42 cd
20 %	8.00 b	7.33 b	9.00 a	4.33 cd
30 %	9.33 a	7.75 ab	9.33 a	6.00 b
40 %	8.83 a	8.33 a	8.75 a	4.92 c
50 %	9.42 a	8.17 a	9.25 a	6.92
lsd	.80	0.80	0.80	0.80

[x]Shoot visual rating, based on the overall appearance, was assigned to each plant and was calculated along a scale ranging from 1 to 10, 1 being worst and 10 being best.

Table 2. Root appearance of greenhouse crops as influenced by growth substrate.

Substrate	Vinca[x]	Marigold	Salvia	Poinsettia
Sunshine #1	6.50 c	4.92 c	6.92 b	3.00 d
Baccto	7.25 bc	5.08 c	6.25 bc	5.00 b
Standard	5.58 d	5.67 c	5.91 c	3.83 c
10 %	6.92 c	6.58 ab	6.75 b	4.42 bc
20 %	8.00 b	6.58 ab	7.75 a	3.08 cd
30 %	9.00 a	7.42 a	6.75 b	4.83 b
40 %	7.41 bc	6.08 b	7.08 ab	3.83 c
50 %	8.50 ab	7.17 a	7.08 ab	6.00 a
lsd	0.83	0.83	0.83	0.83

[x]Root visual rating, based on the overall appearance, was assigned to each plant roots and was calculated along scale ranging from 1 to 10, 1 being worst and 10 being best.

Effects of Composted Cotton Gin Trash on Growth Substrates

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Nature of Work: Growing substrate for ornamental plant production may comprise of different materials. Organic components, such as various types of peat moss, softwood and hardwood barks are becoming increasingly expensive and scarce, resulting in a need for alternative sources of growing substrate. Composted cotton gin trash (CCGT) is a plentiful substrate source in many areas of this country. It is a major economic problem for cotton ginners and producers to dispose of this product. Four common methods are used to dispose of cotton gin thrash: incineration, spreading on soil, feeding to livestock, or solid waste disposal where a ginner dumps cotton gin trash in a landfill or pays a contractor to haul it away. Therefore, a solution to this disposal problem would greatly benefit the cotton industry (3). Inorganic arsenic was used in cotton production from the late 1800's until the middle 1960's. Calcium arsenate was the major arsenical used in cotton production during this time. In the middle 1960's, a change from inorganic arsenical herbicides to organic arsenical chemicals took place. Two common arsenical compounds used in cotton production are monosodium methane arsenate (MSMA) and disodium methane arsenate (DSMA) (1). Composted cotton gin thrash has been shown to be a valuable substrate amendment for adding nutrients and improving water holding capacity, thus, improving plant growth. However, it is not widely accepted because of potential arsenic contamination (2).

Salvia coccinea, Carharanthus roseus, Tagetes erecta, and *Euphoris pulcherrima* were grown in a greenhouse using various amounts of pine bark, sharp sand, spagnum peat and composted cotton gin trash (CCGT). A substrate consisting of a 5:1:1 volume per volume ratio of pine bark, sphagnum peat, and sharp sand, respectively was used as the standard for comparing the other substrate. Sphagnum peat in the standard substrate was replaced with composted cotton gin trash, at 10, 20, 30, 40 and 50 percent by volume, for five of the eight treatments. Sunshine #1 and Baccto, two commonly used commercial substrates, were also included in this study. Substrates used are listed in Table 1. Ammonium nitrate was applied with each irriagation at 200 ppm N until the bedding plants were harvested. However, the 200 ppm N used in fertilizing the poinsettias was obtained from calcium nitrate. After four weeks, the fertilizer was changed to 300 ppm of N using Peter Excel 15-5-15 Ca/Mg applied at each irrigation. Treatments consisted of six replications in a complete randomized design. Growing substrates were analyzed for bulk density, percent pore space, percent air space, water holding capacity, pH, total acidity, total soluble salts, phosphorus (P), potassium (K), calcium (Ca),magnesium (Mg), sodium (Na), zinc (Zn), arsenic (As) and DEF.

Results and Discussion: Physical properties of growth substrate containing increments of CCGT showed a decrease in bulk density, increase in percentage pore space, and decrease percentage air space for 40 and 50 percent CCGT when compared to standard substrate. Water holding capacity increased for 40 and 50 percent CCGT as compared to the standard (Table 2). Root substrate containing CCGT had a higher pH, total acidity, total soluble salts, K, Ca, Mg, Na, and Zn as compared to the other growth substrates (Table 3). Arsenic levels increased with additional CCGT to growth substrates but did not effect plant growth. Substrate pH, total acidity, total soluble salts, phosphorus, potassium, calcium, magnesium, and sodium were highly correlated with CCGT concentration.

Significance to Industry: CCGT had pronounced effects on the physical properties of the substrates when compared to standard substrate. As the amount of CCGT increased, bulk density decreased, but air space and water holding capacity increased. Air space and water holding capacity increased in substrates containing CCGT as compared to the commercial substrates. Addition of CCGT to the growth substrate had more pronounced effects on the chemical properties than the physical properties. Arsenic levels in the growth substrates containing various amounts of CCGT were not a problem thus, making substrate containing CCGT an excellent starter fertilizer.

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Table 1. Substrates reflecting percentage of various components.

Substrate[yz]	Sphagnum Peat Moss	Sand	Pine Bark	Composted Cotton Gin Trash
............................Percentage by volume............................				
Substrate	14.29	14.29	71.42	0
1	0	10	80	10
2	0	10	70	20
3	0	10	60	30
4	0	10	50	40
5	0	10	40	50

*Two Commercial Substrates, Sunshine # 1 and Bacto Professional Mix, were also included among the treatments used.

[y]Percents of amendment are by volume.

[z]The standard substrate was amended using 4 lbs yd^{-3} of P_2O_5 and 2 lbs yd^{-3} Micromax and 5 lbs yd^{-3} Dolomitic limestone. Media 1-5 were amended using 2 lbs yd^{-3} Micromax.

Table 2. Bulk density (BD), percentage pore space (PPS), percentage air space (PAS), water holding capacity (WHC), and arsenic (AS) of eight growth substrate.

Growth Substrate	BD	PPS	PAS	WHC	AS
Sunshine #1	0.06 g[W]	82.42 b	11.41 a	71.01 b	0.17 e
Baccto	0.13 f	96.42 a	9.63 ab	86.79 a	0.54 d
Standard	0.46 a	73.25 c	9.45 ab	63.80 c	1.55 bc
10 %	0.40 c	73.25 c	10.53 ab	62.72 c	1.63 b
20 %	0.36 d	71.92 c	13.21 a	58.71 c	1.63 b
30 %	0.40 c	73.75 c	12.38 a	61.38 c	1.28 c
40 %	0.32 e	77.67 bc	7.98 ab	69.68 b	2.15 a
50 %	0.42 b	70.67 c	3.54 b	69.88 b	2.33 a
lsd	0.02	8.67	7.15	5.30	0.29

[W]Means averaged over six replications and separated within columns by lsd at P = 0.05 level. Means followed by the same letter are not significantly different.

Table 3. Chemical characteristics of eight growth substrates at time of planting.

Growth Substrate	pH	BpH[X]	TSS[Y] (dS m-1)	P (ppm)	K (ppm)	Ca (ppm)	Mg (ppm)	Na (ppm)
Sunshine #1	5.7 d[W]	6.9 bc	1.3 bc	25 e	194 f	942 f	288 f	60 c
Baccto	4.2 f	5.6 f	0.9 c	34 e	159 f	1254 ef	548 e	52 c
Standard	4.4 e	6.1 e	0.5 d	73 d	145 f	1545 e	131 g	53 c
10 %	5.7 d	6.7 d	0.6 cd	111 c	544 e	2923 d	442 d	65 c
20%	6.4 c	6.9 c	0.9 cd	145 b	887 d	3687 c	679 c	75 c
30%	6.7 b	7.0 b	1.4 b	165 a	1435 c	4819 b	984 b	97 bc
40%	6.9 ab	6.9 bc	1.6 b	170 a	1684 b	5116 b	1065 b	111 b
50%	7.0 a	7.1 a	2.8 a	169 a	2970 a	7038 a	1499 a	167 a
lsd	0.20	0.07	0.41	10.48	80.77	385.79	121.22	37.75

[W]Means averaged over six replications and separated within column by lsd at P = 0.05 level. Means followed by the same letter are not significantly different.

[X]BpH equals acidity of substrate.

[Y]TSS equals total soluble salts of substrate.

Impact of Coir-based Media in Azalea Growth

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Nature of Work: Peat moss is often used as a component of azalea potting media. However, the cost, quality, and availability of peat moss has lead to the evaluation of alternative products as peat substitutes. Coconut coir pith is the material left when long fibers have been separated from coconut husks (2). Media using coconut coir pith as a component have been used to successfully produce a variety of plant material (2-5). However, sales literature from sources selling coconut coir pith maintain that the pH of coconut coir pith averages over 6.0, considerably higher than the pH of peat moss. Although the incorporation of dolomitic limestone has either no or a negative impact on azalea growth (1, 6), many growers still incorporate it into their azalea mixes. Addition of a high pH peat alternative may complicate the azalea production process. Therefore, the objective of this experiment was to evaluate coconut coir-based media for azalea production at 2 rates of lime incorporation.

Uniform liners (10 in^3/cell) of *Rhododendron obtusum* 'Girard's Rose', *Rhododendron indicum* 'Formosa', and *Rhododendron eriocarpum* 'Pink Gumpo' were transplanted into 3 quart pots on April 19, 1997. The experiment was terminated on April 20, 1998. All plants were top-dressed with 18 g of Osmocote 17-7-12. The growing media were 4 composted pine bark (cpb):1 sand (s), 3 cpb:1 peat moss (pm):1 s, 3 cpb:1 coconut coir pith (ccp):1 s, 2 cpb:2 ccp:1 s, 1 cpb:3 ccp:1 s, and 4 ccp:1 s. Dolomitic limestone was incorporated at 0 or 2 lb/yd^3. All plants were grown under 33% shade. Treatments were a 6 (media) x 2 (liming rate) factorial arranged in a randomized complete block design with 6 single plant replicates.

Electrical conductivity (EC), pH, growth indices (GI), and foliar color ratings (FCR) were recorded monthly following treatment initiation. Electrical conductivity and pH were measured for 2 replications of Girard's Rose at each sampling date. Growth indices and foliar color ratings were measured for all plants. Growth indices were defined as (height + width1+ width2)/3 where width1 was measured at the widest point of the canopy and width2 was measured perpendicular to the widest point of the canopy. Growth indices are reported as the growth increase since study initiation. Foliar color ratings were on a scale of 1-5 with 5 being dark green and 1 being severely chlorotic. Root ratings were taken at the end of the experiment. Root ratings were on a scale of 1-5 with 5 having 100% of the root ball covered with roots and 1 having 0% of the root ball covered with roots.

Results and Discussion: Electrical conductivity and pH were similar at the end of the experiment regardless of media or liming rate (data not shown). Electrical conductivity and pH of media averaged 0.11 and 7.1, respectively. Electrical conductivity and pH for liming rates averaged 0.20 and 7.1, respectively.

Formosa - There were no differences in shoot growth regardless of media or liming rate, and growth averaged 41.7 for both (Table 1). Foliar color ratings were higher for plants grown in 3 cpb:1 ccp:1 s compared to plants grown in 4 ccp:1 s, and all other treatments were similar (Table 1). Liming rate did not influence foliar color ratings (data not shown). Root ratings were lowest for plants grown in 4 ccp:1 s compared to plants grown in all other media (Table 1). Replacing peat moss with coconut coir pith resulted in similar root ratings. Liming rate did not influence root ratings (data not shown).

Girard's Rose - Plants grown using coconut coir pith had greater growth compared to plants grown with 4 cpb:1 s (Table 1). Plants grown using 3 cpb:1 pm:1 s were similar to all other plants, and amount of coconut coir pith in the media had no influence on plant growth. Liming rate had no influence on growth (data not shown). Neither media (Table 1) nor liming rate (data not shown) influenced foliar color ratings of Girard's rose. Root ratings were lowest for plants grown in 4 ccp:1 s compared to plants grown in all other media (Table 1). Replacing peat moss with coconut coir pith improved root ratings. Liming rate did not influence root ratings (data not shown).

Pink Gumpo - Neither media (Table 1) nor liming rate (data not shown) influenced growth of pink Gumpo. Foliar color ratings were higher for plants grown using 3 cpb:1 ccp:1 s, 1 cpb:3 ccp:1 s, and 4 ccp:1 s compared to plants grown using 3 cpb:1 pm:1 s or 2 cpb:2 ccp:1 s (Table 1). Replacing peat moss with coconut coir pith increased foliar color ratings. Liming rate had no influence on foliar color ratings (data not shown). Plants grown using 3 cpb:1 ccp:1 s, 2 cpb:2 ccp:1 s, 1 cpb:3 ccp:1 s, or 4 cpb:1 s had higher root ratings compared to plants grown using 4 ccp:1 s (Table 1). Replacing peat moss with coconut coir pith had no influence on root ratings. Liming rate also had no influence on root ratings (data not shown).

Significance to Industry: The results of this research again demonstrate that liming of azalea media is unnecessary. Plant growth was not influenced by replacing peat moss with coconut coir pith for 3 azalea cultivars. Additionally, foliar color ratings of Pink Gumpo and root ratings of Girard's Rose were actually increased when coconut coir pith was substituted for peat moss. Coconut coir pith can provide a viable alternative to peat moss for azalea production.

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Table 1. Influence of media and liming rate on growth, foliar color, and root ratings for Formosa, Girard's Rose, and Pink Gumpo azaleas.

Media	Formosa	Girard's Rose	Pink Gumpo
Growth			
4 cpb:1 s	42.0ax	26.0b	19.3a
3 cpb:1 pm:1 s	43.5a	28.3a	20.1a
3 cpb:1 ccp:1 s	40.6a	29.0a	21.1a
2 cpb:2 ccp:1 s	43.6a	30.2a	20.7a
1 cpb:3 ccp:1 s	42.1a	30.8a	21.0a
4 ccp:1 s	38.5a	29.0a	21.0a
Foliar color rating[z]			
4 cpb:1 s	2.5ab	2.1a	3.2bc
3 cpb:1 pm:1 s	2.5ab	2.4a	3.1c
3 cpb:1 ccp:1 s	2.6a	2.4a	3.3ab
2 cpb:2 ccp:1 s	2.5ab	2.4a	3.1c
1 cpb:3 ccp:1 s	2.5ab	2.4a	3.3ab
4 ccp:1 s	2.4b	2.4a	3.4a
Root rating[y]			
4 cpb:1 s	4.8ab	3.0bc	2.7ab
3 cpb:1 pm:1 s	4.9a	2.8c	2.6bc
3 cpb:1 ccp:1 s	4.6ab	3.5ab	2.7ab
2 cpb:2 ccp:1 s	4.5bc	3.8a	2.8ab
1 cpb:3 ccp:1 s	4.2c	**3.7a**	3.0a
4 ccp:1 s	2.8d	2.0d	2.2c

[Z]Foliar color rating where 5=dark green and 1=severely chlorotic.

[Y]Root rating where 5=100% root ball coverage and 1=0% root ball coverage.

[X]Means within the same column followed by the same letter are not different according to Fisher's Protected Least Significant Difference ($p<0.05$).

The Use of Vermicompost as a Media Amendment

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Nature of Work: Vermicomposting is defined as the breakdown of organic materials through the action of earthworms. This process is being put to use as a disposal system for the increasing volumes of agricultural manures being produced in this country (3). The horticulture industry has been interested in utilizing agricultural manures as extenders or constituent components of growing media (1, 5). In most cases, these organic wastes can not be used directly in media due to phytotoxicity, N immobilization, and high salt content. Vermicomposting stabilizes these organic waste materials.

The resulting material, vermicompost, is being investigated as a plant media component. It has been reported that vermicompost positively influences plant growth by increasing water-holding characteristics, containing significant nutrients, having plant hormone-like activity such as improving seed germination, and improving nutrient uptake (2, 4). The objective of this study was to evaluate the effects of vermicompost on the growth of bedding plant plugs.

Commercially produced vermicompost (VC) of pig manure origin (trade name Vermicycle, Vermicycle Organics, Inc.) was added to Metro Mix 360 to achieve VC:Metro Mix 360 (MM360) ratios of 0% VC, 10% VC, and 20% VC. Seeds were planted in 200 cell plug trays with an individual plug size of 33.3 mm x 44.45 mm containing one of the selected media mixes. 'Rutgers' tomato, 'Queen Sophia' french marigold, and 'California Wonder' green pepper were sown at a rate of one seed per cell. Beginning seven days after germination, five seedlings were sampled from each media mix treatment. Seedling emergence, leaf area, and the dry weights of shoots and roots were determined daily for 12 days. All analyses of plant growth data were performed by analysis of variance and where treatments were significantly different, mean separation (LSD, P=0.05) was also used.

Results and Discussion: Seedling emergence was used as the determining factor regarding seed germination in VC amended media in plug trays. There was no promotion of seed germination in any media treatment (data not presented). The germination percentages were similar to the guaranteed germination of each seed batch within each species.

Response to media amendment with VC was species specific. Growth of 'Queen Sophia' french marigold amended with 10% VC resulted in increases in leaf area, shoot and root dry weights (Table 1) when measured at 12 days after germination (DAG). When grown in 20%VC 'Rutgers' tomato seedlings had greater dry shoot weight and leaf area than 0%VC (Table 1). Shoot dry weights and leaf areas were greater for 'California Wonder' pepper grown in the MM360 control than in the 20% VC amended media (Table 1).

Significance to the Industry: The data suggests that bedding plant seedling growth is enhanced by incorporation of vermicompost into the germination media. The use of vermicompost in soilless growing media can be a valuable amendment, particularly as the horticulture industry begins to accept alternative media components

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Table 1. Growth data of 'Queen Sophia' french marigold, 'Rutgers' tomato, and 'California Wonder' pepper harvested 12 days after germination in soilless commercial media amended with vermicompost at two different mix ratios.

	'Queen Sophia' french marigold		
Media	Shoot Dry Wt (g)	Root Dry Wt (g)	Leaf Area (cm^2)
0%VC	0.042 b[z]	0.018b	12.62b
10%VC	0.061a	0.026 a	17.34 a
20%VC	0.037 b	0.021ab	10.16b

	'Rutgers' tomato		
Media	Shoot Dry Wt (g)	Root Dry Wt (g)	Leaf Area (cm^2)
0%VC	0.040 b	0.009a	8.41b
10%VC	0.012ab	0.012a	9.61ab
20%VC	0.053a	0.012a	10.71a

	'California Wonder' pepper		
Media	Shoot Dry Wt (g)	Root Dry Wt (g)	Leaf Area (cm^2)
0%VC	0.031a	0.017a	11.48a
10%VC	0.027ab	0.006 b	10.49 ab
20%VC	0.023 b	0.005b	8.20b

[z]Mean separation within columns and species by least significant difference (LSD), P=0.05.

Monthly Growth Patterns for Red Maple Cultivars

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Nature of Work: Container production of shade and ornamental trees is increasingly important to the horticulture industry. Few studies have investigated specifically the growth periodicity of trees in container production systems (3,6,9). Growth patterns of ten red maple cultivars from the *A. rubrum* L. {Autumn Flame, Fairview Flame, Franksred (Red Sunset™), Landsburg (Firedance™), Olson (NorthfireTM), Northwood, and October Glory} and *Acer x freemanii* E. Murray (red maple x silver maple interspecific cross) {Armstrong, Celzam (Celebration™), and Jeffersred (Autumn Blaze™)} were evaluated using monthly destructive harvests in AHS Heat-Zone 8 (1), (USDA Hardiness Zone 8a). Cultivars included represent a broad cross-section of the red maples in production nationwide.

Materials and methods: Rooted cuttings or acclimated tissue culture liners 2-10" tall, obtained from commercial nurseries (A. McGill & Son Nurseries, Fairview, OR; Bailey Nurseries, St. Paul, MN; and J. Frank Schmidt and Sons, Troutdale, OR), were planted in March, 1996 prior to budbreak in #3 (9.1 l) containers in a pinebark:sand (6:1 v/v) substrate in Auburn, AL. Substrate was amended with 13.0 lb•yd^{-3} 23-4-8 Scotts Southern Formula (O.M. Scotts Co., Maryville, OH), 1.5 lb•yd^{-3} Micromax (O.M. Scotts Co.), and 5.0 lb•yd^{-3} dolomitic lime. Trees were arranged in a RCBD consisting of 9 blocks with 5 plants of each cultivar placed 2 ft on center (450 total plants) and grown in full sun with overhead irrigation supplied twice daily. Height and stem diameter increase data was collected every 30 days, beginning March 28, for one block of trees (50 total plants) through November 28, 1996. Height was taken from the substrate surface to the tip of the uppermost growing point; stem diameter at 2 in above the substrate. For total root growth over time, data was collected by frequent destructive harvests, beginning March 28, for one block of trees each month (50 trees/month). Roots (washed free of substrate) were oven dried at 140°F for 3 days prior to dry weight measurements.

Results and Discussion: More than 50% of height increase occurred in the month of June for all cultivars, with more than 75% of height increase accounted for by the end of July for all cultivars. The cultivars with the greatest height increase for the season were October Glory, Celzam, and Jeffersred, although there were other cultivars with similar height growth.

Large increases in diameter continued longer into the summer months than did height increases. More than 50% of diameter increase was achieved during the eight weeks from mid-June to mid-August, with more than 75% of diameter increase accounted for by the middle of August for all cultivars. Greatest final diameters and greatest diameter increases for the season were for *A. rubrum* cultivars Autumn Flame, Fairview Flame, and October Glory.

Root growth differences were minimal through the first 5 harvests (data not shown). Approximately 25% of the total season root growth had occurred by the end of Aug. with the remaining 75% of root growth equally distributed between the months of Aug. and Nov. Greatest final and seasonal root dry weight increases were found for A. *x freemanii* cultivars Jeffersred and Celzam; and *A. rubrum* cultivars Autumn Flame and October Glory.

The greatest overall growth (when both height, diameter, and root growth increase were considered), was for ‘Autumn Flame’ and ‘October Glory’, both *A. rubrum* cultivars, followed by A. *x freemanii* cultivars Celzam and Jeffersred. The least overall growth was for *A. rubrum* cultivars Northwood and Landsburg.

Significance to the Industry: This study provides good information regarding the impact of a long growing season on growth of container-grown trees. Considerable gains in growth may be obtained by selecting for early budburst and by encouraging rapid spring development. Early budburst is associated with a small chilling requirement, a small thermal time to budburst or both; the two are genetically variable within a species (4). However, early budburst involves an increased risk of early frost damage (2). In this study growth began for five cultivars in April, but not until May for the other five cultivars. Height growth was complete for all cultivars by the end of August, with the exception of ‘Northwood’ which did not show height increase after the end of July.

Stem diameter increases were similar to those reported from previous short-term container studies with red maple (5,7). Diameter growth, while different across cultivars, was not great enough to confer a marketable advantage to any cultivar from a container production standpoint. Based on common practice in the nursery industry and the *American Standard for Nursery Stock* (1990), for trees of a similar height, diameter increases are usually considered marketable in 0.25 in increments up to 2 in. While more than 75% of height and diameter growth for the season was complete for most cultivars before mid-August, only 25% of the final root growth had occurred by the end of August. The functional balance between roots and shoots is normally perturbed by periodicity in the activity of the shoots during a season, and by short-term changes in the environment (2). Current assimilates are used preferentially by the shoots during their elongation, and by the roots in the fall, after shoot elongation has ceased (2). Based on results seen in the current study, we believe there are positive implications for fall transplanting and early spring growth as a result of the root activity seen through Nov. During the late summer and fall carbohydrate reserves are stored in the stems and thick roots and are important for rapid spring regrowth (2,8). This information is beneficial for growers selling a finished product to homeowners or shifting up to larger containers. However, longer term evaluations in field studies or urban landscapes to evaluate fall color, limb and scaffold strength, frost cracking, and pest resistance are necessary to present a complete picture of the desirability of newer introductions.

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Growth Response of Daylily to Bioconverted Swine Solids and Irrigation Volume

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Nature of Work: Swine waste, a by-product of North Carolina's booming hog industry, holds little economic value for hog farmers. Indeed, odors associated with conventional waste management methods and the potential for environmental damage from mismanaged lagoons have turned swine waste into a liability. However, bacterially-digested swine waste (BSW), produced by a proprietary waste treatment system (Bion Technologies, Inc., Smithfield, NC), has been shown to be an effective source of slowly available nutrients in containerized plants (Flinn et al., 1998). Not surprisingly, the addition of BSW to pine bark changed the physical properties of pine bark-based substrates, which would presumably necessitate an adjustment in irrigation protocol (Flinn et al., 1998). Developing a protocol for one of our state's most underutilized resources could reduce total nutrient inputs into the environment by encouraging its use in container production. Therefore, we evaluated the effects of BSW rate and irrigation volume on containerized daylily and azalea.

The 4x4 factorial split plot experiment was conducted on a gravel pad at the Horticulture Field Laboratory of North Carolina State University, Raleigh, NC. Bare root divisions of 'Wilson's Yellow' daylily and rooted cuttings of 'Girard's Red' azalea were potted into 3.8 l (#1) containers on April 22, 1997. Subplot levels of substrate treatment were: a) commercial substrate - pine bark amended with 4.1 kg Scott's High N Southern Formula (23-4-8), 306 g Micro Max minor elements package and 3.6 kg dolomitic limestone; b) 10% BSW – 1:9 BSW:pine bark (by volume); c) 20% BSW – 2:8 BSW:pine bark; d) 30% BSW – 3:7 BSW:pine bark. Nitrogen rates in BSW treatments bracketed that of the commercial substrate. Main plot levels of daily irrigation volume (400, 600, 800, 1000 mls per day) were administered in split applications with an irrigation controller. Water was delivered to plants through a spray stake located in each container. All treatment combinations were replicated four times. Periodically, samples of substrate solution were extracted from azalea substrates via the pour-through nutrient extraction method (Wright, 1986). Shoots of both species and daylily roots were harvested, dried at 62C for 5 days and then weighed. Shoots were subsequently analyzed for foliar nutrients (analyses performed by the Agronomic Division, North Carolina Department of Agriculture). Data were tested for differences with ANOVA and regression analysis. Means separations were based on least significant differences at p (0.05.

Results and Discussion: *Electrical conductivity (EC) and pH.* Initial EC levels for BSW substrates ranged from 2.4 dS/m (10%BSW) to 6.5 dS/m (30%BSW), all of which were in excess of the optimum range (0.5 to 2.0 dS/m). This was expected in unleached containers immediately after potting (Flinn et al., 1997). By the sixth week, EC levels for BSW substrates stabilized within the optimum range where they remained for the duration of the study. In comparison, EC readings for the commercial substrate averaged 1.1 dS/m throughout the study period. In general, plants irrigated with 400 mls of water had higher EC readings than those irrigated with 1000 mls.

pH. Initially, pH of 30% BSW (pH=7.1) was significantly greater than that of 10% BSW (pH=6.6) and the commercial substrate (pH=6.4) at 800 and 1000 mls of irrigation volume. An increase in irrigation volume corresponded with an increase in pH in the 10% BSW substrate. By the end of the study, the pH of 30% BSW (pH=6.7) was significantly greater than that of 10% BSW (pH=6.0) which, in turn, was greater than that of the commercial substrate (pH=4.9). Increasing irrigation volume corresponded to an increase in pH for the 20% BSW treatment. Throughout the study, 10% BSW and 20% BSW maintained pH within the optimal range of 5.2-6.5 without the added cost of dolomitic limestone. Interestingly, the commercial substrate pH fell below the range by the end of the study.

Foliar Nitrogen. Foliar levels of nitrogen and potassium dropped to deficient levels by July 1 in BSW treatments. We applied 9 gm of the fertilizer used in the commercial substrate on July 3 to all test substrates except for the commercial substrate. By the end of the study, irrigation volume had had no effect on azalea foliar nitrogen and, for the most part, in daylily. Daylily foliar nitrogen decreased as irrigation volume increased. Although foliar nitrogen in BSW treatments was generally significantly lower than that of the commercial substrate, all were within optimum growing ranges.

Plant Growth. Daylily dry shoot weights were similar for plants grown in BSW and the commercial substrate (Table 1). Similarly, differences in root growth were not significant except for one irrigation treatment. When irrigated with 800 mls of water daily, daylily roots grew significantly larger in the commercial substrate (Table 2) than than in BSW substrates. Differences in azalea shoot weight among substrates were not significantly different except for the following: at 800 mls of irrigation those plants grown in 10% BSW and 20% BSW were smaller than those grown in other substrates as were azaleas grown in 30% BSW plants at 1000 mls (data not shown). Irrigation volume had no linear effect on either daylily shoot or root growth (Tables 1 and 2, respectively) or azalea shoot growth (data not shown).

Significance to the Industry: This study demonstrated that BSW is an effective source of slowly available N, P, K and micronutrients in container-grown daylilies and azaleas. While N, P, and K supplements were necessary by mid summer, micronutrient reserves were sufficient throughout the study to maintain adequate foliar concentrations (data not shown). Interestingly, 10% and 20% BSW substrates sustained pH within the preferred growing range without the addition of dolomitic lime, while the pH of the commercial substrate fell below the optimal range by the study's end. While these data did not indicate that changes in irrigation volume influenced the performance of BSW with respect to plant growth, water volume did have a dilution effect on substrate nutrient concentrations. Therefore, when using BSW in container media, irrigation protocols should be chosen to minimize nutrient loss and optimize growth.

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Table 1. Daylily shoot growth (g) as influenced by bacterially-digested swine waste (BSW) and irrigation volume[z].

Irrigation	Substrates				Significance
Volume	10% BSW	20% BSW	30% BSW	Comm. Sub.	lsd.$_{05}$[y]
400 ml	24	30	29	31	9NS
600 ml	27	32	32	27	6NS
800 ml	27	34	28	34	6NS
1000 ml	39	35	36	33	8NS
Significance[x]					
lsd .05	8NS	7NS	8NS	8NS	
Regression	NS	NS	NS	NS	

[z]10/8/98.

[y]NS, **, * Not significant or significant at $p \leq 0.01$ or $p \leq 0.05$, respectively.

[x]Commercial substrate excluded from regression analysis.

Table 2. Daylily root growth (g) as influenced by bacterially-digested swine waste (BSW) and irrigation volume[z].

Irrigation	Substrates				Significance
Volume	10% BSW	20% BSW	30% BSW	Comm. Sub.	$lsd_{.05}$[y]
400 ml	16	16	14	22	9NS
600 ml	11	16	16	18	6NS
800 ml	12 By	14 B	12 B	18 A	6*
1000 ml	16	16	18	20	8NS
Significance[x]					
$lsd_{.05}$	8NS	7NS	8NS	8NS	
Regression	NS	NS	NS	NS	

[z]10/8/98.

[y]NS, **, * Not significant or significant at p (0.01 or p (0.05, respectively.

[x]Commercial substrate excluded from regression analysis.

[y]Means within rows followed by the same upper case letter are not significantly different.

Evaluation of Subdue® and Truban® on Five Azalea Cultivars

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Nature of Work: Root rot *(Phytophthora cinnamomi)* is a serious disease problem in azalea (*Rhododendron* sp.) production in the south. There are numerous fungicides labeled to control the disease responsible. Some of these fungicides are formulated as a granular to make application easier. They are usually incorporated into the media prior to planting. There is concern that some of these fungicides may be phytotoxic to young roots. Lee et al. (1983) reported a reduction of poinsettia roots (*Euphorbia pulcherrima*) treated with metalaxyl (Subdue), ferbam, PCNB, and ethazol fungicides. Hagan (1997) reported that neither the granular (15 oz/yd^3) or emulsifiable (2.5 fl oz/100gal) formulations of Subdue caused phytotoxicity to 'Fashion' azalea cuttings. However Truban 5G (etridiazole) (10 fl oz/100 gal.) did significantly reduce root length of 'Fashion' azalea cuttings. Hagan and Gilliam (1997) noted significant reductions in root growth and quality ratings for 'Fashion' azalea cuttings treated with Subdue (metalaxyl) (2.5 fl oz/100gal.) and Truban (etridiazole) (2.5, 5.0, 10.0 fl oz/100gal.). The literature suggests that some fungicides may be phytotoxic to azalea root growth but there is little information about their effect on the large number of azalea cultivars commonly grown. The objective of this study is to evaluate the phytotoxicity of various rates of Subdue (2G) and Truban 5G on five commonly grown azalea cultivars.

On March 28,1997 a study was initiated to evaluate Subdue (2G) and Truban 5G for phytotoxicity on five azalea cultivars. A base media of 100% pine bark was used. 4 lbs/yd^3 dolomitic lime, 1.5 lbs/yd^3 Micromax, and Osmocote 18-6-12 at a rate of 3 lbs N /yd^3 was incorporated into 100% pine bark as a base media. Nine fungicide treatments were used. For each treatment the granular fungicide was incorporated by hand into the previously mixed base media and placed in Lerio 015 containers. The treatments included a control with no fungicide and four rates of Subdue and Truban 5G. The rates were 4, 8, 12, and 16 oz/yd^3 (label rates are Truban 10 oz/yd^3 and Subdue 4-12.5 oz/yd^3). Five replications and five cultivars were used. One inch plugs of the five cultivars ('H.H. Hume', 'Coral Bell', 'Hot Shot', 'President Clay' and 'Formosa') were planted into the filled containers. In July of 1997 the plants were rated and harvested. A rating system where 1 = dead, 6 = commercially acceptable and 9 = highest quality was used to rate the shoots and the roots. The roots and shoots were dried for 48 hours at

60% C and dry weights were measured. Analysis of variance was conducted on the data and means were separated using Duncan's Multiple Range Test ($P \leq 0.05$).

Results and Discussion: Phytotoxic response to the fungicides varied with cultivar and rate. Root dry weight for 'Hot Shot' and shoot and root quality for 'President Clay' (Table 1) were reduced only by the highest rate (16 oz) of Truban. There were no significant reductions in plant quality or shoot dry weight for 'Hot Shot' or dry weight for 'President Clay. There were no reductions in plant quality or dry weight for either cultivar by the Subdue treatments. 'Hot Shot' had the smallest response to fungicide treatments of all the cultivars studied here.

Subdue treatments had no significant effect on quality or shoot dry weight of 'Formosa' (Table 2). Root dry weight was reduced by the 8 and 12 oz Subdue treatments. The 4 oz Truban rate did not reduce shoot quality, otherwise all Truban treatments reduced quality and dry weight for 'Formosa'. 'Formosa' appears to be more sensitive to Truban than to Subdue.

The 16 oz Subdue rate and the12 and 16 oz Truban rate reduced plant quality for 'Coral Bell' (Table 3). None of the fungicide treatments reduced dry weight. Only the treatments greater than the recommended label rates decreased plant quality.

'H.H. Hume' appeared to be more sensitive to the fungicides. The 4, 8 and 12 oz Subdue rates and the 12 and 16 oz Truban rates reduced shoot quality. The 4 oz Subdue rate and the 8, 12, and 16 oz Truban rates reduced root quality. Shoot dry weight was reduced by the 4, 8, and 12 oz Subdue rates and the 12 and 16 oz Truban rates. Only the 8 oz Subdue treatment and the 12 and 16 oz Truban treatment reduced root dry weight.

Significance to Industry: Good information on the phytotoxicity of common fungicides can be very useful to growers. The information gathered from this study indicates that etridiazole (Truban), at higher than recommended rates, can be phytotoxic to some azalea cultivars. 'Formosa' was negatively affected by all rates of Truban 5G . 'H.H. Hume' was negatively affected by most rates of both Truban 5G and Subdue 2G. It appears to have the greatest sensitivity to the fungicides used here. 'Coral Bells', 'Hot Shot', and 'President Clay' were either unaffected by fungicide treatment or only affected by treatments that exceeded recommended rates. It appears that in general the azalea cultivars here were more sensitive to Truban 5G than to Subdue (2G).

The mention of a pesticide or use of a trade name for any product is intended only as a report of research and does not constitute an endorsement or recommendation by Louisiana State University or The Louisiana Agricultural Experiment Station, nor does it imply that a mentioned product is superior to other products of a similar nature not mentioned.

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Table 1. The effect of incorporated fungicides on growth and quality of two azalea cultivars.

Fungicide Treatment oz/yd^3	'Hot Shot'				'President Clay'			
	Quality Rating[d]		Dry Weight (g)		Quality Rating		Dry Weight	
	Shoot	Root	Shoot	Root	Shoot	Root	Shoot	Root
0	5.5	5.6	6.2	4.2ab	7.0ab	6.6a	10.2	4.5
4 S[a]	4.3	4.6	4.3	2.9abc	6.3bc	5.5ab	14.0	3.2
8 S	5.5	5.9	6.6	5.3a	6.8abc	6.5a	10.0	6.2
12 S	5.6	5.1	5.9	4.1ab	7.0ab	6.6a	15.6	4.4
16 S	4.6	4.4	4.8	2.7abc	7.1a	6.3a	13.8	4.1
4 T[a]	4.7	4.8	3.9	2.5bc	6.9ab	6.3a	11.6	5.0
8 T	5.9	5.4	5.2	2.6abc	6.6abc	6.2a	10.1	3.0
12 T	4.5	4.4	3.9	1.7bc	7.3a	6.6a	12.6	4.2
16 T	3.9	3.1	1.8	0.7c	6.1c	4.7b	10.2	3.7
p-value	ns	ns	ns	0.025	0.0206	0.004	ns	ns

[a] S=Subdue (2G) and T=5G Truban
[b] means with the same letter are not significantly different for Duncan's Multiple Range Test.
[c] ns=not significant at the $p \leq 0.05$ level for General Linear Models Procedure.
[d] Quality ratings are from a 1 to 9 scale, where1=dead, 6=commercially acceptable and 9= highest quality.

Table 2. The effect of incorporated fungicides on growth and quality of 'Formosa' azalea.

Fungicide Treatment oz/yd^3	'Formosa'			
	Quality Rating		Dry Weight	
	Shoot	Root	Shoot	Root
0	7.9a	7.7a	23.2a	9.9a
4 S[a]	8.0a	7.4a	22.2a	9.7ab
8 S	7.5a	7.0a	20.2a	6.6cd
12 S	8.0a	6.8a	20.6a	6.8bcd
16 S	7.9a	7.2a	19.1a	8.3abc
4 T[a]	7.7a	5.7b	11.9b	5.7cd
8 T	6.4b	5.5b	12.0b	4.7d
12 T	5.9bc	5.6b	13.1b	4.7d
16 T	5.1c	5.3b	13.2b	5.6cd
p-value	0.0001	0.0001	0.0002	0.0018

[a] S=Subdue (2G) and T=5G Truban
[b] means with the same letter are not significantly different for Duncan's Multiple Range Test.
[c] ns=not significant at the $p \leq 0.05$ level for General Linear Models Procedure.
[d] Quality ratings are from a 1 to 9 scale, where1=dead, 6=commercially acceptable and 9= highest quality.

Table 3. The effect of incorporated fungicides on growth and quality of three azalea cultivars.

Fungicide Treatment oz/yd^3	'Coral Bells'				'H.H. Hume'			
	Quality Rating[d]		Dry Weight (g)		Quality Rating		Dry Weight	
	Shoot	Root	Shoot	Root	Shoot	Root	Shoot	Root
0	4.8ab	4.3ab	3.1	1.7	7.5a	7.8a	12.6a	4.8ab
4 S[a]	5.6a	4.4a	3.7	3.7	5.5bc	6.2b	6.5bc	3.2bcd
8 S	3.1bc	2.5bc	2.6	2.3	5.6bc	6.8ab	5.3c	2.3cd
12 S	3.2bc	3.0abc	1.8	1.6	4.9c	6.7ab	6.1bc	3.7bcd
16 S	2.4c	2.4c	1.7	2.1	6.1abc	7.3ab	8.4abc	3.9bc
4 T[a]	3.4abc	2.6abc	1.6	1.0	7.5a	7.6a	11.0a	6.3a
8 T	3.4abc	2.2c	2.1	1.1	7.0ab	6.4b	10.2ab	5.5ab
12 T	1.4c	1.6c	0.9	0.6	5.0c	3.4c	4.8c	1.5d
16 T	2.0c	1.7c	1.4	0.5	4.9c	3.2c	5.5c	1.9cd
p-value	0.008	0.013	ns	ns	0.003	0.0001	0.002	0.001

[a] S=Subdue (2G) and T=5G Truban
[b] means with the same letter are not significantly different for Duncan's Multiple Range Test.
[c] ns=not significant at the $p \leq 0.05$ level for General Linear Models Procedure.
[d] Quality ratings are from a 1 to 9 scale, where1=dead, 6=commercially acceptable and 9= highest quality.

Plant Responses To Sequential Use Of Spin Out®-Treated Containers During Up-Canning Is Species Specific

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Nature of Work: Two tree (*Quercus virginiana* Mill. and *Fraxinus velutina* Torr.) and two shrub species (*Myrica cerifera* L. and *Raphiolepis indica* Lindl.) were grown sequentially from seedlings (trees) or cuttings (shrubs) beginning with 0.24 L (2" liner cups), then 2.7 L (#1) black plastic nursery containers (Lerio Corp., El Campo, TX), and finally in 10.4 L (#3) for shrubs or 12.7 L (#5) containers for trees. One hundred forty-four plants of each species were planted in non-treated liners and 144 in liners treated on interior surfaces with 100 g•L^{-1} (7% wt.:vol.) $Cu(OH)_2$ in a latex carrier (formulated as Spin Out®, Griffin Corp., Valdosta, GA). As the majority of plants in liners reached a marketable size (based on ANLA standards) (1), they were transplanted to treated and non-treated 2.7 L (#1) containers. As marketable size was reached in the # 1 containers, plants were similarly transplanted to the largest container sizes. Transplanting was accomplished such that by the final stage of production eight container-wall treatment combinations were tested for each species. The result was a 2 x 2 factorial at the 2.7 L (#1) container stage and a 2 x 2 x 2 factorial design at the final container stage for each species. Twelve plants per species and container treatment combination were destructively harvested to determine dry matter partitioning and efficacy of control of circling roots at each transplant stage. Various growth measures and market ratings were assessed at each stage of production. Growth conditions in the nursery simulated as closely as possible those encountered in large volume production facilities within Texas as determined by Obst (2) via a modified Delphi technique.

The purpose of the experiments were to 1) determine the effects of factorial combinations of sequential use of $Cu(OH)_2$-treated containers during the production of four widely grown landscape plants and 2) to provide plant growth response data for use in later cost of production analysis.

Results and Discussion: Growth responses to Cu-treated containers were species and often production stage dependent. Some statistically significant differences ($P = 0.05$) occurred at the liner and #1 container stages, but the magnitude of the responses was likely not commercially significant (data not presented). Table 1 illustrates typical responses of the four species at the final container stages for selected shoot growth characteristics. In general, some positive responses occurred with *Q. virginiana* and *R. indica* in response to $Cu(OH)_2$-treated containers, but the best growth responses for *F. velutina* and *M. cerifera* were when non-treated containers were used at most production stages.

Significance to the Industry: Several studies have reported the morphological and physiological responses of various taxa to growth in Cu-treated containers (3). Most of these studies have concentrated on the performance of taxa in a single container growth stage. Of the few studies investigating post-transplant growth responses of taxa produced in Cu-treated containers, some reported positive responses due to Cu-treated containers on subsequent post-transplant growth and/or flowering (3). The present study was designed to investigate the effects of factorial combinations of Cu-treated and non-treated containers on sequential transplanting to larger containers. Results of this study suggest that growth responses to sequential use of $Cu(OH)_2$-treated containers is species and probably production stage dependent. The study suggests that early production stages may be the most cost effective stage at which to use $Cu(OH)_2$ treatments. This finding is supported by two observations: 1) treatment at early container stages are those that most often benefit plant effects in later production stages; and 2) less volume of Spin Out® was required to treat the liner and #1 container stages. Decisions on the use of Cu-treated containers should be based on the species, the desired stock size, and production system in use at the nursery. These studies do not take into account any long-term impacts on root system morphology associated with use or non-use of Cu-treated containers following post-transplant establishment in the landscape.

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Table 1. Selected shoot growth responses of four species to Cu(OH)2-treated or non-treated containers at marketable size in 10.4 L (shrubs) or 12.7 L (trees) containers.

Container treatments			Growth index		Trunk diameter	
0.24 L	2.7 L	10.4/12.7 L	*R. indica* (cm)	*M. cerifera* (cm)	*Q. virginiana* (mm)	*F. velutina* (mm)
-Cu	----	----	50 aY	60 a	24 a	27 a
+Cu	----	----	49a	52 b	25 a	27 a
----	-Cu	----	48 b	57 a	23 b	28 a
----	+Cu	----	51 a	56 a	25 a	27 a
----	----	-Cu	49a	59a	24a	28a
----	----	+Cu	50 a	54 a	24 a	27 a
-Cu	-Cu	----	48 a	60 a	23 a	28 a
-Cu	+Cu	----	51 a	60 a	24 a	27 a
+Cu	-Cu	----	49a	53a	24a	28a
+Cu	+Cu	----	50 a	51 a	25 a	27 a
-Cu	----	-Cu	49a	62a	24a	28a
-Cu	----	+Cu	50 a	59 a	23 a	27 a
+Cu	----	-Cu	49a	55 a	25 a	27 a
+Cu	----	+Cu	49a	49a	24a	27a
----	-Cu	-Cu	48 a	60 a	24 a	28 a
----	-Cu	+Cu	49 a	54 a	23 a	27 a
----	+Cu	-Cu	50a	57a	25a	27a
----	+Cu	+Cu	51 a	54 a	25 a	27 a
-Cu	-Cu	-Cu	48a	62a	23a	29a
-Cu	-Cu	+Cu	49a	59a	22 a	27ab
-Cu	+Cu	-Cu	51 a	62 a	25 a	27 b
-Cu	+Cu	+Cu	52 a	59 a	24a	27 b
+Cu	-Cu	-Cu	49a	58 a	24a	28ab
+Cu	-Cu	+Cu	48a	49a	23a	27ab
+Cu	+Cu	-Cu	50a	53 a	25 a	27 ab
+Cu	+Cu	+Cu	50a	50a	26 a	28 ab
ANOVA Effects						
0.24 L			ns[z]	*	ns	ns
2.7 L			*	ns	ns	ns
10.4 or 12.7 L			ns	ns	ns	ns
0.24 Lx2.7 L			ns	ns	ns	ns
0.24 L x 10.4/12.7 L			ns	ns	ns	ns
2.7 L x 10.4/12.7 L			ns	ns	ns	ns
0.24 L x 2.7 L x 10.4/12.7 L			ns	ns	ns	*

[y]Means within a column and container combination not followed by the same letter are significantly different using least squares means procedures (P= 0.05).

[z] *, **, ns = non-significance, significance at P = 0.05 or P = 0.01, respectively.

Biodegradable Fiber Containers Improve the Growth of 'Aztec Gold' Daylily

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Nature of Work: With concerns about recycling of black plastic containers, use of biodegradable containers manufactured from recycled paper fiber is an appealing alternative for nurseries and consumers. Some of the advantages of biodegradable fiber containers are increased aeration for better root development, insulation against high and low temperature extremes, and the containers are plantable or compostable. Experimental fiber containers treated with SpinOut (Griffin Corp., Valdosta, GA) have lasted longer under production conditions in south Georgia compared to nontreated fiber containers (1-3). While the use of SpinOut for root pruning in plastic containers is well known, there is little information known about using copper hydroxide in fiber containers to improve plant growth.

A study was conducted with *Hemerocallis* 'Aztec Gold' to evaluate growth and flowering in black plastic containers (BPC), black plastic containers treated with SpinOut (BPS), thin-walled fiber containers (Henry Molded Products, Inc., Lebanon, PA; thickness 1-3 mm) treated with SpinOut (FCt), and thick-walled fiber containers (Keiding, Inc., Milwaukee, WI; thickness 5-6 mm) treated with SpinOut (FCT). Both fiber containers were impregnated with 2800-3000 ppm copper hydroxide within the container walls as determined by inductively coupled plasma emission spectroscopy.

Plants were obtained from Wight Nurseries (Cairo, Ga) in 2.8 L (#1) containers. The initial number of fans per plant was approximately four. Potting substrate was milled pine bark and sand (4:1 by vol) amended with dolomitic limestone (7.0 lb/yd$^{3)}$ and 1.5 lb/yd^3 micronutrient mix (Graco Fertilizer Co., Cairo, GA). Plants were transferred from their original plastic containers (BPC) to the other containers in the study so that the same volume of substrate (0.68 gal) was added to each container type. The plants were placed on black woven ground cloth at a spacing of 6 in. between containers. Plants were fertilized with 30 g of High N Southern Formula (23-4-8; The Scotts Co., Marysville, OH) applied to the substrate surface. Plants were irrigated as needed at the rate of 0.5 inches using solid set sprinklers. The experiment was conducted at the Coastal Plain Station in Tifton, GA using a completely randomized design with six single plant replicates and was initiated on March 14, 1996. Numbers of flowers per plant were counted at peak bloom on June 12, 1996.

The study was terminated on October 3, 1996. A growth index [(height + width 1 + width 2 (perpendicular to width 1))/3) was measured. Final number of fans were counted. Root coverage (a visual rating of the amount of root area present at the container:substrate interface) was rated using the scale: 1 = < 25% of the container interface covered with white roots, 2 = > 25 but < 50% coverage, 3 = > 50 but < 75% coverage, and 4 = > 75% coverage. Foliage and root dry weights were determined after plants had been oven dried at 70C (158F) for 72 hours. Data were evaluated by analysis of variance and means were compared using the Waller-Duncan K-ratio t-test.

Results and Discussion: Plant height and growth indices increased up to 42% when plants were grown in the thick-walled FCT containers compared to BPC. There were no differences for height or growth index among the FCt, BPS, and BPC. Foliage dry weight increased up to 3x for plants in the FCT and FCt containers compared to the two plastic containers. Root dry weights of plants grown in the FCT and FCt containers increased 3.5-4x compared to plastic containers. Similarly, total biomass increased for plants grown in fiber containers. The root:shoot ratio of plants grown in the BPC was 2.0 compared to 3.8 for the FCt plants. The root coverage ratings were higher for plants in the fiber containers (~2.2) compared to plants grown in the plastic containers (~1.2). Container design had no affect on the number of flowers produced per plant (range 7.8 to 12.8). The final number of fans produced was greatest for the two fiber containers (FCt - 19.8, FCT - 17.7) compared to the plastic containers (BPC - 12.2, BPS - 11.8).

Significance to Industry: The data indicate that SpinOut-treated biodegradable fiber containers are beneficial for the production of ‘Aztec Gold’ daylilies. With the FCT, growth indices increased, shoot dry weight increased 300 percent and root dry weight increased approximately 400% compared to plants grown in BPC’s. Lower substrate temperatures and improved aeration for the plants grown in the fiber containers resulted in higher root ratings and root dry weights. Increased plant size and root development should be excellent selling points. The average daylily has a 300% fan increase rate which is what occurred for the plants in the plastic containers, compared to 443% for the FCT and 495% for the FCt. For the propagator, fiber pots could be beneficial for increasing the number of fans available for division from container-grown plants. The FCt’s began to deteriorate towards the end of the study so thicker-walled fiber containers would be beneficial for crop production cycles greater than six months.

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Pot-In-Pot Production and Fertilizer Rates Influence Growth of River Birch

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Nature of Work: Pot-in-pot production (PIP) is increasing in popularity in the southeastern United States (1,2,5). This new production method is being adopted by in-field nurseries and growers of larger container-grown trees. Recent studies have shown that PIP production can be less costly than conventional above-ground (CAG) or in-field production methods (1,2).

Fertilizer release from multicoated controlled release fertilizers is regulated by substrate temperature. Root-zone temperatures are consistently lower when plants are grown PIP compared to CAG production systems (3,4). To my knowledge, little if any research has been conducted on the effects of fertilizer rates on plants grown PIP. Therefore, the objectives of this study were to compare the growth of plants produced PIP and CAG with three rates of a controlled release fertilizer.

The experiment was conducted outdoors under full sun at the University of Georgia Coastal Plain Station, Tifton. Uniform liners of *Betula nigra* 'Cully' Heritage were transplanted from 2.8 l (#1) containers to 26 l (#7) containers in May, 1996. Potting substrate consisted of milled pine bark and sand (8:1 by vol) amended with micronutrients at 0.6 kg/m3 (1.0 lb/yd3) and dolomitic limestone at 3.0 kg/m^3 (5.0 lb/yd^3). Substrates were surface-incorporated to a depth of 2.5 cm (1.0 in) with 23N-1.7P-6.6K (23-4-8, High N - Southern Formula; The Scotts Company, Marysville, OH) at the rates of 2.2, 2.8, and 3.4 lbs. N/yd^3 on 31 May, 1996. Holder pots were placed in the ground with 2.5 cm (1 in) at the top of the pot remaining above grade.

The experiment was a randomized complete block with two container production systems (PIP and CAG), three fertilizer rates, and six replications. Cyclic irrigation [~1033 ml (35 oz)] was applied three times per day at 8:00, 12:00, and 4:00 PM. Irrigation was applied using 160^o low volume spray emitters (Roberts Irrigation, San Marcos, CA). All containers (PIP and CAG) had SpinOut-treated landscape fabric placed beneath the bottom of the planted container to eliminate any problems with rooting-out into the surrounding soil.

On 29 October, 1996, final plant height and width measurements were taken. Growth indices were calculated as: [(height + width 1 + width 2 (perpendicular to width 1))/3]. Shoot dry weight and root dry weight were determined after drying in a forced-air oven for 72 hr at 65.5C (150F). Substrate was removed from the root system before drying. Total biomass was calculated as the sum of shoot and root dry weights.

Foliage was removed after dry weight was determined, ground to 20 mesh, and duplicate 1 g samples were analyzed for N by macro-Kjeldal. Phosphorous was determined using a molybdovandate method while leaf K, Ca, Mg, Zn, Mn, Fe, and Cu were determined by atomic absorption spectrophotometry. At 15, 30, 60, and 120 days after fertilizer application (DAA), the pour-through method was used to collect container substrate leachate. Soluble salts (dS/m) and pH of leachate samples were determined using a conductivity meter and pH meter, respectively. Nitrate-N concentrations were determined with ion specific electrode. Data analysis for all parameters were evaluated by analysis of variance and regression analysis where appropriate.

Results and Discussion: Growth indices of plants grown PIP were 7% larger compared to plants produced CAG, but production system had no effect on plant height. For PIP plants, shoot dry weight and root dry weight were 20% and 31% greater, respectively, than plants grown CAG. The increase in shoot and root dry weight resulted in a 27% increase in total biomass. The root:shoot ratio increased 12% when plants were grown PIP.

Fertilizer rate had no effect on growth indices, root dry weight or total biomass. Shoot dry weight increased linearly as fertilizer rate increased. At the highest rate of application (3.4 lbs. N/yd^3), shoot dry weight increased 34% compared to the lowest rate. The root: shoot ratio decreased linearly as rate of fertilizer application increased, ranging from 2.1 at the lowest rate to 1.6 at the highest rate.

Production system had no influence on the concentration of foliar nutrients. Fertilizer rate influenced foliar Mg, Zn, and Fe. Both Mg and Zn decreased linearly as rate of fertilizer increased while Fe showed a curvilinear response to rate of application. The ratio of P to Zn increased with rate of fertilizer. Production system had no effect on soluble salts or nitrate-N until 60 DAA when both parameters were greater for CAG plants compared to PIP. At 120 DAA, nitrate-N in the leachate was higher for the CAG plants. Soluble salt and nitrate-N levels increased linearly as rate of fertilizer increased at 15 and 60 DAA. Rate of fertilizer application had no affect on soluble salts and nitrate-N at 30 DAA and there was a curvilinear response to fertilizer rate for both parameters at 120 DAA.

Significance to Industry: Plants grown PIP produced more biomass in terms of shoot and root growth compared to a CAG production system. Fertilizer rate had no effect on growth indices but did increase shoot dry weights, indicating that a denser canopy was produced by putting more dry weight into the same volume of space. Production system and rate of fertilizer application had no effect on tree height.

Fertilizer rate had minimal affects on foliar nutrient concentrations. For both production system and fertilizer rate, soluble salt levels were below the recommended minimum of 0.2 dS/m at 30 and 120 DAA while nitrate-N concentrations were generally within or above the acceptable range of 15 to 25 ppm for controlled release fertilizers. With the PIP system, slower fertilizer release rates coupled with increased nutrient uptake due to a larger root system should increase plant growth and fertilizer longevity as well as decreasing the potential for nutrient leaching.

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Production of 'Rotundiloba' Sweetgum Using Tex-R Agroliners

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Nature of Work: Tex-R Agroliners (Texel USA Inc., Henderson, NC) are needlepunched, nonwoven polypropylene bags treated on one side with a latex coating of Spin Out (copper hydroxide) to control root circling and rooting-out when used in a modified pot-in-pot system called bag-in-pot. Previous work in Canada (1) and Georgia (4) indicated that experimental Agroliners worked well controlling root growth of several species.

Rooting-out is a well documented problem for producers of pot-in-pot plants (2,3). Spin Out (Griffin Corporation, Valdosta, GA) has been useful for reducing rooting-out problems but does not eliminate the problem (2,3). Several landscape fabrics have been evaluated for controlling rooting-out with varying degrees of success (2,3). Treating field-grow bag material with Spin Out complicated removal of the fabric due to the extensive root branching which occurred (2). Difficulty in removing field-grow bags from the root system is considered to be one of the limitations of the grow bag system. Previous research has shown that Tex-R Agroliners could be easily removed from the rootball of two ornamental tree species (4).The purpose of this study was to evaluate the effects of different production systems and Tex-R Agroliner bags on the growth and rooting-out of 'Rotundiloba' sweetgum.

The experiment was conducted outdoors under full sun at Okefenokee Growers in Folkston, Ga. Uniform liners in #3 containers of Liquidambar styraciflua 'Rotundiloba' were potted into #15 containers during the spring of 1996. Potting substrate consisted of milled pine bark, Florida peat moss and sand (51:34:15 by vol) amended with 2.0 lb. of Micromax (The Scotts Company, Marysville, OH) and 6 lb. of Milorganite (Milwaukee, WI) per cubic yard.

The treatments were: 1) control (above-ground), 2) pot-in-pot, 3) bag-in-pot (Tex-R Agroliner inside a #15 container which was placed into the ground similar to pot-in-pot), and 4) bag-in-ground (similar to a field-grow bag system). The study was initiated in June of 1996. Plants were fertilized with Woodace 20-6-10 (Vigoro, Winter Haven, FL) at the rate of 225 g per container at the initiation of the study and with Leonard's Ornamental Mix 22-6-14 (Harrell's, Inc., Lakeland, FL) at the rate of 170 g per container in March of 1997. Plants were irrigated as needed using low volume spray stakes. The study utilized a completely randomized design with 15 single plant replicates.

Plant height and stem diameter were measured in June, 1996, February, 1997 and at the end of the study in November, 1997. At the termination of the study, plant harvestability (had the roots growing out of the containers or bags anchored the plants into the surrounding soil so they could or could not be lifted by two men) and root dry weight outside of the planted container or bag was determined. Data was analyzed using analysis of variance with mean separation by Waller-Duncan K-ratio t-tests.

Results and Discussion: Production system had no influence on plant height or stem diameter during the course of this study. Mean initial plant height and stem diameter across treatments was 43 in. and 0.5 in., respectively. Plant height did not increase between June 1996 and February 1997 but the change in stem diameter across treatments was 0.4 in. Final plant height was 7.3 ft. and final stem diameter was 1.7 in. Plant height and stem diameter increases across treatments for the period between February 1997 and November 1997 were 3.7 ft. and 0.8 in., respectively.

All control and bag-in-pot trees were harvestable. Eighty-five percent of the pot-in-pot trees were harvestable whereas none of the bag-in-ground trees could be harvested without the use of a shovel. Plants grown pot-in-pot had the greatest root dry weight outside of the planted container with 38.1 g. Bag-in-ground plants had 23.5 g of roots outside of the bag compared to 10.1 g for the bag-in-pot plants. Control plants grown above-ground had no roots growing out of the containers into the soil.

Significance to Industry: Production system had no affect on plant height or stem diameter increases in this study. The ‘Rotundiloba’ sweetgum plants used in this study were grown on their own roots and did not appear to be as vigorously-rooted as seedling sweetgums. Similar to previous research (1,4), the Tex-R Agroliner used in this study (150 g/m^2 of fabric) effectively controlled rooting-out in a bag-in-pot production system. The difficulty in harvesting the bag-in-ground plants was not due to rooting-out but rather the fact that the bags sagged in the middle when placed into the augered holes, thus lodging themselves into the holes. The soil type was extremely sandy and the surrounding soil molded to the shape of the bags over time. Simple prying of the bags with a shovel easily facilitated removal of the bags from the ground. No root circling was observed on the plants grown in the Tex-R Agroliners and they were easily removed from the rootball at the end of the study. Results of this study indicate that Tex-R Agroliners may be useful for bag-in-pot or bag-in-ground production of certain tree species.

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Evaluation of Deciduous Holly Production in USDA Zones 7b and 8b.

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Nature of Work: Deciduous hollies are grown for their colorful fruit display in the fall and winter as well as their foliage in the summer. The three most common species grown are *Ilex decidua, Ilex serrulata,* and *Ilex verticillata*, a small tree, large shrub, and small to medium shrub, respectively. Deciduous hollies have a wide potential geographic distribution with some species being hardy from USDA zones 4 to 9 (Dirr, 1988). Flowers of these species are dioecious and form on new spring growth and second year spurs (Maleike, 1979). Other species of male hollies blooming at the same time can serve as effective pollinators (Dirr, 1988; Klingaman, 1981; Maleike, 1979). Many cultivars of deciduous hollies exist and offer a wide range of sizes. *Ilex decidua* and *I. verticillata* are both native to North America and are common in the nursery trade (Klingaman, 1981). The objective of this study was to evaluate the production of cultivars of *I. decidua* and *I. verticillata* in USDA hardiness zones 7b and 8b.

One year, bedded liners of 3 cultivars of *Ilex decidua* ('Red Cascade', 'Sentry', 'Warren's Red') and 7 cultivars of *Ilex verticillata* ('Afterglow', 'Cacapon', 'Jim Dandy', 'Red Sprite', 'Sunset', 'Southern Gentleman', 'Winter Red') were potted into full 1 gallon or trade 2 gallon containers on 8 April 1996. After planting, the plants were trimmed to 4 inches measuring from the rim of the pot. All side canes below 1 inch above the soil on the primary cane were removed at planting. All treatments were replicated 5 times and were located at the Mississippi State University campus in Starkville, Mississippi (USDA zone 7b) and at the South Mississippi Branch Experiment Station in Poplarville, Mississippi (USDA zone 8b). Plant size and dry weight was measured after 1 (spring 1997) or 2 years in production (spring 1998). The medium used was composed of 4 parts bark: 1 part sand: 1 part peat (v/v/v) with 1 lb./yd^3 Micromax, 4 lbs./yd^3 Dolomite, and 10 lbs./yd^3 17-7-12 Osmocote (The Scott's Co., Marysville, OH). The experiment was arranged in a split plot design split by location. Each spring during production the plants were fertilized with 27 or 39 grams Osmocote 17-7-12 for the 1 or 2 gallon containers respectively. Those plants remaining for the second year harvest were transplanted to full 3 or trade 5 gallon containers respectively in early June 1997. The plants grown in zone 7b were overwintered in an unheated, white poly covered greenhouse, and the plants grown in 8b were overwintered outdoors. Plant width at the widest point and width perpendicular to that point were used to obtain average plant width. Plant height and dry weight were also measured at harvest. Width and height were used in the following formula to calculate a plant size index: 3.14*(width/2)2*height.

Results and Discussion: After one year of growth there were no differences in dry weight or plant size between USDA hardiness zones 7b or 8b (table 1). There was, however, less growth and dry weight accumulation than after two years growth. Plants grown at the zone 7b location grew larger and weighed more after two years than those grown in zone 8b. The exception was *I. verticillata* 'Cacapon'. While it did grow larger the second year in zone 7b, it did not differ in dry weight between locations. 'Sentry', Warren's Red', 'Jim Dandy', 'Sunset', and 'Winter Red' did not differ in size when grown one or two years in zone 8b. All cultivars increased in dry weight when grown for two years.

The winter of 1997-98 was considered mild and the plants grown in zone 8b probably completed their spring growth flush before the spring application of fertilizer. In zone 7b the fertilizer preceded the spring growth flush. This is likely one explanation for the considerable size differences between plants grown in these two locations. However, five of the cultivars did not increase in size between the first and second year of growth in zone 8b. Another difference in growing conditions was a March freeze in spring 1998. While the zone 7b plants were still under protection, the zone 8b plants were putting out new growth when temperatures in south Mississippi dropped to below -1°C (29°F) for four days and as low as -4°C (25°F) one night. The plants were damaged slightly from this freeze.

'Red Cascade' and 'Sentry', both cultivars of *I. decidua*, did not differ in dry weight regardless the container size (table 2). All *I. verticillata* cultivars increased in dry weight when the container size increased. However, in addition to 'Red Cascade' and 'Sentry', 'Jim Dandy', an *I. verticillata* cultivar, did not increase in plant size with increasing container size. This may be due to the cultivar Jim Dandy's tendency to sucker from the roots. This can lead to many thin shoots which increase the plant dry weight without greatly increasing the overall size. After two years growth, 'Jim Dandy' had from 2 to 6 times as many canes as the other cultivars (data not shown).

Significance to Industry: The results indicate there is a cultivar dependent growth response in deciduous hollies to production location. In selecting cultivars for production, growers in the extreme south may not be able to grow all cultivars desired by northern buyers. *Ilex decidua* and *I. verticillata* fill two marketing niches: plants with fall color and winter interest, and native plants.

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Table 1. Plant size and dry weight by cultivar of deciduous holly grown in USDA hardiness zones 7b and 8b and harvested in the month of May after one or two years of growth.

	Dry Weight (g)				Plant Size Index			
	Year 1		Year 2		Year 1		Year 2	
Cultivar	7b[z]	8b	7b	8b	7b	8b	7b	8b
Ilex decidua								
'Red Cascade'	68cy	102c	380a	237b	0.032c	0.180bc	1.135a	0.341b
'Sentry'	85c	110c	307a	226b	0.067b	0.123b	0.773a	0.180b
'Warren's Red'	73c	122c	309a	194b	0.044b	0.156b	0.908a	0.198b
Ilex verticillata								
'Afterglow'	135c	131c	354a	237b	0.065c	0.084c	0.434a	0.171b
'Cacapon'	98b	105b	236a	237a	0.038c	0.062c	0.377a	0.195b
'Jim Dandy'	125c	126c	294a	208b	0.104b	0.090b	0.370a	0.139b
'Red Sprite'	119c	108c	232a	189b	0.063c	0.055c	0.261a	0.118b
'Southern Gent.'	124c	128c	339a	257b	0.154c	0.209c	0.764a	0.371b
'Sunset'	134c	132c	370a	247b	0.237b	0.240b	1.019a	0.388b
'Winter Red'	128c	153c	490a	240b	0.133b	0.151b	1.007a	0.247b

[z] USDA hardiness zone 7b (Starkville, MS) and 8b (Poplarville, MS).

[y] Means separation within cultivar using Student-Newman-Keul's, P=0.05.

Table 2. Plant size and dry weight by cultivar of deciduous holly grown in two different size containers. There were no interactions between container size and location grown or between container size and harvest date.

	Dry Weight (g)		Plant Size Index	
Cultivar	1&3 gallon[z]	2&5 gallon	1&3 gallon	2&5 gallon
Ilex decidua				
'Red Cascade'	184ay	196a	0.429a	0.428a
'Sentry'	168a	183a	0.267a	0.296a
'Warren's Red'	151b	202a	0.258b	0.442a
Ilex verticillata				
'Afterglow'	182b	238a	0.146b	0.217a
'Cacapon'	148b	188a	0.133b	0.204a
'Jim Dandy'	168b	203a	0.159a	0.192a
'Red Sprite'	147b	173a	0.096b	0.152a
'Southern Gent.'	189b	242a	0.332b	0.445a
'Sunset'	189b	255a	0.364b	0.594a
'Winter Red'	206b	293a	0.306b	0.473a

[z] Trade 1 gallon and true 2 gallon were used the first year and then plants were transplanted to trade 3 and true 5 gallon containers respectively for the second year of growth.

[y] Means separation within cultivar and variable measured using Student-Newman-Keul's, P=0.05.

Growth of Red Maple Cultivars in Multiple Locations Affected by Production Environment

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Nature of Work: National and regional surveys have shown red maple to be one of the most frequently planted trees (2, 9). Several field studies have been conducted in the Southeastern United States to determine performance of red maple cultivars (6, 7, 10). Container production of shade and ornamental trees is increasingly important to the horticulture industry. However, limited information regarding container production of red maple cultivars is available. Studies have demonstrated effects of different climates on growth of field (7) and container-grown plants (3, 5, 8). In this study, growth of eight container-grown red maple cultivars at four locations in Georgia and Alabama with different environmental conditions (Table 1) and irrigation practices was evaluated for two years. Rooted cuttings and tissue cultured plantlets 2-10 in (5-25 cm) tall of *Acer rubrum* and *A.* x *freemanii* cultivars (Table 2), were obtained from A. McGill & Son Nurseries, Fairview, OR; Bailey Nurseries, St. Paul, MN; Grassland Nursery, Muscle Shoals, AL; and J. Frank Schmidt and Sons, Troutdale, OR, in April 1995. Trees were planted in #3 (9.1 l) containers in a pinebark:sand (6:1 v/v) substrate amended with 14 lbs/yd^{-3} of 17-7-12 Osmocote (O.M. Scotts Co., Maryville, OH), 1.5 lb/yd^{-3} Micromax (O.M. Scotts Co.), and 5.0 lb/yd^{-3} dolomitic lime on the same day in Auburn, AL in May 1995. Trees were transported the second week of June to Blairsville, GA; Tifton, GA; Auburn, AL; and Muscle Shoals, AL in USDA hardiness zones 6b, 8a, 8a and 7a, respectively. Trees were arranged at each location on landscape fabric covered beds in a randomized complete block design consisting of 6 blocks with 3 plants per replication of each cultivar placed pot to pot. Trees were overhead irrigated, using standard production practices for each location, at 0.5 in per day in Blairsville and Tifton; and 1.5 in per day in Muscle Shoals and Auburn. All trees were pruned to a central leader the last week of July 1995. Dormant trees were transplanted to #10 (38 l) containers the second week of December 1995. Substrate for transplanting was prepared in Auburn for each location one day prior to use, receiving the same amendments as in 1995. Trees were transported to a single location for harvest at the end of Dec. 1996. Final stem diameter (caliper) (6 in above the soil line) and plant height were measured prior to dry weight measurements for each tree. Root:shoot ratios were determined after roots (washed free of medium) and stems were oven dried at 140F (60C) for 3 days.

Results and Discussion: At the conclusion of the study growth differed by location and cultivar. Despite differences in temperature and moisture (irrigation and rainfall) among locations, growth response across cultivars in Blairsville and Tifton was similar, with growth response in Muscle Shoals similar to Auburn (Tables 2-4). Height and caliper increase were greatest at the 2 Alabama locations for most cultivars and were least at the 2 Georgia locations. Root:shoot ratios were greatest at the 2 Georgia locations, an indication of increased carbon partitioning of photoassimilates to roots over stems under dryer growing conditions. Number of rainfall events varied little by location during the 2 growing seasons, however total rainfall was greater in Blairsville, Auburn, and Muscle Shoals than Tifton in 1995 (8) (Table 1) and greater in Blairsville and Muscle Shoals than Auburn and Tifton in 1996.

Significance to Industry: Much can be gained from this study regarding cultivar performance under different environmental conditions. Three cultivars: ‘Celzam’, ‘Landsburg’, and ‘Olson’ are new introductions and have not been included in container or field studies prior to this report. ‘Franksred’ demonstrated the greatest adaptability to varied environmental conditions across locations. For each location ‘Franksred’ had the greatest height and caliper growth, with the exception of caliper at one location (Table 3). ‘Olson’ and ‘Celzam’ appear to be well adapted to container production in growing conditions of the Southeast. Based on results of this study, we can not recommend ‘Landsburg’ as a suitable choice for container producers in the Southeast. This Zone 3 selection had the least height, caliper, and root growth for each of the four locations.

This study shows that differences in temperature and substrate moisture levels (irrigation and rainfall) consequently impact total growth of red maple cultivars over a 2 year period in containers using typical production practices. Greater overall growth across cultivars at the Alabama locations, compared to the Georgia locations, is attributed to non-limiting irrigation at the Alabama locations during the greatest period of growth. This study provides good information regarding the impact of a long growing season on the growth of container-grown trees. For example, although Tifton had 118 more frost free days (almost 4 months) than Blairsville, these days apparently did not contribute to a growth advantage for Tifton over Blairsville as might be expected with container-grown ornamental shrubs. With primary shoot extension occurring early in the growing season in Tifton, the extended growing season may have caused a depletion in reserves through extended maintenance respiration (1, 4). However, greater growth might have been realized from the longer growing season in Tifton, compared with Blairsville, if irrigation rates had replaced 100% of evapotranspiration, as opposed to 0.5 in (1.3 cm) per day.

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Table 1. Length of growing season, mean monthly maximum (T_{max}) and minimum (T_{min}) temperatures[z] and rainfall totals[y], by location June, 1995 - December, 1996.

	1995	1996	June - Dec., 1995			Jan. - Dec., 1995		
	Frostfree	Frostfree	T_{max}[z]	T_{min}[z]	Rain[y]	T_{max}[z]	T_{min}[z]	Rain[y]
Blairsville	171	164	22.1	9.6	98.0	18.5	5.7	161.8
Tifton	247	282	26.7	14.7	40.1	24.4	12.0	100.4
Auburn	247	244	26.4	14.9	81.8	22.5	12.4	113.4
Muscle Shoals	238	206	24.9	13.7	77.9	21.4	10.8	167.3

[z] Mean temperature June - Dec., 1995; Jan., - Dec., 1996 in°C.
[y] Total rainfall June - Dec., 1995; Jan., - Dec., 1996 in cm.

Table 2. Height increase from Spring 1995 to December 1996 for eight red maple cultivars grown at four locations[ZYX]

	Location			
Cultivar	Blairsville	Auburn	Tifton	Muscle Shoals
October Glory	133.6 DE[Y] bc[X]	157.8 E b	118.6 CD c	203.3 BC a
Franksred (Red Sunset™)	166.9 A c	229.8 A b	175.9 A c	261.7 A a
Armstrong	153.4 A-D c	200.4 BC b	151.3 ABC c	276.8 A a
Fairview Flame	136.4 CDE bc	147.1 E b	114.4 D c	201.4 BC a
Celzam (Celebration™)	142.7 B-E c	218.7 AB b	110.3 D d	256.3 A a
Autumn Flame	156.6 ABC c	198.4 CD b	138.9 BCD c	223.0 B a
Landsburg (Firedance™)	129.8 E bc	146.6 E b	109.9 D c	196.9 C a
Olson (Northfire™)	163.2 AB b	180.8 D b	160.9 AB b	261.4 A a

[Z] Height increase (cm) determined by difference in initial height (6/95) and final height (12/96). Mean separations by Waller-Duncan K ratio *t* tests (n=18) considered significant at the 0.05 level.

[Y] Differences by cultivar at each location within columns in uppercase.

[X] Differences by location for each cultivar within rows in lowercase.

Table 3. Caliper increase from Spring 95 to December 1996 for eight red maple cultivars grown at four locations[ZYX]

Cultivar	Location			
	Blairsville	Auburn	Tifton	Muscle Shoals
October Glory	16.0 B b	21.6 BC a	14.0 B b	21.1 B a
Franksred (Red Sunset™)	20.5 A c	26.7 A a	20.6 A c	23.2 AB b
Armstrong	17.3 B b	21.8 BC a	15.5 B b	23.3 AB a
Fairview Flame	16.8 B ab	17.7 D ab	14.5 B b	20.1 B a
Celzam (Celebration™)	16.7 B b	24.0 AB a	14.0 B c	25.1 A a
Autumn Flame	19.3 A b	25.8 A a	19.1 A b	23.5 AB a
Landsburg (Firedance™)	10.9 C b	11.0 E b	7.7 C c	13.9 C a
Olson (Northfire™)	16.3 B b	19.1 CD ab	16.3 B b	23.0 AB a

[Z] Caliper increase (mm) determined by difference in initial caliper (6/95) and final caliper (12/96). Mean separations by Waller-Duncan K ratio t tests (n=18) considered significant at the 0.05 level.

[Y] Differences by cultivar at each location within columns in uppercase.

[X] Differences by location for each cultivar within rows in lowercase.

Table 4. Red maple cultivar root:shoot ratio December 1996 at four locations[ZYX]

Cultivar	Location			
	Blairsville	Auburn	Tifton	Muscle Shoals
October Glory	0.56 CDE b	0.54 B b	0.75 BC ab	0.83 A a
Franksred Red Sunset™)	0.54 DE b	0.46 B b	0.69 BC a	0.50 B b
Armstrong	0.68 B a	0.52 B b	0.68 BC a	0.53 B b
Fairview Flame	0.65 BC ab	0.46 B b	0.89 B a	0.59 B ab
Celzam (Celebration™)	1.05 A b	0.77 A c	1.53 A a	0.88 A bc
Autumn Flame	0.53 E ab	0.40 B b	0.60 C a	0.56 B ab
Landsburg (Firedance™)	0.66 BC a	0.46 B a	0.76 BC a	0.50 B a
Olson (Northfire™)	0.63 BCD ab	0.44 B b	0.53 C ab	0.64 B a

[Z]Mean separations by Waller-Duncan K ratio t tests (n=18), significant at the 0.05 level.
[Y] Differences by cultivar at each location within columns in uppercase.
[X] Differences by location for each cultivar within rows in lowercase.

Comparing Above-ground and In-ground Pot-in-pot Container Systems

(Student)

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Nature of Work: In-ground pot-in-pot (IGPNP) was designed to control blow-over in container nurseries. The system utilizes sockets below the soil surface to stabilize containers. An additional benefit of IGPNP is insulation provided by the surrounding soil on media temperature. High soil temperatures were found to reduce root growth in five genera (1,2). IGPNP was found to buffer media temperature and promote the formation of a larger root mass in plants when compared to conventional nursery container placement (3). However, the cost of IGPNP is high. The installation of IGPNP often requires heavy equipment and is labor intensive, additional drainage is often required, and IGPNP is permanent once installed. These considerations make IGPNP undesirable for many nurseries.

To reduce the installation requirements of IGPNP, yet still provide blow-over control, at least two container manufacturers have introduced above-ground pot-in-pot (AGPNP) systems. The AGPNP socket is placed on the production surface and uses flared sides to control blow-over. AGPNP is easily installed, allows for adjustments in spacing, and eliminates the need for additional drainage. The ability of AGPNP to moderate media temperature is questionable since the AGPNP socket is exposed to the elements.

A study to determine the effect of AGPNP on media temperature was initiated in May of 1997 in an existing IGPNP field at Carolina Nurseries in Moncks Corner, SC. The existing IGPNP sockets were compared with AGPNP systems manufactured by The Lerio Corp. and Nursery Supplies, Inc. and conventional containers (CC) without sockets. Twelve replicates of *Ligustrum lucidum* 'Repandens' per treatment were placed in a randomized block design. Thermocouples were placed at the center, east-north-east face (ENE), and south face of the containers at depths of 2 inches (5 cm) (top) and 7 inches (18 cm) (middle) of four replicates, areas of the container with characteristic thermal qualities (3). The highest media temperature extremes were found to occur in the ENE region of nursery containers (3), and media temperatures from this region will be reported in this paper. Temperatures were recorded every

15 minutes with an Acromag datalogger. Growth index was recorded monthly. Four replicates were harvested in November 1997 for dry weights of leaf, stem, and the outer 4 inches (10 cm) of root mass.

Results and Discussion: The rates of heating and cooling were most rapid for CC, intermediate for the two AGPNP, and slowest for IGPNP. Media temperature highs were usually between 90 to 95 F (32 to 35 C). Figure 1 shows media temperature curves for all treatments on an average summer day. The peak media temperatures reached by the Lerio AGPNP and CC were not different on most days, reaching ENE container region temperatures near 100 F (38 C), but were slightly lower for the Nursery Supplies AGPNP. Media temperatures for IGPNP averaged 10 F cooler in all container regions measured on most days with a maximum difference of approximately 25 F versus CC. On days that the temperature exceeded normal highs, differences between the two AGPNP were more pronounced (Figure 2). Neither the Lerio nor Nursery Supplies AGPNP reached the peak temperatures of CC on days with media temperatures in excess of 110 F (43 C). However, during the afternoon hours there was no difference between the Lerio AGPNP and CC. Nursery Supply AGPNP buffered media temperature better than the Lerio AGPNP and CC, but still had media temperature highs near 100 F (38 C). The CC temperature rise, peak, and duration was quicker, higher and longer than either AGPNP. A more moderate temperature range occurred in the IGPNP on days of extreme heat, with highs peaking around 90 F (32 C). Growth index of IGPNP was usually greater than the other systems with few other differences (Table 1). Dry weights of roots, shoots, and leaves had similar results. Plants grown in IGPNP had 20% more top growth and nearly twice the exterior root mass compared to the other production systems (Table 2).

Significance to Industry: Container blow-over is a major problem for nurseries. The most effective means to control blow-over is the use of stable sockets to hold containers. The added benefits of IGPNP results in more rapid plant growth, however the cost associated with IGPNP installation and its land use restrictions make it impractical for many nurseries. For container nurseries that desire blow over control without the restrictions associated with IGPNP, AGPNP may be an option. The system provides blow-over control while producing plants comparable to those grown in conventional containers. The moderate temperature buffering provided by the AGPNP systems did not improve plant growth, however, future studies are underway to focus on increasing the buffering capacity of AGPNP systems with the hopes of improving plant growth.

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Table 1. Growth index ((height (cm) + width (cm))/2) for Ligustrum grown in in-ground (IG), conventional, or above-ground (AG) pot-in-pot (PNP) production systems.

	Growth Index by Date			
Treatment	6/27/97	8/08/97	9/09/97	10/09/97
IGPNP	55.20	76.33 a[z]	83.13 a	92.33 a
Lerio AGPNP	56.29	75.46 ab	73.92 b	76.25 b
Nursery Supplies AGPNP	54.75	70.58 c	71.20 b	71.33 b
Conventional	56.12	71.25 bc	71.17 b	75.33 b

[z]Means followed by different letters are significantly different at P = 0.05 by Duncan's.

Table 2. Leaf, shoot, and root dry weight for *Ligustrum* grown in in-ground (IG), conventional, or above-ground (AG) pot-in-pot (PNP) production systems.

	Dry Weight (g)		
Treatment	Leaf	Root	Shoot
IGPNP	395.08	174.50 az	257.20 a
Lerio AGPNP	420.06	86.61 b	211.17 ab
Nursery Supplies AGPNP	384.90	66.68 b	198.66 b
Conventional	367.95	92.39 b	191.97 b

[z]Means followed by different letters are significantly different at P = 0.05 by Duncan's.

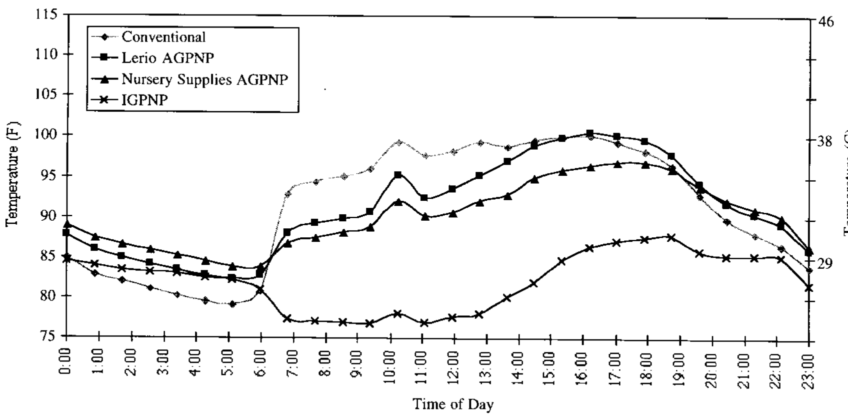

Figure 1. Media temperature from the ENE, middle of the container thermocouple placement on June 30, 1997. Ambient air temperature reached 94 F (34 C) on site. AGPNP - above-ground pot-in-pot; IGPNP - in-ground pot-in-pot.

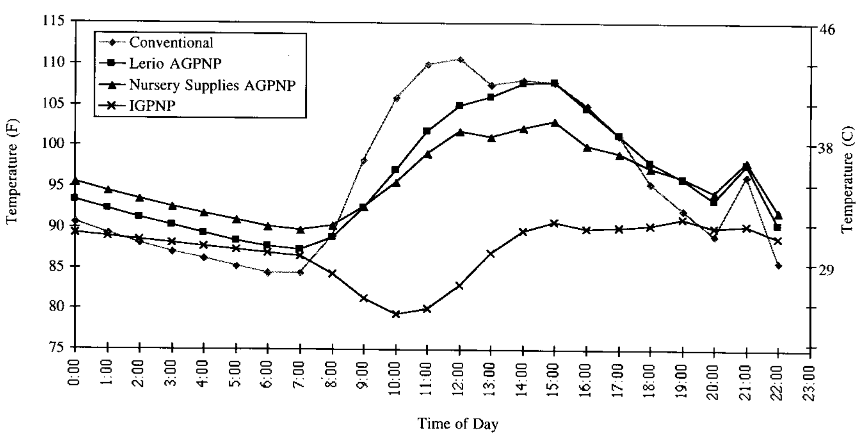

Figure 2. Media temperature from the ENE, middle of the container thermocouple placement on July 5, 1997. Ambient air temperature reached 100 F (38 C) on site. AGPNP - above-ground pot-in-pot; IGPNP - in-ground pot-in-pot.

Recycled Newspaper Reduces Nitrate Leaching from Nursery Containers
(Student)

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Nature of Work: Nurseries in the Southeastern United States use large volumes of ground and surface water to meet irrigation demands of container-grown plants in pine bark-based media. This practice results in high intensity fertilization which may lead to contamination of nursery runoff water, especially with nitrate nitrogen (NO_3-N). Best management practices for water pollution control (BMPs) have been developed in the southern region. These menu- based BMPs are valuable; however, many nursery sites are not suitable for implementation of some or all of these BMPs or the BMPs available at a particular site do not adequately control NO_3/NH_4 nitrogen leaving the property. Evidence of high nutrient levels in runoff from liquid feed fertilizers has motivated most nursery growers to switch to control release fertilizers. However, nitrogen losses from control release fertilizers can still be high, especially immediately following application. For many container nursery production sites, the only alternative for remediation of runoff water may be in the container itself. The objective of this study was to develop a method for reducing NO_3-N levels in leachate before it leaves the container. In laboratory tests recycled newspaper has been shown to adsorb nitrate from water in filter columns. If the same technique was effective in nursery containers, it would greatly reduce the risk of ground and surface water contamination from container leachate, while providing another alternative for runoff containment and treatment.

Two studies were conducted to evaluate recycled paper products ability as nitrate filters from container leachate. Products included: ground paper, paper crumble and paper pellets, which were placed 2 cm or 3 cm deep in the bottom of containers. Newsprint was ground using a hammer mill equipped with a series of three screens, the smallest approximately 0.03 inches. Ground paper was compressed using pelletizing equipment to form recycled paper pellets approximately 1/4 inch in diameter and 1 1/4 inches in length. Pellets were put through a granulator with variable pressure plates to obtain the recycled paper crumble. V-14 red poinsettia “Glory”(*Euphorbia pulcherima*) were potted on September 12, 1997 in 6 1/2 inch pots in a 3 pine bark:1 peat moss medium amended with 6 lb lime, 2 lb gypsum, and 1.5 lb Micromax per yd^3.

Fertilization included 200 ppm N at potting, then 250 ppm N (20-20-20) weekly for two weeks, then it was increased to 500 ppm N weekly. Ten days after potting Osmocote 14-14-14 was topdressed at 7 g per plant. Experimental design included 8 treatments: 2 and 3 cm ground paper, 2 and 3 cm paper crumble, 2 and 3 cm paper pellets, pine bark/peat moss control, and pine bark/sand control; and 10 single-pot replications. Leachate samples were collected by Virginia Tech Extraction Method (VTEM) at the first irrigation after each liquid feed, which corresponded to 3, 10, 17, 25, 32, 39, 43, 50, 57, 64, 73, and 83 days after potting (DAP).

Experiment 2 was conducted to evaluate how paper pellets affect nitrate leaching from containers when control release fertilizers are used. Pellet treatments included 3 paper depths (0, 1, and 2 cm) placed in the bottom of containers, so that all drainage holes in the container were covered. Equal amounts of container medium (700 g) consisting of pine bark and sand (7:1) amended with lime (5 lb/yd^3) and Micromax (1.5 lb/yd^3) were used to fill one-gallon containers. Osmocote 14-14-14 was incorporated in the medium at 10 lb/yd^3. *Impatiens balsamina* "Lilac Splash" were potted in trade gallon containers on April 14, 1998 and irrigated by micro-irrigation system. The irrigation system delivered water to containers via individual spray stakes and was turned on manually as needed. Leachate samples were collected at 3, 7, 9, 14, 17, 20, 24, 27, 30, 31, 33, 35, 37, 39, 40, and 42 days after potting DAP in individual plastic trays after irrigation and frozen for subsequent analysis of nitrate, ammonia, and phosphorus levels. Due to space limitations only nitrate data will be presented in the paper. Plants were harvested after 6 weeks for dry weight determination and analysis of foliage and paper pellets for total N content. The experiment consisted of 3 treatments and 16 single-pot replications.

Results and Discussion: Pelletized recycled newspaper in the bottom of the container reduced nitrate levels in the container leachate from 27 to 81% depending on the depth of paper (Table 1). Leachate samples taken 25 DAP showed that recycled paper pellets at 2 or 3 cm depths reduced nitrate-N levels by 69 or 81%, respectively, compared to the pine bark/peat control (PB/P). Relative to PB/P control, NO_3 levels were reduced by 52 or 62% with paper crumble at 2 or 3 cm depths; and by 59 and 27% with ground paper at 2 or 3 cm depths. While poinsettia bract color was not affected by paper treatments, plant growth was generally reduced with recycled paper pellets. With growth index and plant dry weights, the lowest values occurred in the recycled paper treatments. For example, plants grown with recycled paper pellets at 2 or 3 cm depths were 45 or 57%, respectively, smaller than PB/P control plants. Foliar color was also lighter when paper pellets were used.

In the second experiment paper pellets provided effective nutrient leaching control at both depths (Table 2). At 14 DAP paper pellets at 1 or 2 cm depths reduced nitrate leaching by 83 and 85%, respectively. However, after 27 DAP, when nitrate levels declined to about 1.0 ppm, nitrate leaching was similar among all treatments. Impatiens dry weight decreased by 12% with 2 cm paper pellet treatment when compared to control plants. Total foliar N levels and total N levels in paper showed no significant differences among treatments. Better root growth occurred in 1 cm of pellets than in 2 cm of pellets. Although in the first experiment paper pellets negatively impacted plant growth at 2 and 3 cm depths, the second test showed that 1 cm of pellets provided a comparable level of leaching control with no impact on plant quality.

Significance to Industry: These preliminary studies indicate that paper pellets in the bottom of containers may have a great potential in reducing nitrate levels in leachate from individual containers. Additional work is being conducted to determine the fate of nitrogen filtered from the leachate and to develop management practices using the recycled paper in the bottom of containers. Most nurseries can utilize this technique without changing current plant production practices.

Table 1. Nitrate levels in container leachate, experiment 1.

Treatment	Paper depth (cm)	DAP 3	DAP 25	DAP 50	DAP 83	Plant dry wt (g)
		NO_3-N (mgL^{-1})				
Ground Paper	2	47.1	59.7	106.1	3.5	31.6
Ground Paper	3	53.3	33.9	58.7	9.6	24.2
Paper Crumble	2	17.3	39.6	78.7	2.7	29.0
Paper Crumble	3	13.4	31.0	35.8	0.7	22.9
Paper Pellet	2	13.3	25.5	52.1	0.9	16.3
Paper Pellet	3	7.6	15.6	18.2	0.4	12.8
PB/Peat Control	0	27.5	81.8	87.6	6.9	29.8
PB/Sand Control	0	30.2	119.5	100.9	5.0	24.0
$LSD_{(0.05)}$		15.5	30.2	18.8	4.9	11.8

Table 2. Nitrate levels in container leachate, experiment 2.

Treatment	DAP				Plant dry wt (g)
	3	14	27	35	
	NO_3-N (mgL^{-1})				
Control (0 cm)	44.3	36.2	1.4	1.2	15.9
Paper Pellet (1 cm)	26.9	6.3	1.0	1.1	15.2
Paper Pellet (2 cm)	17.7	5.4	0.8	1.0	14.0
$LSD_{(0.05)}$	10.5	9.4	0.8	0.7	1.6

The Use of Crumb Rubber as a Media Component for Container-Grown Woody Ornamentals

(Student)

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Nature of Work: Several researchers have evaluated shredded waste tire and crumb rubber as a media amendment in container production (1, 3, 4). However, less research has been conducted using woody ornamentals. The high levels of zinc associated with the crumb rubber have lead many to conclude that it should not be included in soilless potting media (2). Crumb rubber could possibly be used in mixes for crops that can tolerate higher levels of zinc. Studies funded by the Louisiana Department of Environmental Quality were initiated by the LSU Agricultural Center to evaluate crumb rubber as a container growing amendment. The objective of this study was to evaluate the effects of crumb rubber as a media amendment on the growth of container-produced *Carya illinoensis* (Pecan) and *Quercus phellos* (Willow oak).

Bare root seedlings of pecan and liners of willow oak were planted on 26 March 1997 at the Burden Research Plantation in Baton Rouge into three-gallon containers. The media was composed of either 0, 12.5, 25, 37.5, or 50% crumb rubber (v/v) mixed with pine bark. Each medium treatment was amended with either 6 or 12 lbs/yd^3 dolomitic lime, 1.5 lbs/yd^3 of Micromax, and 12 lbs/yd3 of 18-6-12 Osmocote fertilizer. Shoot height and stem calipers were taken on 2 May, 7 August, and 15 October. Shoot height was taken from the base of the plant to the apical zone of the main stem. The stem caliper was taken 2 inches from the media surface. Visual quality ratings were taken on 14 May and 13 August. Visual quality ratings were based on a scale from 1 to 10 (1=dead, 10=superior quality) and were based on the overall appearance and growth habit of the plant. On 15 November, shoot dry weight was determined by severing the plant at the media surface and drying for 72 hours at 70° C. Data was analyzed using General Linear Models Procedure . Treatment means were separated by Duncan's Multiple Range Test ($P \leq 0.05$).

Results and Discussion: There were no significant differences between the two rates of dolomitic lime (6 or 12 lbs/yd^3) for either pecans or willow oaks. Therefore, lime treatments were pooled. Pecans growing in media containing crumb rubber exhibited no significant difference in height when compared to the control (Table 1). However, stem caliper was reduced in media containing 37.5 and 50% crumb rubber. Visual quality ratings in August were lower for plants grown in 37.5% crumb rubber. Similar results were observed with the shoot dry weights. Dry weights were significantly lower for trees grown in 37.5% crumb rubber.

Willow oaks were more adversely affected by the addition of crumb rubber. Plants growing in 12.5% crumb rubber produced taller trees for August and October (Table 2). Height was significantly reduced when grown in 50% crumb rubber. Fifty percent crumb rubber also reduced the caliper of oaks for the month of August. In October, a reduction in the caliper was observed for trees grown in 25 and 50% crumb rubber when compared to the control. Visual quality ratings for May were lower for trees growing in 50% crumb rubber. In October, trees growing in 25% or greater rubber had significantly lower visual quality ratings. There were significant reductions in dry weights for plants grown in the higher rubber rates (≥25%).

Significance to Industry: The continued growth of the ornamental nursery industry is placing limitations on the availability of traditional media, primarily pine bark and peat moss, causing prices to increase and availability to decrease. Therefore, the need for alternative media is of significance. Some plant species have shown success when grown in media containing low levels of crumb rubber. However, growers must consider price and availability before choosing any alternative medium.

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Table 1. Effects of crumb rubber on the growth and quality of pecan (*Carya illinoensis*) in pine bark based media (1997).

Pine	Rubber	Caliper (mm)			Shoot Height (cm)			Visual Rating (1-10)		Dry Weight (g)
%	%	5/2	8/7	10/15	5/2	8/7	10/15	5/14	8/13	11/15
100	0	5.3 a [z]	8.3 a	11.1 a	37.9 a	64.2 a	58.5 a	5.4 a	5.7 a	16.8 a
87.5	12.5	5.0 ab	7.5 ab	11.0 a	34.4 a	52.8 a	55.3 a	4.7 a	4.5 ab	16.8 a
75.0	25.0	4.7 ab	7.4 ab	11.1 a	31.9 a	55.3 a	55.7 a	5.6 a	5.4 ab	13.9 ab
62.5	37.5	4.4 b	6.3 b	8.4 b	32.6 a	32.5 a	48.2 a	4.6 a	4.0 b	8.7 b
50.0	50.0	4.4 b	6.7 ab	8.2 b	32.9 a	62.2 a	63.3 a	5.0 a	4.1 ab	10.9 ab

[z] Means within columns followed by the same letter are not significantly different according to Duncan's Multiple Range Test ($P \leq 0.05$).
Visual quality ratings were based on a scale from 1 to 10 (1=dead, 10=superior quality).

Table 2. Effects of crumb rubber on the growth and quality of Willow Oak (*Quercus phellos*) in pine bark based media (1997).

Pine	Rubber	Caliper (mm)			Shoot Height (cm)			Visual Rating (1-10)		Dry Weight (g)
%	%	5/2	8/7	10/15	5/2	8/7	10/15	5/14	8/13	11/15
100	0	4.5 a[z]	9.3 a	14.3 a	42.2 a	86.1 ab	104.9 b	6.0 a	7.2 a	87.6 a
87.5	12.5	3.9 a	7.9 ab	13.7 ab	46.0 a	99.9 a	127.5 a	4.9 bc	6.5 a	71.5 a
75.0	25.0	4.0 a	8.2 ab	10.7 c	46.9 a	82.3 bc	90.4 bc	5.4 ab	4.3 b	28.0 b
62.5	37.5	4.0 a	8.3 ab	11.5 bc	44.9 a	78.4 bc	84.0 bc	5.2 ab	5.1 b	42.0 b
50.0	50.0	4.2 a	6.7 c	8.1 d	46.3 a	65.9 c	67.9 c	4.2 c	3.8 b	19.8 b

[z] Means within columns followed by the same letter are not significantly different according to Duncan's Multiple Range Test ($P \leq 0.05$).
Visual quality ratings were based on a scale from 1 to 10 (1=dead, 10=superior quality).

Root And Shoot Development After Early Radicle Pruning in Oak (*Quercus rubra*)

(Student)

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Nature of Work: *Quercus* is among the most important hardwoods found on the North American continent. It is very popular as an ornamental and is used for timber, shade and fuel. Container nursery production of oaks has many advantages when compared with other forms of nursery production. Oaks produced in containers are, however, very susceptible to root deformation because its dominant tap root can grow in circles and produce a poor root system (Hataway, 1977). Root system malformation due to restricted root volume in containers leads to kinked, circling, and matted roots forming at the medium-container wall interface. Following transplanting, this root deformation has been reported to increase mortality or reduce initial transplant growth (Arnold and Struve, 1989; Struve, 1993), increase mechanical instability (Nichols and Alm, 1983), and other undesirable symptoms. Several methods of root pruning have been used to avoid root malformation, such as chemical and air pruning. The objective of this work was to determine how the method and timing of root pruning in oak seedlings affects root and shoot development before and after transplanting.

Acorns were collected from the University of Kentucky campus during fall 1997 and a hot water bath treatment was applied (45º C for 50 min) in order to kill weevils. Seeds were then stratified in plastic bags containing moist vermiculite (2 acorn:1 vermiculite) at 4º C for 3 months, in order to break dormancy. To ensure 100% germination only acorns that started to crack were used. Anderson-band containers (Anderson Die & Manufacturing CO, Portland, OR) with dimensions of 7.3 x 7.3 x 14 cm were used. One acorn was sown in each container and the following treatments applied: 1) chemical pruning: bottom of containers were covered with weed barrier painted with a commercial solution of copper hydroxide and latex paint (Spin Out(, Griffin Co., Valdosta GA, USA;. 2) no pruning: the same as chemical treatment, but weed barrier was painted with latex paint only; 3) Air pruning: containers were open on the bottom, to kill root tips that exit the container. Metro mix 510 (Scott's) was used as growing medium. Irrigation was applied as required with fertilization (200 ppm of Peters 20-10-20) included at every other irrigation . The experiment was located in the Department of Horticulture greenhouse at the University of Kentucky. Night temperature was 20 ºC and day temperature ranged from 22ºC to 30ºC with supplemental lighting to provide a 14 hour photoperiod. The experiment was set on the first week of January 1998.

A completely randomized design with 16 plants assigned per treatment was used. Half the plants were harvested 30, 45 and 60 days after sowing and dry weight of roots and shoots was collected. The remaining plants were transplanted the day of harvest (30, 45 and 60 days after sowing) into a 10 x 10 x 32 cm deep Anderson-band container and data collected after 75 days.

Results and Discussion: Oaks seedlings showed a linear increase in growth in all treatments over a 60 day period (Figure 1). However, seedlings grown without root pruning in 32 cm deep containers showed increased growth when compared to seedlings exposed to root pruning treatments and grown in smaller 14 cm deep containers. Hanson et al. (1987) also found that northern red oak seedling biomass was reduced as the volume of the container medium was reduced. There was no difference in biomass accumulation in the pruning treatments until day 60 where seedlings in copper-treated containers showed increased growth (Figure 1). Burdett and Martin (1982) grew conifer seedlings in copper-treated containers and also found a reduction in height and dry weight, especially of roots, when compared to plants grown in non-treated container.

Following transplanting, all treatments had similar biomass to non-pruned control plants after 75 days (Figure 2). Only seedlings grown for 30 days in copper-treated containers prior to transplanting showed a significant increase in shoot and root growth. Latimer and Baden (1993) found a reduction in root dry weight in tomato seedlings planted in copper- treated flats, but after transplanting, total dry weight of roots was 4% greater than untreated tomato transplants. In the present study, only oak seedling root pruned early (30 days) with copper showed inproved biomass growth.

Significance to the Industry: Chemical root pruning using copper has been shown to be effective in pruning roots of several ornamentals. Liners produced in copper- treated containers have a better branched root system, while girdling and kinked roots are avoided. These data suggest that early chemical root pruning improve root and shoot dry weight in oaks grown in 14-cm deep container. Further research is needed to verify the factors that make chemical pruning better than other methods of root pruning.

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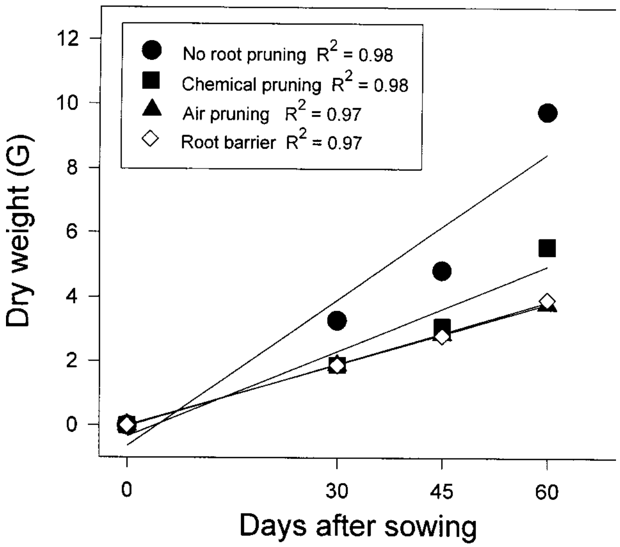

Figure 1: Root and shoot dry weight (g) in northern red oak seedlings either non-root pruned in 32-cm deep containers (control), root pruned by air or chemical (copper) treatments or grown with a root barrier in 14-cm deep containers for 30, 45 or 60 days.

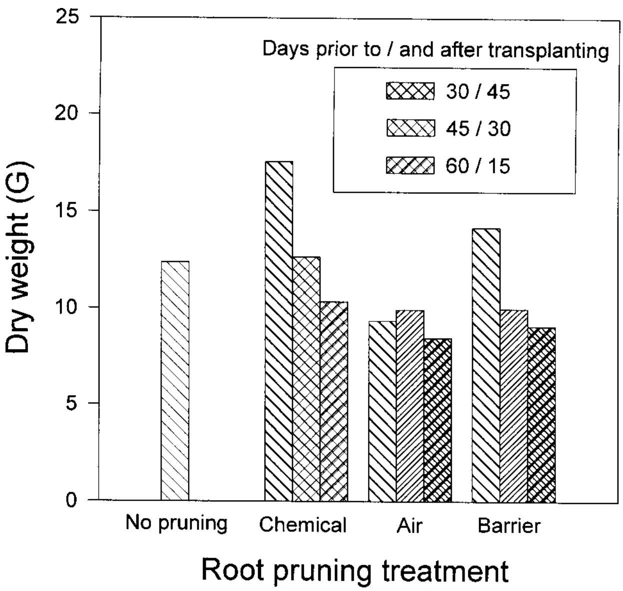

Figure 2: Root and shoot dry weight (g) in northern red oak seedlings grown in root pruning or restricting 14-cm deep containers for 30, 45 or 60 days prior to transplanting to 32-cm deep containers. Non-root pruned controls were grown in 32-cm deep containers for the entire 75 days.

Effects of Cyclic Micro-Irrigation and Substrate in Pot-in-Pot Production

(Student)

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Nature of Work: This study was conducted to evaluate production techniques that would increase irrigation application efficiency [(water volume applied-water volume lost)/water volume applied] to large container trees. Three irrigation treatments (continuous, three cycle and six cycle) and three substrate treatments (100 percent pinebark, 4:1 (v:v) pinebark:coir and 4:1 (v:v) pinebark:peat) were evaluated to determine their effects on irrigation application efficiency, and growth of *Acer rubrum* 'Franksred' (Red Sunset™) in a pot-in-pot production system in Auburn, AL.

Bare root liners, 5-6 ft, of *Acer rubrum* 'Franksred' (J. Frank Schmidt & Son's Co., Boring, Oregon) were planted in #15 containers (Nursery Supplies Fairless Hills, PA) in April 1997 in full sun. Three substrate combinations were used: 100 percent pinebark; 4:1 (v:v) pinebark:peat; and 4:1 (v:v) pinebark:coconut coir. Substrates were amended with 7.7 lbs dolomitic limestone. Trees were topdressed with 0.74 lbs of Scotts 15N-9P-11K plus minors.

Three irrigation treatments were used: application of a given volume in one continuous application at 10:00 a.m., the same volume divided into three applications at 10:30 a.m., 1:00 p.m. and 3:30 p.m., and the same volume divided into six applications beginning at 8:00 a.m. with a 90 minute rest between cycles. Irrigation was applied through maxi-jet spray stakes with a Bosmith pressure compensating emitter (Acuff Irrigation Company, Cottondale, FL) at a rate of 13.5 oz per minute. Total leachate volume was collected on a biweekly basis throughout the study. Leachate samples were taken from all containers monthly using the Virginia Tech Extraction Method (VTEM) and frozen for N analysis at the end of the study. Leachate volumes were collected one day prior to VTEM collection. Total inorganic-N concentrations determined from the VTEM were used to calculate total inorganic-N lost per container (volume x concentration).

Results and Discussion: Irrigation application efficiency was greatest for 4:1 pinebark:peat among substrate treatments while 100 percent pinebark and 4:1 pinebark:coir were similar (Table 1). Irrigation application efficiency was greatest for the six-cycle treatment followed by the three-cycle and continuous, respectively, (Table 1). These results are consistent with prior research showing increased irrigation application efficiency with cyclic irrigation (2, 3, 4). While not compared statistically, irrigation application efficiency appeared to increase as the season progressed, possibly due to increasing plant demands and environmental conditions. This suggest that maximum benefits from cyclic irrigation occur early in the season.

Tree growth was affected by substrates and irrigation treatment (Table 1). Shoot dry weight was about eight percent greater with plants grown in 4:1 pinebark:peat compared to plants grown in 100 percent pinebark. Plants grown in 4:1 pinebark:peat had a 17 percent and 12 percent greater height increase than those grown in pinebark:coir and 100 percent pinebark, respectively. Plants grown with cyclic irrigation had the greatest shoot dry weight among irrigation treatments with plants in the three-cycle and six-cycle having 23 percent and 17 percent greater shoot dry weight, respectively than plants grown with continuous irrigation. Plants receiving three-cycle and six-cycle irrigation treatments had a 23 percent and 26 percent greater trunk diameter increase respectively than plants grown with continuous irrigation. Tree height was also affected by irrigation treatment. Plants grown with three-cycle irrigation had a 16 percent greater height increase than plants grown with continuous irrigation. These results support a previous study showing an increase in growth with cyclic compared to continuous irrigation (3).

Inorganic-N concentration in VTEM samples was greatest for 100 percent pinebark in June. In two of the three sample dates total N lost (mg/pot) was greater in the 100 percent pinebark substrate compared to the other substrates. Summing total N lost from the three sample dates suggest that using a substrate with greater water holding capacity can reduce effluent N by almost 40 percent. Similarly cyclic irrigation reduced total N by a minimum of 82 percent when compared to continuous irrigation. While substrate inorganic N concentration was generally higher in cyclic treatments, reduced leachate volume (i.e. greater irrigation application efficiency) results in less total N leached. These data suggest greater retention of N in the substrate with cyclic vs. continuous irrigation. These results support a previous study showing a decrease in N leached from cyclic treatments compared to continuous (1).

Significance to the Industry: With increasing emphasis on the quantity of water used, growers should consider management practices that improve irrigation application efficiency of pot-in-pot container-grown trees. Cyclic irrigation is a proactive method to improve water quality by reducing runoff and nutrient loss from containers. Also, cyclic irrigation may lead to increased growth in production of specimen trees. Most nurseries can apply cyclic irrigation methods without changing existing equipment.

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Table 5. Effects of cyclic irrigation and substrate on irrigation application efficiency and growth of *Acer rubrum* 'Franksred' in a pot-in-pot production system.

Treatment	Irrigation application efficiency[1] (%)	Shoot dry wt (g)	Diameter[2] (cm)	Height (cm)
Substrate				
Pinebark	81.8 b[3]	1203.8 b	1.72 a	109.4 b
Pinebark:peat (4:1)	88.9 a	1303.8 a	1.81 a	122.9 a
Pinebark:coir (4:1)	83.0 b	1223.8 ab	1.74 a	105.3 b
Irrigation				
Continuous	70.6 c	1098.3 b	1.51 b	103.8 b
Three-Cycle	87.6 b	1349.2 a	1.86 a	120.6 a
Six-Cycle	94.3 a	1283.8 a	1.90 a	113.3 ab

[1]Irrigation application efficiency = [(water volume applied-water volume lost)/water volume applied].

[2]Diameter 15 cm above substrate surface.

[3]Mean separation within columns by Duncan's Multiple Range Test, $P = 0.05$.

Root and Shoot Growth Periodicity of 15-Gallon Pot-in-Pot Red and Sugar Maples

(Poster)

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Nature of Work: In order to ascertain the relationship between root and shoot growth over time (periodicity) for red maple (*Acer rubrum*) and sugar maple (*Acer saccharum*) trees, 6-ft.-tall liners were obtained from J. Frank Schmidt and Sons, Inc. Nursery (Boring, OR) and planted into a 15-gallon pot-in-pot production system in Blacksburg, VA in the spring of 1994. Each production container was fitted with a 30-cm wide X 35-cm tall polycarbonate window, through which root growth could be observed (rhizotron). Substrate was unamended pine bark (pH = 6.2). Four trees of each species were planted in a completely random arrangement and grown until February 1995, at which time root growth measurements began. All trees were fertilized with 161 grams of Osmocote 18-6-12 slow release fertilizer just after planting (spring 1994) and again in the spring of 1995. Substrate temperatures were monitored for each species with thermocouples, one placed in the container of a randomly chosen tree of each species, just inside the polycarbonate window and 20-cm deep. Temperatures were recorded in early afternoon, approximately twice weekly for the duration of the experiment. Since temperatures did not vary between species, data were averaged for the two species at each measurement. Shoot extension was measured weekly on each of five shoots which had been randomly selected before budbreak for each tree. The mean of these five shoots was the shoot extension for that tree for that measurement period. Root growth was monitored weekly for approximately 14 months by digitizing 35-mm photographic slides and employing a combination of image-processing computer software (Adobe Photoshop, ver. 3.0; Adobe Systems, Mountain View, CA and SigmaScan/Image, ver. 1.2; Jandel Scientific, San Rafael, CA). Total root length against rhizotron windows was estimated with the line intersect method (Marsh 197;Newman, 1966) by counting root:line intersections on an electronic grid (SigmaScan).

Results and Discussion: Root and shoot growth periodicity and substrate temperatures for red and sugar maples are shown in figure one. Root growth was well under way for both species by the middle of March 1995. Substrate temperatures at this time were around 10 degrees C (50 F). Similar soil temperature has been found to accompany the beginning of spring root growth for green ash, scarlet oak, Turkish hazelnut, and Japanese tree lilac trees in upstate New York (Harris et al., 1995). Unlike that study, however, a substantial amount of root growth occurred before budbreak (around May 1) in both species in the current experiment. Early, rapid shoot growth was accompanied by a temporary cessation of root growth in both species. Shoot growth was biphasic in red maple, with a similar pattern of reduction then stimulation of root growth at the beginning of rapid shoot growth in both phases. The most rapid root growth for the season in red maple occurred in mid-May and was concomitant with the most rapid shoot extension, although sustained rapid root growth was evident after the end of seasonal shoot extension and until fall decline. Fall cessation of root growth was accompanied by substrate temperatures near 7 degrees C (45 F), also similar to that found by Harris et al. (1995) In sugar maple, the most rapid root growth of the season occurred approximately two weeks later (around June 1) than for red maple. This was during the period of rapid decline in shoot growth. A temporary cessation of rapid root growth occurred from early-to-late August, but returned and stayed until the fall decline. For both species, root growth began approximately two weeks later in 1996 (around April 1) than in 1995 (around March 15), although this was before spring budbreak. Budbreak timing was similar for both years (around May 1), resulting in less root growth before budbreak in 1996 than in 1995. Some root growth occurred in sugar maple throughout the winter, but red maple roots were quiescent.

Significance to the Industry: Root growth occurs before budbreak for 15-gallon pot-in-pot red and sugar maples in regions with climate similar to Blacksburg, VA (USDA climate zone 6a), although timing between the two events can vary from year to year. Trees need to be planted very early in the spring (e.g. February) or in the previous fall in order to take advantage of establishment before spring budbreak. Root growth slows dramatically at the beginning of rapid spring shoot extension. This is not an optimum time to transplant. Root growth begins in the spring and dramatically slows in the fall when substrate temperatures are 45-50 degrees F for both species. Some root extension occurs throughout the winter for sugar maple, red maple has almost no root growth at this time.

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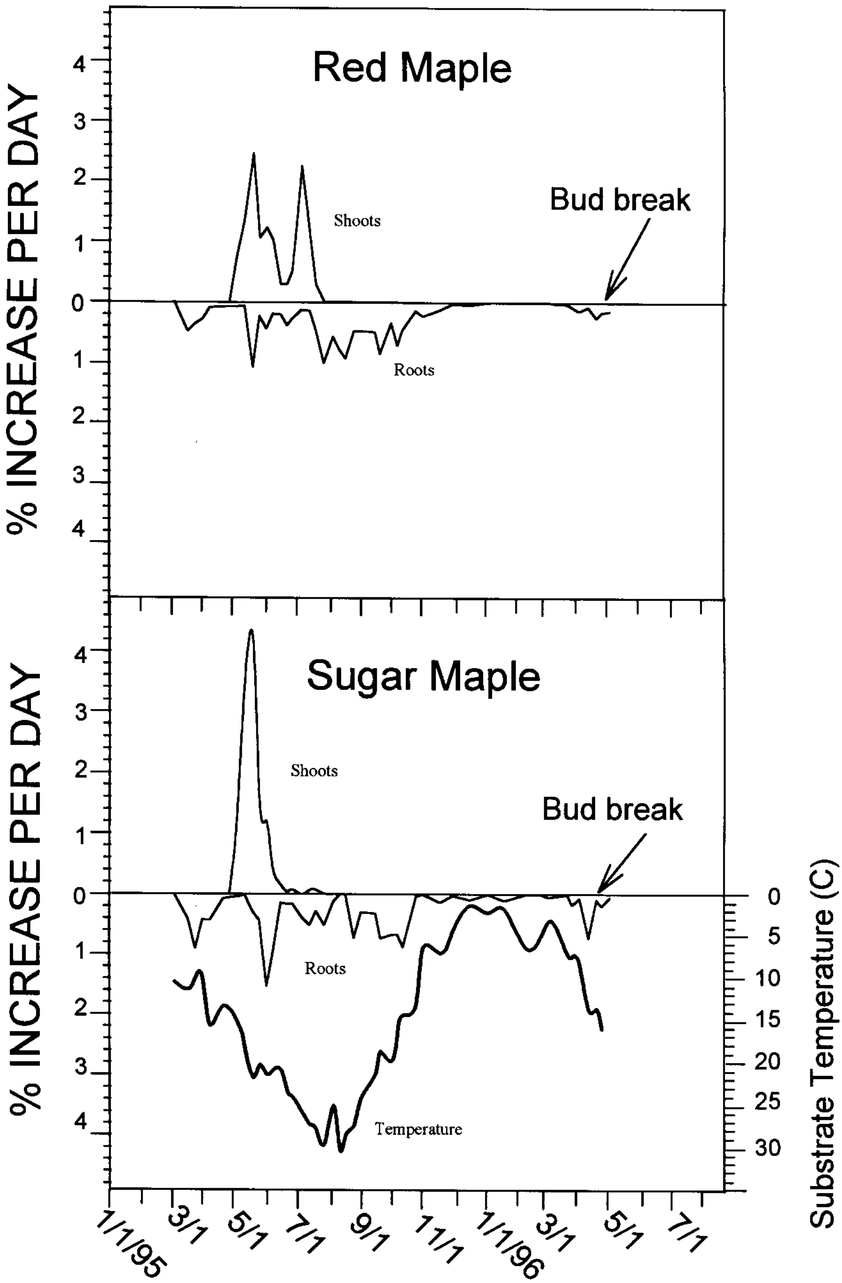

Figure 1. Shoot extension and root length against rhizotron windows for red maple and sugar maple trees over a 14-month period. Data were taken weekly. n = 4. Substrate temperatures for the same period are shown in the lower quadrant.

Micronutrient Fertilization Essential Regardless of Pine Bark pH

(Poster)

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Nature of Work: Growth response to soilless substrate pH varies with substrate and species. *Abies fraseri* (Pursh) Poir. seedlings in a sphagnum peat substrate were found to grow best in a pH range of 4.2 to 4.5 obtained via lime rates of 1 and 2 kg•m^{-3} (0.6 and 1.2 lb(yd^{-3}), respectively (Bryan et al. 1989). In the same study, growth at substrate pH values of 5.0 and 7.6 (lime rates of 4 and 8 kg•m-3 [2.4 and 4.8 lb(yd^{-3}], respectively) was less than at the lower pH. In contrast, *Buddleia davidii* Franch. 'Royal Red' growth in pine bark was greatest when the substrate pH was 5.6 (2.4 kg•m^{-3} lime) (Gillman et al., 1998). When micronutrients were added to pine bark in conjunction with lime, there was no growth response of *Juniperus virginiana* to micronutrients and a negative growth response to micronutrient only additions (Wright and Hinesley, 1991). In this case, pine bark pH was 3.7 to 4.0. Because micronutrient cation availability increases as pH decreases, micronutrient fertilization may be unnecessary in cases of low pH bark. Wright et al. (1997) showed that a lime addition to pine bark decreased growth, while added micronutrients increased growth of 9 species of landscape trees; pine bark pH ranged from 4.7 to 5.8. There is very little information on the effect of micronutrient additions on containerized tree growth in a substrate with a wide pH range, especially below 4.7. Since micronutrient cation availability increases as substrate pH decreases, the possibility exists that micronutrient amendments are unnecessary at a relatively low pH. The purpose of this experiment was to determine the effect of a micronutrient amendment on growth of *Koelreuteria paniculata* Laxm. for a wide substrate pH range. The growth response of *K. paniculata* to micronutrient and lime treatments has been shown to be very similar to that of several tree species (Wright et al., 1997).

Preplant amendment treatments to pine bark (Summit Bark Plant, Waverly, Va.) were four lime rates (0, 1.2, 2.4, or 3.6 kg m^{-3} [0, 2, 4, or 6 lb(yd^{-3}, respectively]) which resulted in initial bark pH values of 4.0, 4.5, 5.0, and 5.5, respectively) each with and without micronutrients (0.89 kg•m^{-3} [1.5 pine bark]) in a 4 (lime) x 2 (micronutrient) factorial arrangement. Ground dolomitic limestone (18% Ca, 10% Mg; James River Limestone Co., Inc., Buchanon, Va.) had a calcium carbonate equivalence of 100%. Micronutrients (in sulfate form except B and Mo) were supplied by Micromax™ (Scotts-Sierra, Marysville, Ohio) with the composition: 0.1% B (sodium borate), 0.5% Cu, 12% Fe, 2.5% Mn, 0.05% Mo (sodium molybdate), and 1% Zn.

Plastic 11.3 liter (3-gallon) containers were filled with bark of each lime-micronutrient combination. About 20 *Koelreuteria paniculata* seeds per container were sown just below the bark surface on 24 March 1998 (week 0). Seedlings were thinned at week 8 to five seedlings per container. Seedlings were greenhouse-grown and irrigated as needed with 500-ml fertilizer solution (in mg•liter^{-1}) of 300 N (as NH_4NO_3), 45 (as H_3PO_4), and 100 K (as KCl). Irrigation water Ca, Mg, and alkalinity concentrations were 10, 4, and 36 mg(liter-1, respectively. Bark solutions were extracted at weeks 3, 7 and 10 from three containers per lime-micronutrient treatment combination (pour-through method). Solutions were analyzed for pH, Ca, Mg, Fe, Mn, Zn, and Cu. Seedlings were harvested at week 10 and shoot dry mass and height were determined. Treatments were assigned in a completely randomized design with six single-container replications per treatment.

Results and Discussion: The main effect of micronutrients was significant for growth indicating that both dry mass and shoot height were higher when plants were grown in pine bark amended with micronutrient than that of plants in bark without micronutrient additions (Table 1). Thus, even at a low bark pH, micronutrient additions were necessary for maximum growth. Lime additions had no significant main effect on dry mass or height (Table 1).

Considering the main effect of lime, bark solution concentrations of Mg increased and Fe decreased as lime rate increased (Table 2). Only week 3 data are shown since week 7 and 10 data were very similar. These results were expected since dolomitic lime supplies Mg as well as increases pH and thereby decreases Fe availability. In terms of the main effects of micronutrients, micronutrient addition expectedly increased solution concentrations of Mg, Fe, and Cu (Table 2). Magnesium concentrations were 173% higher in the plus micronutrient treatment than without micronutrients. This is because micronutrients in the sulfate form undergo hydrolysis and thereby acidify the substrate which in turn increases the solubility of dolomitic limestone.

There was a significant lime x micronutrient interaction for pH and Ca, Mn, and Zn solution concentrations (Table 3). Contrast analysis showed that at each lime rate, micronutrient additions increased Ca, Mn, and Zn solution concentrations compared to corresponding values for bark without added micronutrients (analysis not shown) (Table 3). The reason for the increased Ca and Mn and Zn is the same as described above for

Mg and Fe and Cu, respectively. Thus, the positive growth response to micronutrient additions may be explained by the increased Fe, Mn, Zn, and Cu concentrations in solution.

Significance to Industry: Results of this experiment illustrate that micronutrient fertilization of plants grown in pine bark is necessary over a wide bark pH range. This was the case when initial pH values ranged from 4.0 to 5.5. Because *K. paniculata* performed similarly to other common landscape tree species in a previous experiment (Wright et al., 1997), results of this experiment suggest that this micronutrient recommendation is applicable to many other species of containerized trees. In this experiment and similar work (Wright et al., 1997), we found no positive influence of lime on growth of tree species and question the routine use of this amendment if the irrigation water or substrate supplies ample Ca and Mg.

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Table 1. Main effects of lime and micronutrients on shoot dry mass and height of *K. paniculata*, week 10.

Main effect		Shoot dry mass (g)	Height (cm)
Lime rate	(kg(m-3)		
	0	1.1azy	10.7a
	1.2	1.4a	10.9a
	2.4	1.3a	10.7a
	3.6	1.2a	10.8a
Micronutrients	(kg(m-3)		
	0	0.90b	8.4b
	0.89	1.57a	13.1a
Significance[x]	Lime	NS	NS
	Micronutrients	***	***
	Interaction	NS	NS

[z] Means reported are for n = 12 observations.

[y] Pairs of means within main effect are not significantly different when followed by the same letter (Tukey HSD, α (= 0.05).

[x] NS, *** nonsignificant or significant at $p < 0.001$, respectively.

Table 2. Main effects of lime and micronutrients on pine bark solution Mg, Fe, and Cu concentrations at week 3.

		Substrate solution concentration (mg(liter^{-1})		
Main effect		Mg	Fe	Cu
Lime rate	(kg(m^{-3})			
	0	21.5bz[y]	0.64a	0.03a
	1.2	22.5b	0.50ab	0.03a
	2.4	25.6b	0.31b	0.03a
	3.6	35.6a	0.22b	0.04a
Micronutrients	(kg(m^{-3})			
	0	38.5a	0.61a	0.05a
	0.89	14.1b	0.23b	0.01b
Significance[x]	Lime	**	**	NS
	Micronutrients	***	***	***
	Interaction	NS	NS	NS

[z]Means reported are for n = 6 observations.
[y]Pairs of means within main effect are not significantly different when followed by the same letter (Tukey HSD, α (= 0.05).
[x]NS, **, ***, nonsignificant or significant at $p < 0.01$, 0.001, respectively.

Table 3. Pine bark solution pH and element concentrations at week 3.

Treatment		Substrate solution concentration (mg(liter^{-1})			
		pH	Ca	Mn	Zn
+ Micros					
Lime rate (kg(m^{-3})					
	0	4.0z	118	6.9	1.2
	1.2	5.1	57	2.1	0.32
	2.4	5.5	45	0.98	0.18
	3.6	5.9	55	1.1	0.17
Linear		***	***	***	***
Quadratic		***	***	***	***
- Micros					
Lime rate (kg(m^{-3})					
	0	4.5	21	0.41	0.16
	1.2	5.0	22	0.34	0.11
	2.4	5.4	27	0.27	0.07
	3.6	6.0	29	0.22	.05
Linear		***	**	**	***
Quadratic		NS	NS	NS	NS
Significance	Lime[y]	***	***	***	***
	Micros	*	***	***	***
	Interaction	***	***	***	***

[z]Means reported are for n = 3 observations.
[y]NS, *, **, ***, nonsignificant or significant at $p < 0.05$, 0.01, 0.001, respectively.

Production of Potted Chrysanthemum with Selected Slow Release Fertilizers

(Poster)

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Nature of Work: Slow release fertilizers (SRFs) provide relatively low, sustained levels of nutrient release. Compared with liquid fertilization (LF), SRFs reduce labor inputs for fertilization and maximize efficiency of nutrient utilization (1,3). SRFs and LF have produced similar growth of chrysanthemum [*Dendranthema x grandiflorum* (Ramat.) Kitamura] (1,4). Recent advances in product formulation offer growers a wide range of commercially available SRFs which differ in their duration, pattern and mechanism of release. This study compared the growth of potted mums treated with selected, commercially available SRFs or LF.

Rooted cuttings of 'Charm' chrysanthemum (Yoder Bros., Barberton, OH) were potted singly in 6" azalea pots with a peat-based commercial medium (Fafard 2, Conrad Fafard Inc., Agawam, MA) on February 20, 1998. Plants were grown in a glass greenhouse at day/night temperatures of 74/66F (23/19C). Plants were soft pinched on February 24. Night interruption (10 p.m.-2 a.m.) was provided until March 6, after which natural photoperiod was provided. A foliar spray of B-Nine SP (daminozide, 0.25% w/v) was applied on March 11 and March 16.

The experiment was laid out in a randomized complete block design with 4 blocks, 5 treatments and 3 samples/treatment/block. Fertilizer treatments were applied on March 13 as follows: (1) 0.4 oz (10 g)/pot of Howard Johnson's Turf Fertilizer (Howard Johnson's Enterprises, Inc., Milwaukee, WI), 14-14-14, (2) 0.4 oz (10 g)/pot of Osmocote (Scotts-Sierra Horticultural Products Co., Marysville, OH), 14-14-14, (3) 0.3 oz (8 g)/pot of Polyon Landscape Supreme (Pursell Technologies, Inc., Sylacauga, AL), 17-17-17, (4) 200 ppm (mg/l) N supplied as Peters Pot Mum Special (Scotts-Sierra), 15-10-30, at every watering, and (5) no fertilizer control. SRFs (trts. 1-3), all of which were 3-4 month formulations, were topdressed. Plants were irrigated with tap water (trts. 1-3) or fertilizer solution (trt. 4) on March 13, and each treatment was irrigated thereafter when plants dropped to 60% of container capacity (determined by weight). Sufficient solution was applied to ensure 20% excess, or a leaching fraction of 0.2. All fertilizer treatments had a total of 0.05 oz (1.4 g) of nitrogen applied per pot over the course of the experiment.

The study was terminated 7 weeks after treatments were initiated. Shoot fresh weight, plant height, and plant width in 2 directions were recorded. Root systems were washed and their fresh weights recorded. Shoots and roots were dried to constant weight, and root:shoot ratios calculated. Data were subjected to analysis of variance and means separated (lsd=0.05) where appropriate.

Results and Discussion: All fertilizer treatments resulted in plants of acceptable quality, but plants were noticeably smaller with SRFs than with LF. Shoot dry weight was lower with SRFs than with LF, and trends for height and width were similar. Several explanations exist for the growth differences observed. Suboptimal nutrient levels for SRF plants were likely early in the 7-week period, since SRFs do not become available immediately upon application. The differing amounts of phosphorus and potassium for SRFs vs. LF may have attributed to the differences in shoot growth, also.

Root weights and root:shoot ratios were generally higher with SRFs than with LF. This trend is consistent with previous findings that large root systems are produced at relatively low fertility levels (2). Among SRFs, root:shoot ratio was higher with Osmocote and Howard Johnson's Turf Fertilizer than with Polyon Landscape Supreme.

Significance to Industry: LF and the SRFs used in this study produced 'Charm' mums of acceptable quality. SRFs tended to produce a higher proportion of root growth, while LF produced a higher proportion of shoot growth. The high root:shoot ratios produced by SRFs may result in superior postproduction performance. Additionally, results illustrate the importance of scheduling SRF applications to ensure that nutrient levels are adequate throughout the vegetative growth stage.

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Interaction of Irrigation Frequency and Container Drain Hole Design on Growth of Three Nursery Crops
(Poster)

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Nature of Work: Containers with water storage capacity have been reported to increase plant growth by providing an even supply of water between irrigation cycles (Merritt et al., 1996; Tilt et al., 1994), but increased growth has not been observed in all studies (Ranney et al., 1995). For each species, increased growth may be a function of the interaction between the irrigation frequency and the amount of water stored in the container.

The objectives of this study were: A) To determine growth and water use for ornamental crops produced using a combination of container drainhole designs and irrigation frequencies; B) To determine if ornamentals grown in containers with raised drainholes will grow normally under traditional commercial production systems; C) To compare the weight of fully-grown ornamentals in traditional and raised drainhole containers.

Ilex 'Hetzii,' *Rhododendron* 'Hino Crimson,' and *Geranium* 'Claridge Druce' were transplanted from 3-inch (7.6-cm) pots into trade 1-gal (2.5-liter) containers. The growing medium used was a blend of fir bark, moss peat and compost (8:1:1 by volume). Plants were top-dressed with 14 grams of Apex 20N-4P-8K controlled-release fertilizer. Irrigation water was injected with a water soluble fertilizer (20N-9P-17K), providing 75 ppm nitrogen once weekly. The study was performed using the facilities at a commercial nursery.

One-third of the containers had four 1-inch (2.54-cm) round drainholes located at the base of the sidewalls, and spaced an equal distance apart around the circumference of the container base. One-third of the containers had four drainholes located above the base to provide 20% water storage at the base of the pot when filled with water. One-third of the containers had four drainholes located above the base to provide 40% water storage. Ninety plants of each species were potted into each of the three types of containers. Ten plants of each species from each type of container were placed in one of three blocks under each of the three irrigation frequencies. The experimental design was a 3 irrigation frequency X 3 container design factorial treatment arrangement within a randomized complete block design using ten plants placed in three replicated blocks. After 90 days, plant size was measured as two widths (cm) and height (cm), and a size index was calculated. Geranium shoots were severed at the crown, and dried at 140°F for six days before recording weight. Data was analyzed using Analysis of Variance. Species were analyzed as separate experiments.

Results and Discussion: There were significant irrigation frequency X container design interactions within all three species. The largest 'Hetzii' holly were grown using high-frequency irrigation in containers with 0% water storage, using medium-frequency irrigation in containers with 20% water storage, and using low-frequency irrigation in containers with 40% water storage (Table 1). Hollies grew roots below the level of the raised drainholes in containers with 20% or 40% water storage. The roots growing in the water storage area had thickened, enlarged diameters, and contained large air spaces between the cells, compared to roots growing above the water storage area.

The largest 'Hino Crimson' azaleas were grown using high-frequency irrigation in containers with 0% water storage, using medium frequency irrigation in containers with 20% water storage, and using low-frequency irrigation in containers with 20% water storage (Table 1). Azaleas did not grow roots below the level of the raised drainholes in containers with 20% or 40% water storage.

The largest 'Claridge Druce' geraniums were grown using high-frequency irrigation in containers with 0% water storage, using medium frequency irrigation in containers with 20% water storage, and using low-frequency irrigation in containers with 20% water storage (Table 1). Geraniums did not grow roots below the level of the raised drainholes in containers with 20% or 40% water storage. Geranium shoot weight was significantly less only when grown using low-frequency irrigation in containers with 0% water storage, or when grown using high-frequency irrigation in containers with 40% water storage (Table 2). The former may not have received sufficient water for optimal shoot growth, while the latter may have received excessive water for optimal shoot growth.

When Rhododendron and Geranium were grown in containers with raised drainholes, the root ball would break at the level of the raised drain holes when plants were removed from the container. Circling roots were not observed if the species did not grow roots below the level of the raised drainholes. No increased incidence of root disease was observed during the study.

Significance to Industry: Growth of some ornamental crops can be increased if the correct combination of irrigation frequency and container water storage is identified. Nursery crops grown in 1-gal. containers with raised drain holes will grow normally under typical commercial production systems. Using containers with water-storage capacity, irrigation application can be reduced up to 65% without a reduction in plant growth. Using containers with water-storage capacity prevents the formation of a circling root system for some nursery crops.

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Table 1. Influence of irrigation frequency and in-container water storage provided by raised drainholes on the shoot size index of *Ilex* 'Hetzii,' *Rhododendron* 'Hino Crimson,' and *Geranium* 'Claridge Druce.

		Shoot size index[1]		
Irrigation frequency2	Water storage3	Ilex 'Hetzii'	*Rhododendron* 'Hino Crimson'	*Geranium* 'Claridge Druce'
High	0%	21.3	29.8	37.9
	20%	18.7	25.2	36.6
	40%	15.4	23.2	33.9
Medium	0%	19.3	27.6	37.7
	20%	22.2	28.5	39.2
	40%	16.2	25.9	35.6
Low	0%	14.8	22.2	27.8
	20%	19.2	29.3	38.4
	40%	21.4	27.9	36.7
Significance (PR>F)				
frequency X storage		0.001	0.001	0.001

[1]Calculated from measurements of height, widest width, and narrowest width of the shoot (in centimeters).

[2]High frequency provided daily irrigation using a volume equivalent of one inch of rainfall; medium irrigation frequency and low irrigation frequency provided 35% and 22% of water applied to the high frequency treatment, respectively.

[3]0% water storage used containers with drainholes at the base of the container sidewall; drainholes were raised to provide 20% or 40% water storage respectively, compared to a container filled with 100% water.

Table 2. Influence of irrigation frequency and in-container water storage provided by raised drainholes on the shoot weight of *Geranium* 'Claridge Druce.'

		Shoot Weight[1]
Irrigation frequency[2]	Water storage[3]	*Geranium* 'Claridge Druce'
High	0%	34.2
	20%	32.8
	40%	29.1
Medium	0%	33.1
	20%	35.0
	40%	32.6
Low	0%	24.0
	20%	34.8
	40%	33.2
Significance (PR>F):		
frequency X storage		0.001

[1]Shoot dry weight, grams.

[2]High frequency provided daily irrigation using a volume equivalent of one inch of rainfall; medium irrigation frequency and low irrigation frequency provided 35% and 22% of water applied to the high frequency treatment, respectively.

[3]0% water storage used containers with drainholes at the base of the container sidewall; drainholes were raised to provide 20% or 40% water storage respectively, compared to a container filled with 100% water.

"Cold-Trapping" in Retractable Roof Structures To Avoid Spring Frost Damage of Container-Grown Nursery Crops

(Poster)

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Nature of Work: Unheated quonset structures covered with a single layer of white poly-film are commonly used in Oregon to protect container grown nursery crops from winter injury. The accumulation of heat in these structures during daylight hours may decrease plant cold hardiness, and may encourage early growth of vegetative and flower buds. If plants are shipped from film-covered overwintering structures to colder regions of the country, they may be susceptible to cold damage at retail nursery sites.

Retractable roof cold protection/shading structures have been shown to increase the growth of some ornamental crops when managed for shading during the growing season (Svenson et al., 1992; Svenson, 1996). The ventilation capacity of these structures may prevent the daylight accumulation of heat during winter, keeping plants cold hardy for a longer period of time. The objective of this study was to examine the growth and flowering of nursery crops overwintered in a retractable roof structure managed for "cold-trapping" compared to a white poly-film covered quonset structure.

Arctostaphylos uva-ursi 'Vancouver Jade,' *Buxus* 'Alyce,' *Erica* x *darleyensis* 'Irish Bell,' *Euonymus fortunei* 'Emerald-n-Gold,' *Rhododendron* 'Hino Crimson,' and *Spiraea* x *bumalda* 'Anthony Waterer' potted in 2.5-liter (#1) containers were placed in a retractable roof cold protection/shading structure (flat roof design covered with woven, water permeable white-poly film) or in a white poly-film (6 mil) covered quonset structure in October 1995. Twelve replicated blocks were used within each structure to create a split-block treatment arrangement.

Plants in the quonset structure were watered twice a month when covered with white poly (50% shading). Poly was installed on the quonset structure on Nov. 1, 1995, and removed on Feb. 16, 1996. Plants were treated for insect and disease pests as needed. After Feb. 16, plants received irrigation as needed to supplement natural rainfall. The retractable roof structure was operated to close just before dawn each day (trapping cold air inside the structure), and not open for ventilation until the air temperature inside the structure was as warm as the outdoor air temperature. The roof was left in the fully-open position except when outdoor temperatures dropped below 35 F, or during morning "cold trapping." Plants were irrigated as needed, to supplement natural rainfall.

Air temperatures were recorded hourly outdoors, and in both structures, throughout the duration of the study. Plant size was periodically recorded as the average of height and two width measurements, and flowering of *Rhododendron* 'Hino Crimson' and Erica 'Irish Bells' was recorded in spring as the percentage of open flower buds. Growth and flowering responses for each species were compared using t-tests.

Results and Discussion: *Arctostaphylos* was larger in the retractable roof structure in May (Table 1). A higher incidence of foliar disease was observed on *Arctostaphylos* grown in the quonset structure (requiring the application of fungicides) compared to no diseases on plants grown in the retractable roof structure.

Buxus were larger in the quonset structure in April, but there was no difference in size in May (Table 1). Vegetative growth of *Buxus* started at a later date in the retractable roof structure. Slight frost damage was observed on *Buxus* grown in the quonset structure following a frost on April 24.

Erica were larger in the quonset structure in March, but were larger in the retractable roof structure in May (Table 1). *Erica* did not bloom in the quonset structure (Table 2). Frost damage observed on *Erica* growing in the quonset structure on March 4 caused all flower buds to abort, while *Erica* grown in the retractable roof structure flowered normally.

Euonymus were larger in the quonset structure in March and April, but not in May (Table 1). Vegetative growth of *Euonymus* started at a later date in the retractable roof structure. Powdery mildew was observed on *Euonymus* grown in the quonset structure in January (requiring an application of fungicide), but no disease was observed on *Euonymus* in the retractable roof structure.

Rhododendron were larger in the retractable roof structure in May (Table 1). *Rhododendron* flowered earlier in the quonset structure compared to the retractable roof structure (Table 2). *Rhododendron* grown in the retractable roof structure could be shipped in full bloom at a later date compared to the *Rhododendron* grown in the quonset structure.

Spiraea were larger in the quonset structure in March, April and May (Table 1). Most of the size difference was in plant height, with *Spiraea* in the quonset structure having longer internodes. *Spiraea* were infested with aphids in February in the quonset structure (requiring an insecticide application). In contrast, *Spiraea* grown in the retractable roof structure had a more compact appearance, a deeper golden color to the foliage, and were never infested with aphids.

Average daily temperatures, and daily maximum temperatures, were lower in the retractable roof structure compared to the quonset structure (Table 3).

The lower daily maximum temperatures, and the lower average daily temperature (ADT) in the retractable roof structure operated with “cold trapping” helped prevent early vegetative and flowering bud expansion. The cooler temperatures in the retractable roof structure helped prevent *Erica* from losing its flower buds, delayed the flowering of *Rhododendron*, and delayed the vegetative growth of *Buxus, Erica, Euonymus* and *Spiraea.*

From November 1 to February 16, crops in the quonset structures required 8 irrigation applications, while crops grown in the retractable roof structure obtained all needed water from natural rainfall. Higher warmer daylight temperatures, higher humidity, and lack of exposure to full sun may have contributed to earlier growth and flowering and a higher incidence of diseases and pests on crops grown in the poly-film covered quonset structure.

Significance to Industry: When retractable roof structures operated with “cold trapping” were used for unheated cold protection of container grown nursery crops, plants required fewer irrigation applications and fewer pesticide applications. *Rhododendron* flowering was delayed about 4 weeks in the retractable roof structure, providing an opportunity to ship blooming plants at a later date. Based on delayed initiation of vegetative growth, crops grown in the retractable roof structure maintained cold hardiness for a longer period of time. Crops grown in the quonset structure were susceptible to frost damage before Nov. 1, and after Feb. 16 and suffered some damage, while crops grown in the retractable roof structure were always protected from extreme temperatures and had no frost damage.

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Table 1. Size of plants grown in a retractable roof cold protection structure compared to plants protected in a poly-covered quonset structure (means and standard errors).

		Date			
Plant	Structure	Dec. 12	March 20	April 5	May 15
Arctostphylos uva-ursi	Quonset	9.8+0.2	10.0+0.2	10.1+0.2	12.0+0.4*
	Retractable	10.3+0.2	10.3+0.2	10.3+0.2	12.8+0.3
Buxus 'Alyce'	Quonset	13.2+0.2	13.5+0.2	14.5+0.2*	18.5+0.2
	Retractable	13.1+0.2	13.1+0.3	13.5+0.2	18.0+0.3
Erica 'Irish Bell'	Quonset	10.1+0.3	11.4+0.3*	11.2+0.4	11.9+0.4*
	Retractable	10.2+0.2	10.2+0.2	10.6+0.2	12.9+0.3
Euonymus 'Emerald-n-Gold'	Quonset	9.3+0.2	10.4+0.3*	12.4+0.3*	14.4+0.3
	Retractable	9.5+0.2	9.5+0.2	10.3+0.2	14.1+0.5
Rhododendron 'Hino Crimson'	Quonset	11.8+0.2	12.0+0.3	12.1+0.2	12.3+0.2*
	Retractable	11.8+0.3	11.8+0.2	11.8+0.2	13.1+0.2
Spiraea 'Anthony Waterer'	Quonset	7.9+0.1	9.5+0.4*	11.6+0.2*	23.6+0.7*
	Retractable	6.4+0.1	6.5+0.2	8.1+0.2	20.3+0.4

* Indicates significantly different (P=0.05), T-test.

Table 2. Percentage of buds flowering for plants grown in a retractable roof cold protection structure compared to plants protected in a poly-covered quonset structure (means and standard errors).

		Date		
Plant	Structure	March 20	April 5	May 15
Erica 'Irish Bell'	Quonset	0.0+0.0	0.0+0.0*	0.0+0.0*
	Retractable	0.0+0.0	2.8+0.4	65.3+6.8
Rhododendron 'Hino Crimson'	Quonset	40.2+2.9*	93.6+8.2*	2.3+0.4*
	Retractable	2.1+0.4	18.2+3.4	75.8+4.4

* Indicates significantly different (P=0.05), T-test.

Table 3. Air temperatures inside the quonset structure and the retractable roof structure compared to outdoor air temperatures.

		Temperature (F)		
Month	Temperature parameter	Outdoor	Quonset Structure	Retractable Roof Structure
November	Maximum	58.0	72.3	58.1
	Minimum	43.9	44.1	44.1
	Average[1]	50.9	57.0	49.9
December	Maximum	49.2	64.9	51.1
	Minimum	35.6	37.4	37.2
	Average	42.5	51.2	41.6
January	Maximum	47.6	54.3	47.7
	Minimum	36.8	38.2	38.6
	Average	42.2	46.3	40.9
February	Maximum	50.8	57.6	50.7
	Minimum	32.6	37.4	37.1
	Average	41.7	47.5	40.7
March	Maximum	58.3	58.4	58.8
	Minimum	37.0	37.0	40.1
	Average	47.7	47.7	45.8
April	Maximum	59.1	59.1	60.
	Minimum	42.1	42.2	43.2
	Average	50.6	50.6	49.7
May	Maximum	63.1	63.2	64.2
	Minimum	44.2	44.1	44.1
	Average	53.7	53.7	52.6

[1]Average daily temperature (ADT) computed as the average of 12 temperatures recorded every two hours throughout each 24-hour cycle.

Container Plant Production in Multiple Pot Box[1]
(Poster)

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Nature of Work: The research presented here was conducted to evaluate a multipot box as a means of increasing the efficiency of overhead irrigation in container plant production. *Viburnum odoratissimum* (Ker-Gawl.) plants were grown for 15 weeks in 3-liter (#1) containers in black multipot boxes that contained a water reservoir and in a conventionally spaced (1-ft centers) system on black polypropylene. Irrigation events were based on plants in multipot boxes which resulted in under-watering of plants in conventionally spaced containers. Approximately 210 mm (8.3 in) of overhead irrigation was applied during the experiment, in addition to 340 mm (13.3 in) of rain.

Production of marketable plants requires that containers be spaced several inches apart to allow for canopy growth. Due to this spacing, a large portion of the water applied through an overhead irrigation system falls between containers, and is unavailable to the substrate within a container (1, 5, 8). Only about 15 to 60 % of the irrigation applied is captured in containers for plant use (1, 8). Despite its inefficiency, overhead irrigation is typically the only economically viable method to supply water to plants grown in containers smaller than 18-liters (#5) because material and labor costs make microirrigation too expensive at current and projected plant market values (7).

Briggs and Green designed and tested The Closed Insulated Pallet System (CIPS) (3) where water retained in the pallet reservoir was available to the plants by a wick suspended from the containers. The container surface was covered with a foil disc and sealed around the plant stem with urethane foam and was not designed to capture rain or overhead irrigation.

Multipot boxes were constructed in two sections from fiberglass which was painted black for UV protection (Fig. 1). The lower section had four longitudinal channels that formed water reservoirs with three ridges. Each ridge was covered with 3 mm thick unsupported polyester (Troy Mills, Inc., Troy NH) to serve as wicking material. The upper section fitted within the lower piece and had round holes that enabled container plant foliage to extend above the surface while the containers rested on the ridges. The surface of the upper section was concave around each hole to increase the effective surface area and capture most overhead irrigation water. The lower section of the box stored the captured water and was provided with holes between the ridges to provide sufficient drainage for the substrate in the containers.

Experimental Procedures. The field research experiment was located in Gainesville, Fla. A substrate of pine bark, Canadian peat, and sand (2:1:1by volume) mix, amended with 4.2 kg (7 lb) of dolomitic limestone and 0.9 kg (1.5 lb) of Micromax (The Scotts Company, Marysville, OH) per m^3 (yd^3), was placed in seventy-two, black #1, 3-liter (1 gal) containers. Half of the containers (C-650 the Lerio Corporation, El Campo, TX) were modified by drilling four equally spaced holes in the bottom of the containers to assure contact with wicking material in the multipot boxes. A multipot box containing nine plants and the same number of plants in conventional containers set on black polypropylene ground cloth were placed in the center of each of four irrigated areas 6.1 m x 6.1 m (20 ft x 20 ft) on September 9, 1996. Conventional containers were spaced in three rows 30 cm apart (1 ft centers). Each area was irrigated with four sprinkler heads Each container received a topdress of 14 g of Osmocote 18N-2.6P-9.7K (18-6-12) controlled-release fertilizer (The Scotts Company) September 9.

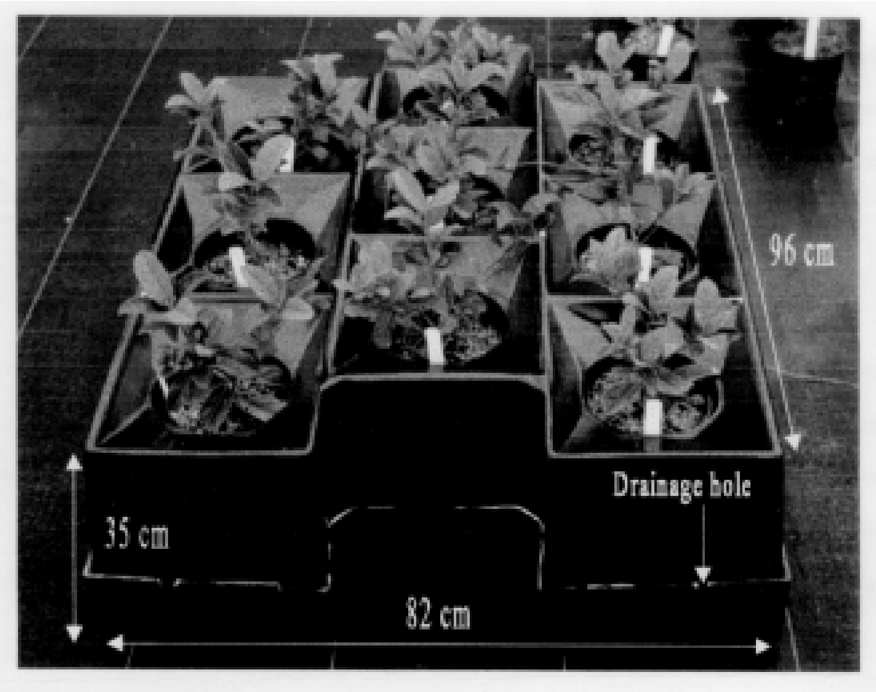

Fig. 1. Photograph of multiple pot box that contains nine #1, 3-liter (1 gal) containers.

Plants were irrigated for 1.7 hr on September 14 and 0.5 hr daily on September 17-25. Subsequent irrigations were applied when the reservoir in the bottom of the boxes receded to approximately 25 mm (1 in) and continued until depth of water in the reservoir was about 60 mm (2.5 in). The depth of water in the reservoir was measured by placing a wood dowel vertically through a hole in the box surface. Rainfall was collected in a rain gauge and recorded.

Results and Discussion: The total amount of water applied by irrigation during the 15-week experiment was 210 mm (8.3 in). According to the literature, typical water application in container nurseries is between 13 and 25 mm/day (0.5 and 1.0 in/day) of water (4, 6, 2). Assuming the most conservative amount of 13 mm/day (0.5 in/day), presented by Harrison (6), a nursery operation with the conventionally spaced container system would apply about 1360 mm (53 in) of irrigation during the time of our experiment. The most commonly reported amount of irrigation, 18 mm/day (0.7 in/day) (4, 2) would result in a total of 1,800 mm (76 in) of water applied.

After the initial nine irrigations for plant establishment, plants were irrigated only three times because rain provided adequate water for plants grown in multipot boxes. The maximum collection of water in the boxes, 95 mm (3.7 in), was obtained four times during the experiment. This indicates that an overflow occurred and that during the frequent/ large rain events of October 1-6 and December 1, 7, and 13, a significant portion of the rainfall was not 100% effective because the total rainfall exceeded reservoir capacity in the boxes. Smaller rainfall events, distributed in time, were highly effective since the water was stored in the reservoirs and available for later use by the plants. The total rainfall during the experiment was 338 mm (13.3 in). The longest time without rain was 16 days. Other extended rainless times were 10, 13, and 15 days.

Significance to Industry: Over 4 months of experiment, 84% less water was applied to the multipot boxes than would have been applied with an overhead irrigation system that delivered 13 mm (0.5 in) daily. According to Beeson and Haydu (2), the plants require at least 18 mm (0.7 in) per day to avoid water stress during peak evapotranspiration. Using this less conservative water application, the water savings would amount to 89% during 4 months. The experiment was conducted during months of relatively low rainfall in North Florida. The water savings can be only greater during other months when the rainfalls are more frequent. It is likely that during the rainy season only the first irrigation may be necessary and the rest can be provided by the rain.

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Chilling Injury on Twenty Aglaonema Cultivars
(Poster)

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Objectives of Research: The primary criteria for introducing tropical foliage plants until recently was new plants should have unique and attractive pictorial characteristics. Now commercial growers and professional interiorscapers like to know the growth rate, pathogen and pest resistance, and chilling sensitivity of new cultivars. Plants with extreme sensitivity to chilling are most likely to be stunted or conspicuously injured during production, shipping, retail display or interior landscape applications where chilling can occur.

This research project was initiated to generate science-based information on the relative chilling sensitivity of several new Aglaonema hybrids. It was felt that this information would be useful to nurserymen, brokers, shippers, interiorscapers, retailers and the consuming public.

Nature of Work: The experiment was conducted during fall 1997 at the Central Florida Research and Education Center - Apopka using finished 3-gallon plants. The test plants were produced using good cultural practices in shadehouses covered with 73% shade fabric. The 20 Aglaonema cultivars selected for the study are listed below:

Amelia	Manila Pride	Patricia	Royal Queen
Black Lance	Maria	Penny	Royal Ripple
Green Lady	Mary Ann	Queen of Siam	Silver Frost
Green Majesty	Moonshine	Rembrandt	Silver Queen
Jubilee	Painted Princess	Rhapsody in Green	Stars

The five chilling treatments were 35, 40, 45, 50 and 55º F for a 24-hour period in 10-foot by 10- foot walk-in coolers. Because of the spacial requirement for these relatively large plants, in coolers and in holding areas, one plant of each of the 20 cultivars was use in each chilling treatment and during each of the five chilling dates. Chilling treatments were initiated on September 6, 10 and 13, October 14 and November 12.

Plants were placed in paper sleeves which were closed across the top with staples prior to the chilling treatment. Following the chilling exposure, plants were removed from the coolers and unsleeved. Plants were then placed in a greenhouse which was maintained within a temperature range of 68-80º F and provided approximately 1500 foot candles. Plants were evaluated for chilling injury 2, 7 and 14 days after removal from the coolers. The primary indicator of chilling injury in this research was visual foliage color blemish development following exposure to chilling temperatures.

Results and Discussion: As anticipated, visual symptoms of damage was most severe on plants from the 35ºF treatment and least severe in the 55ºF exposure. The percent of total leaves per plant damaged from the chilling exposures for each cultivar is presented in Table 1. Values presented are the means from the plants of each cultivar used in the five chilling treatments and the five exposure dates.

There were distinct cultivar chilling sensitivity differences among the aglaonema cultivars evaluated. A practical representation of the aglaonema chilling damage data appears in Table 1 where each cultivar is assigned one of five chilling resistance categories. ‘Maria’, which is known in the trade to have chilling resistance, is among the three cultivars classified as “highly resistant” to chilling. ‘Silver Queen’, currently the most popular aglaonema in the trade, and ‘Queen of Siam’ are classified in this report as “highly sensitive” to chilling temperatures.

Another dimension to chilling sensitivity is the state of plant vigor as influenced by production temperatures prior to the chilling exposure. Although tropical plants do not have the ability to resist cold temperatures as effectively as temperate hardiness zone plants entering the winter season, there is some increased “hardiness” of aglaonemas as they are exposed to periods of reduced production temperatures during autumn. This is illustrated in Table 2 which contains the means of recorded injury measurements for all cultivars from all five chilling temperatures during each of the five chilling treatment dates.

Significance to Industry:

1. Based on the proposed chilling sensitivity classification, growers and buyers may be cautious to grow or buy some of the most chilling sensitive aglaonema cultivars.

2. Those who do choose to grow or buy the more cold sensitive aglaonemas in a vigorous state know they should maintain plants at 60ºF or above.

3. Use of chilling resistant aglaonema cultivars will not only reduce the chance of plant damage during periods of marginally cool conditions, but by tolerating lower temperatures, the chill resistant cultivars can save energy for heating.

4. Chilling resistance should be an important criterion for plant breeders or those involved with development or evaluation of new plants for industry and consumers.

The authors express thanks to the owners of Sunshine Foliage World, Inc., Zolfo Springs, Florida for their enthusiastic support of this project with plant material and a grant which partially funded the work.

Table 1. Influence of chilling on twenty Aglaonema cultivars (% of total leaves damaged, mean of five temperature exposures and five exposure dates).

Cultivar	% leaves damaged	Classification of chill resistance
Stars	7.6	Highly resistant
Black Lance	9.0	
Maria	12.0	
Rembrandt	14.8	Moderately resistant
Patricia	15.3	
Green Lady	15.9	
Moonshine	16.3	
Silver Frost	17.7	
Amelia	19.0	Intermediately resistant
Penny	19.3	
Mary Ann	20.0	
Green Majesty	21.5	
Manila Pride	22.2	
Royal Ripple	22.5	
Royal Queen	23.7	
Rhapsody in Green	26.2	Moderately sensitive
Painted Princess	26.7	
Jubilee	43.9	Highly sensitive
Silver Queen	48.7	
Queen of Siam	53.2	

Table 2. Influence of chilling date on the level of chilling damage to Aglaonema plants.

Chilling date	% leaves damaged
September 6	27.8
September 10	26.3
September 13	26.8
October 16	21.4
October 30	12.4