SECTION 2
CONTAINER-GROWN PLANT PRODUCTION

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Section Editor and Moderator

Full vs. Partial Container Coating with SpinOut™

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Nature of Work: The application of copper-containing products to interior container surfaces can produce a dramatic effect on root growth within those containers. Cupric hydroxide in a liquid carrier (SpinOut™, Griffin Corporation, Valdosta, GA) is highly effective in redirecting root growth at the container-medium interface in many landscape plant species, as summarized in a recent review (1). Reducing root circling in a container may prevent the eventual formation of girdling roots in the landscape. It may also lead to the development of a more fibrous root system that establishes more readily after transplanting.

As nursery growers seek to produce plants with the above characteristics, SpinOut™ has clearly been a popular product with progressive growers. However, due to the expense of the product, some growers apply it more sparingly than at the full interior coverage recommended by the manufacturer.

Some growers only partially coat their containers with SpinOut™. They accomplish this by painting individual or multiple stripes of the product on interior container surfaces. The objective of this study was to determine whether partial container coating is sufficient to produce the beneficial effects associated with SpinOut™ applied at full container coverage.

Uniform liners of *Lagerstroemia indica* 'Miami', *Koelreuteria paniculata*, and *Acer ginnala* were potted 19 May 1994 in a 5:1 (v:v) pine bark:sand medium. *K. paniculata* was potted into four gallon containers, the other species into three gallon containers. All containers were of the smooth wall plastic type (Nursery Supply, Fairless Hills, PA). Five container wall treatments were used: container only with no copper coating, full interior coating of SpinOut™, a single painted center stripe of SpinOut™, two stripes of SpinOut™ painted at a 90° angle, and three stripes of SpinOut™ painted at a 120° angle (Figure 1). All painted stripes were 1.5 to 2.0 inches wide. Plants were topdressed with either 70 g. (three gallon) or 90 g. (four gallon) Osmocote 17-7-12 (Grace/Sierra, Milpitas, CA) and grown under overhead irrigation. Treatments were replicated five times in a randomized complete block design.

Visual evaluation and plant harvest took place on 17 October 1994 for *L. indica* 'Miami' and *A. ginnala*, and on 24 October 1994 for *K. paniculata.* Visual evaluations consisted of a subjective rating of the quantity of roots covering the exterior root ball after container removal. Each root ball was rated on a scale of 1 to 5, with 1 indicating zero root coverage and 5 indicating prolific root coverage. Dried root and shoot weights were recorded for *L. indica* and *K. paniculata*. On 19 October 1994, all five replications of *A. ginnala* were planted to the landscape in the same randomized complete block design. These *A. ginnala* transplants were dug 4 June 1995 and post-transplant root growth was visually evaluated. Data were analyzed using analysis of variance and Duncan's Multiple Range Test.

Results and Discussion: There were no significant differences in root covering of the medium balls between the control plants with no container treatment and any of the three partial SpinOut™ treatments. By comparison, full-coverage SpinOut™ made a profound difference in root growth at the container-medium interface (Figure 2). There were little or no significant differences in dried root and shoot weights of *L. indica* 'Miami' and *K. paniculata* for any of the five container treatments.

The post-transplant root growth evaluation for *A. ginnala* revealed a notable difference in the root growth of trees that originated in containers with total SpinOut™ coverage. These root systems were much more fibrous with no obvious circling. Trees from containers with no SpinOut™ and all three of the partial SpinOut™ treatments had more coarsely branched root systems and considerable root circling (Figure 3). Although stripes were often still visible on the root balls of trees from partial SpinOut™ treatments, new roots had crossed and circled over the previously treated areas (Figure 4).

Significance to Industry: Rather than being a wisely frugal use of SpinOut™, partial coverage (via striping) may be simply an extravagant waste of product. Partially coating interior container surfaces with SpinOut™ was not significantly better than no surface coating with regard to stopping root circling or promoting fibrous root production. Partial coverage was not beneficial either during production or once trees were transplanted to the landscape.

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Figure 1. One, two and three stripe applications of SpinOut™.

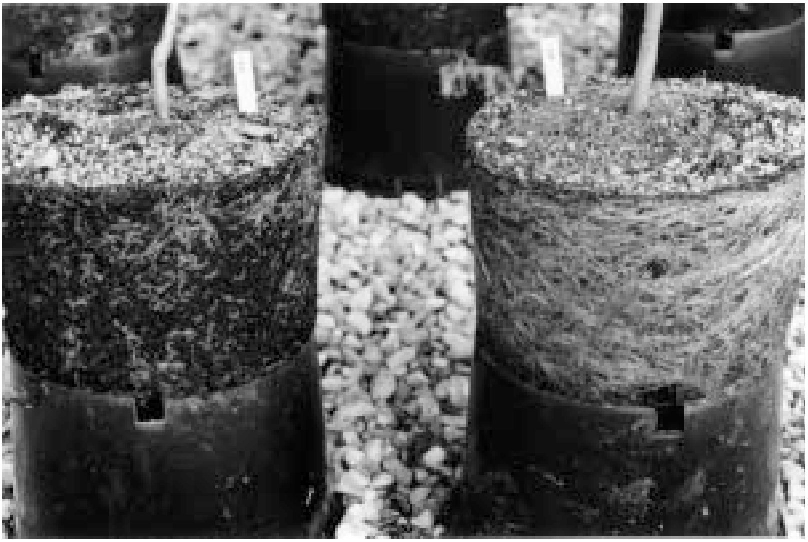

Figure 2. Minimal root growth on outside of rootball for goldenraintree grown in a SpinOut™-treated container (left) vs. considerable root growth on outside of rootball for the same tree grown in an untreated container (right).

Figure 3. More fibrous root system with no root circling on an Amur maple grown in a SpinOut™-treated container (left) vs. a more coarse root system with considerable root circling for the same tree grown in an untreated container (right).

Figure 4. Amur maples, both from SpinOut™-treated containers, with differing amounts of root circling over the copper stripes.

Preliminary Evaluation of Composted Poultry Litter as a Potting Mix Component

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Nature of Work. Composted poultry broiler litter (CPL) can be used as a component of container mixes to produce ornamental plants. Each CPL must be evaluated for physical and chemical properties. Composts have been shown to be beneficial by providing nutrients necessary for plant growth and supplying organic material to improve water and nutrient holding in potting mixes. Compost with high nutrients can contribute to surface and ground water pollination by releasing nitrogen and phosphorus faster than plants can absorb them. Proper management is necessary to control this pollution potential.

Questions arise on how much compost should growers use in their potting media. Suggestions for sludge compost include replacing peat with 10-30% by volume for woody plants. Container media must meet exacting porosity and fertility requirements. Not all compost are created equal so each material must be evaluated independently (3).

Work with CPL and pine bark by Bilderback (1) found an addition of 33% of composted poultry litter to pine bark had little or no affect on total porosity and container capacity, but increase bulk density and unavailable water. The 33% compost increase pH and electrical conductivity after five weeks and NO_3-N, P, K, Ca and Mg levels while NH_4-N decreased. Warren (4) found that additions of CPL to a sandy loam soil in pots increased pH and P, K, Ca and Mg. With increasing levels of CPL there were increases in porosity, unavailable water, total water content, available water and bulk density.

Turkey broiler litter compost (TBL) added at 10 and 20% to pine bark and sand (4:1 v/v) increased or had no affect on total porosity. The container capacity was increased three to six percent by volume and electrical conductivity, pH, leachate phosphorous, calcium and magnesium also increased. Nutrition levels were deficient after 83 days. TBL reduced air space, increased container capacity and increased unavailable water content (2).

Composted poultry broiler litter (CPL) was combined with nursery grade pine bark at 0%, 5%, 10%, 20%, 30% and 40% by volume. The treatments were placed in four-inch round plastic pots and placed on a greenhouse bench under plastic cover. Five replicates of each treatment were included in a completely randomized design. Water was added in 100 milliliter increments which approximated 1/2-inch of water per pot. Leachate was collected from each replicate after the addition of 200, 300, 500 and 800 milliliters of total water. Leachate samples were analyzed for soluble salt levels. Treatments were statistically analyzed as completely randomized one way analysis of variance with means separated by Student-Newman-Keuls test.

Single media samples of treatment were collected after application of 200, 800, 1500 and 2200 milliliters of total water. After completely draining, samples were collected and submitted to The University of Georgia Soil Testing Laboratory for the routine soilless media test to determine soluble salts, pH, phosphorus, ammonium nitrogen, nitrate nitrogen, phosphorus, potassium, calcium and magnesium.

Media samples of the six treatments were tested to determine the physical properties using the methods developed by North Carolina State University Horticultural Substrates Laboratory. The NCSU porometer was used to determine the physical properties of moisture content, mass wetness, air space, container capacity, porosity and bulk density.

Results and Discussion. The leachate soluble salt levels were significantly different for all treatments at each water level (Figure 1). All CPL additions resulted in excessive soluble salts after application of 200 milliliters water. The addition of 300 and 500 milliliters water resulted in excessive levels for 10%, 20%, 30% and 40% treatments. After 800 milliliters water only the 40% CPL treatment was excessive. These high soluble salt levels would be injurious to plants. From the media samples, addition of 800 milliliters of water was required reduced the soluble salt levels down to the acceptable range (Figure 2).

Initial levels of NH_4 nitrogen were high for the 20%, 30% and 40% CPL. After 800 milliliters water, the high levels of ammonia were leached from the media. Nitrate nitrogen was low initially but at 800 milliliters of water there was a significant increase in the nitrate nitrogen which was reduced with additional water. This rise in NO_3 nitrogen probably occurred because of the conversion of NH_4 nitrogen to NO_3.

CPL at 0% was initially low in phosphorus, but all additions of CPL increased phosphorus to excessive levels. After leaching with 2200 milliliters water the 5% CPL to 40% CPL were still excessive. Potassium, calcium and magnesium leachate levels were very high with 5% to 40% CPL. Addition of 800 to 1500 milliliters of water reduced all these nutrients to acceptable or low levels. Additional water leached these nutrients from the media to very low levels.

The physical properties of moisture content and mass wetness are directly linked. Moisture content is the percent of water in the sample based on mass wetness. Mass wetness indicates the amount of water needed to wet a dry sample. The moisture content and mass wetness decreased with increasing amounts of CPL (Table 1).

The air space, percent volume of air filled pores after saturation and drainage of gravitational water, increased to a high of 26% for the 10% CPL. Container capacity, the percent of water-filled pore space after saturation and drainage of gravitational water, decreased initially with a slight rise at the 30 and 40%. The same trend follows with total porosity, percent volume of pore space (Table 1). The bulk density increased with increasing percent CPL with 0% at .18 g/cc and 40% CPL at .37 g/cc.

Significance to Industry. The initial high levels of soluble salts, NH_4-nitrogen, phosphorous, potassium, calcium and magnesium in pine bark media amended with composted poultry broiler litter can cause plant injury. Excessive levels can be reduced by leaching, however, the run-off has the potential for surface and ground pollution. The best physical properties of the pine bark media occurred with the addition of 5% CPL to 20% CPL.

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Table 1. Physical Properties of Composted Poultry Litter Media

TREATMENT	MOISTURE CONTENT	AIR SPACE	CONTAINER CAPACITY	POROSITY
0% CPL	38.8%	17.8%	71.1%	88.9%
5%CPL	29.4%	23.7%	63.3%	87.0%
10% CPL	26.1%	26.0%	59.92%	86.0%
20% CPL	25.0%	24.8%	58.3%	83.0%
30% CPL	20.4%	14.4%	62.5%	76.9%
40% CPL	18.2%	14.0%	66.5%	80.5%

Figure 1. Composted Poultry Litter (CPL)
Soluble Salts From Leachate

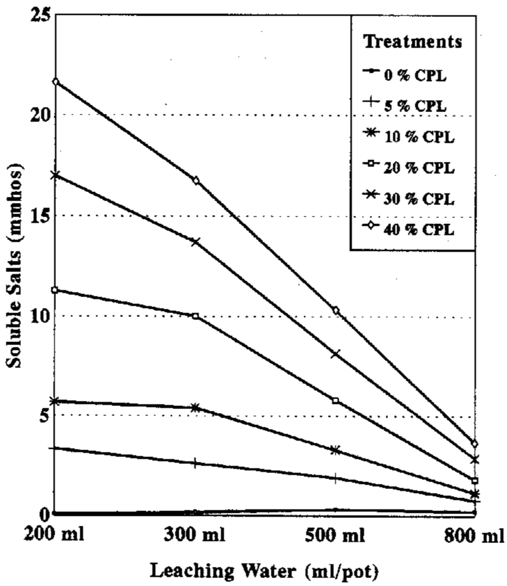
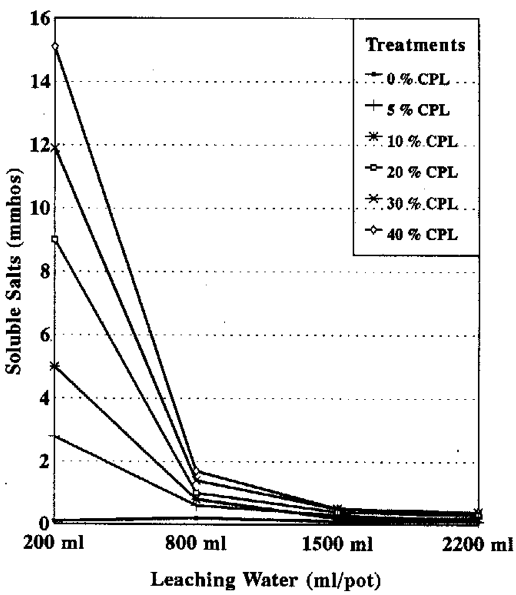


Figure 2. Composted Poultry Litter (CPL)
Soluble Salts From Media



Evaluation of Waste Products as Peat Substitutes in Container Substrates

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Florida

Nature of Work: Many traditional container substrates are composed of bark, peat and sand. Varying cost and availability of sphagnum peat have inspired growers to seek less costly alternatives. Since disposal of organic waste products has become difficult due to environmental regulations, generators of these waste products have approached nursery growers in hopes of simultaneously solving the problems of waste disposal and costly substrate components.

Rice hulls, cocoa shells, cotton gin trash and many other waste products have been incorporated into container substrates with varying levels of success (1, 2, 3). Shipping costs of peat alternatives dictate that locally-produced wastes are the most economical alternatives to peat.

This study examined the feasibility of using locally-available mushroom compost, dairy waste, or a paper production waste as substitutes for peat in a container substrate at Simpson Nurseries, Monticello FL. Mushroom compost, from Quincy Farms, Quincy FL, was made from chicken litter, wheat straw, peat, and other components. The fresh mushroom compost used in this study is the spent, unaged compost remaining after several crops of mushrooms have been harvested. Dairy waste (Bassett Dairy, Monticello FL) is the fibrous material that remains after the liquid portion is drained from lagooned dairy cow manure. The paper production waste, locally called "knotsand-chives", consists of small knots and woody material removed during the production of a high quality paper pulp. The paper production waste (PPW) was obtained by a local bark supplier, Georgia Florida Bark & Mulch Co., Monticello FL, and further processed by shredding.

Simpson Nursery's standard substrate is composed of pine bark, sphagnum peat, and 6B gravel (65/20/15, v/v/v) amended with 4 Ibs. dolomite, 2 Ibs. Micromax (The Scotts Company, Marysville OH) and 12 Ibs. Osmocote 18-6-12 (The Scotts Company, Marysville OH) per cubic yard. We evaluated the waste materials for physical properties and, based on these results, developed and tested these waste products as a complete or partial substitute for peat. All tested substrates contained 65% pine bark, 15% 6B gravel and other amendments; the remainder of each mix contained peat or waste products as follows: 20% peat (Standard Mix), 20% mushroom compost, 10% mushroom compost + 10% peat, 20% dairy waste, 10% dairy waste + 10% peat, 20% PPW, 10% PPW + 10% peat. On 19 May 1993, standard nursery mixing and potting procedures were used to pot 10 liners each of Cornus florida, Lagerstroemia x 'Biloxi', and Magnolia x 'Ann' into trade 3-gallon containers using each of the 7 substrates. All plants were placed on a container bed at the nursery and received standard nursery irrigation, fertilization and pest control practices. Plant height and width were measured initially and 4 months later, September 1 5, 1 993. Results were analyzed by species .

Results and Discussion: Preliminary experiments indicated that physical properties of substrates exceeded recommended ranges when content of waste products was greater than 20% (data not shown). Excluding 10% PPW + 10% peat, all substratescontaining waste products had greater % airspace and reduced pot weight as compared to the Standard Mix (Table 1). The substrate containing 10% PPW + 10% peat had greater water holding capacity and similar % airspace as compared to the Standard Mix. Water holding capacity for most substrates containing waste products was similar to that of the Standard Mix.

Growth responses to the test substrates varied with plant species, but substrates containing waste products generally performed as well as Simpson Nurseries' Standard Mix (data for plant height shown in Table 2). Statistical comparisons of crapemyrtle treatments were not appropriate because crapemyrtles were not properly randomized, and plants in the Standard Mix treatment were placed on the edge of the bed where they did not receive adequate irrigation.

Significance to Industry: Growth responses to the test substrates varied with plant species, but replacing 20% peat with up to 20% mushroom compost, dairy waste, or paper production waste generally resulted in plant growth equivalent to Simpson Nurseries' standard substrate of 65% pine bark, 15% 6B gravel, and 20% sphagnum peat.

Literature Cited

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Acknowledgement

The authors gratefully acknowledge Simpson Nurseries, GeorgiaFlorida Bark & Mulch Co., Quincy Farms, and Bassett Dairy for their contributions to this project. Florida Agricultural Experiment Station Journal Series Number x-xxxxx.

Table 1. Physical Properties of substrate tested at Simpson Nurseries. Means are of 3 3-gallon containers. Letters within columns indicate mean separation by Duncans Multiple Range Test.

	PHYSICAL PROPERTIES		
	% Airspace	% Water Holding Capacity	Pot Weight (lbs.)
SUSTRATES			
Standard (20% Peat)	25.4 d	21.6 b	17.3 a
10% Mushroom Compost + 10% Peat	27.7 c	19.5 bc	17.0 a
20 % Mushroom Compost	29.6 b	17.6 c	16.4 b
10% Dairy Waste + 10 % Peat	27.7 c	19.5 bc	17.0 a
20 % Dairy Waste	32.4 a	19.0 bc	16.0 bc
10 % Paper Production Waste + 10 % Peat	26.9 cd	24.8 a	15.8 bc
20 % Paper Production Waste	32.3 a	19.9 bc	16.0 bc

Table 2. Means of final plant height by species and medium. Means are for 10 plants. Letters within each column indicate mean separation by Duncan's Multiple Range Test.

	Dogwood	Species 'Biloxi' Crape Myrtle	'Ann' Magnolia
	Final Height (in.)	Final Height (in.)	Final Height (in.)
SUBSTRATES			
Standard (20% Peat)	43.4 a	36.5	27.4 ab
10% Mushroom Compost + 10% Peat	43.1 a	74.4	28.2 ab
20 % Mushroom Compost	36.6 a	71.6	24.7 bc
10% Dairy Waste + 10 % Peat	45.3 a	52.1	30.0 a
20 % Dairy Waste	42.7 a	65.4	21.1 c
10 % Paper Production Waste + 10 % Peat	46.2 a	77.5	24.8 bc
20 % Paper Production Waste	44.3 a	65.8	25.5 b

Growing Better Growers: Taking Applied Research into the Field

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Nature of work: Nursery growers frequently question release rates of slow release fertilizers. Early products developed a reputation for rapid release or"dumping" of the entire nutrient package with sudden temperature increases. When slow release fertilizers did not last as long as expected, growers reached the end of winter with a crop of poor color that may not have been suitable for sale. If this situation were noticed early enough the previous season, the grower was forced into judgements regarding whether to fertilize late in the summer and hazard the risk of growth too young and vigorous to adequately harden before onset of cold temperatures. Such experiences occasionally put them in the position of making judgement calls based solely on visual observation, experience, or hunches. A grower experiencing this type of situation approached Extension personnel for assistance in understanding how to manage his crop. The intent of this study was to compare rate of release of fertilizers through a complete growing cycle from spring to spring and to demonstrate the value of field measurements in determining the status of the crop.

Six fertilizer treatments were compared on Rhododendron X ‘Roseum Elegans’ and Rhododendron X ‘Maximum Roseum’ in three gallon containers. Growing medium was a fine pine bark with about 5% coarse gravel screenings. Potting mix included 10 pounds of dolomitic limestone per yd3 and a complete minor element supplement (STEPtm Scotts Company, Marysville, OH). Magnesium sulfate was added to Nutricote products and the Sierra High N formulation at a rate of 6.8 g/gal container. Fertilizer applications were made as a topdressing on April 28, 1994. All cultural practices including irrigation, weed and pest management followed standard practices of the nursery except that plants were not pruned during the study. Containers were placed in 10 blocks by cultivar in a random design in full sun. Each container was labeled for cultivar, treatment, and block number with a color coded flag.

Fertilizer applications were as follows: (1) Scott’s 17-3-6, 50g/pot = 8.5 g N/pot; (2) Scott’s 21-5-8, 55 g/pot = 11.6 g N/pot; (3) Meister 21-7-14 with minors, 55 g/pot = 11.6 g N/pot; (4) Sierra High N 22-4-7 with minors, 50 g/pot = 11.0 g N/pot; (5) Nutricote 17-7-8 T-270 with minors, 67.5 g/pot = 11.5 g N/pot; (6) Nutricote 17-7-8 T-360 with minors, 75 g/pot = 12.8 g N/pot; (7) Control, no topdress (3 containers only).

The Pour-Through extraction procedure was used to collect leachate samples from 5 blocks of one cultivar. Samples were collected 1 and 4 weeks after fertilizer application and at approximately 4 week intervals thereafter during the 1994 growing season and before bud break in spring, 1995. Leachate samples were collected from 30 treatment plants, 3 untreated controls and from the irrigation hydrant. Leachate was field tested for pH and electrical conductivity using a Myron AG-6/pH Agri Meter. On 4 sampling dates (May, July, and October 1994 and April 1995) leachate and irrigation samples were also sent to the Horticultural Substrates Lab at North Carolina State University to be analyzed for nitrate- N, ammonium-N, and phosphate. On the same 4 dates foliar samples were collected and sent to the NCSU Soil Science Service Lab for nutrient analysis including percent nitrogen, phosphorous, potassium, calcium, and magnesium. During the spring '95 sampling, buds were counted on each plant. Treatments were also evaluated qualitatively by 3 judges.

Results and discussion: All fertilizers provided quick availability of nutrients as evidenced by electrical conductivity of the leachate in the week 1 samples (Table 1). Assuming a desirable EC range of 0.5 to 2.0 mmhos/cm, four of the treatments were at or above the upper range at this time. The Scotts 17-3-6 treatment, with the highest EC at this date, had the lowest nitrogen levels (nitrogen data not shown). By week 4 the Scotts 17-3-6 treatment still had a relatively high EC (1.9) but less than 50 ppm total N in the leachate. By week 8 (June) all EC levels had dropped to within the desired range. At week 12 (July) and 16 (August) all ECs were increasing, and no treatment was below 2.0 by week 16. During these two sampling dates, untreated control EC levels also rose significantly. We have to consider the possibility that an ambitious nursery employee may have fertilized the demonstration block. No visual evidence of application was noted, however, and total nitrogen levels in the control leachate were very low at week 12 (17.16 ppm). By week 20 (September) EC levels were dropping although Miester, Sierra High N and Nutricote 17-7-8, 360 treatments were still greater than 2.0 mmhos/cm. By week 24 (October) all levels were less than 1.0.

Laboratory analysis of the leachates reported total nitrogen at week 4 was below 50 ppm for Scotts 17-3-6; between 50 and 100 ppm for Scotts 21-5-8, Meister 21-7-14 and Nutricote 17-7-8, 360; and slightly above 100 ppm for Sierra High N and Nutricote 17-7-8, 270. By week 12 total N was in the 50 to 100 ppm range for Scotts 21-5-8 and Meister 21-7-14 and above 100 ppm for other fertilizer treatments. The week 24 (October) leachate had total N levels still considered to be in the growing range for Nutricote 270 and 360 day release products (56.26 ppm N) and (50.24 ppm N) respectively. Other treatments ranged from 13.0 to 48.8 ppm.

Foliar N levels were generally within desired ranges throughout the growing season (foliar data not shown). At week 1 nitrogen dry weight ranged from 1.9% to 2.1% with the control at 1.6%. All treatments remained above 2% through the October sampling. Spring 1995 samples showed foliar N levels slightly higher than the week 1 sampling in treatment Meister, Sierra and Nutricote treatments and slightly lower in Scotts treatments. Foliar phosphate levels were seldom as high as 0.3 % tissue dry weight as might be desired. At week 1 they ranged from 0.16% to 0.19%. In July the highest level of P was 0.28%. October foliar P levels ranged from 0.25% to 0.27%. Foliar phosphorous in the spring was only slightly less than in October except for Nutricote 17-8-7, 270 which increased slightly.

Average bud count per plant varied by less than four flower buds among all treatments and treatment ranking was not consistent between cultivars. Qualitative evaluations of treatments were inconsistent. Among fertilizer treatments examined electrical conductivity data indicate that the EC was high enough to cause grower concern with all treatments. July and August levels above 2.0 mmhos / cm could pose a risk for rhododendrons if container media should become dry between irrigation cycles. Recommended application rates should perhaps be reconsidered, if irrigation management is not altered to increase leaching .

Significance to the Industry: The results may vary one nursery to another due to factors such as irrigation application and water quality and substrate components, but the methodology for monitoring demonstrates that growers have tools available to assist them in making judgement calls in the field. It is relatively easy to collect leachate samples after rainfall or irrigation. By measuring electrical conductivity, growers can reasonably assess the status of fertility and track release rates through the growing season, adjusting their programs accordingly. Field readings may be backed up through laboratory analysis. Research and Extension personnel may assist growers in learning how to use such techniques to help improve skills. Growers who have previously had to depend on experience and visual observation have the capacity to take steps to increase their technical capabilities.

Table 1. Effect of fertilizers on leachate EC on eight collection dates for *Rhododnedron X* ' Roseum Elegans' in 3 gallon containers[z]

	Weeks after Initiation of Study							
Fertilizer	1	4	8	12	16 (mmhos / cm)	20	26	54
							ns	ns
Scotts 17-3-6 {8.5 g N/Pot}	2.5a	1.9a	1.5ab	2.5a	2.5a	1.7ab	0.7	0.4
Scotts 21-5-8 {11.6 g N/Pot}	1.2c	1.5a	1.1ab	1.8ab	2.3a	1.7ab	0.9	0.7
Meister21-7-14 {11.6g N/ Pot}	1.5bc	1.5a	1.0b	1.6abc	2.0ab	2.2a	0.9	0.6
Sierra High N (22-4-7) {11.0 g N/Pot}	2.3ab	2.2a	1.9a	2.4a	2.9a	2.1a	0.9	0.8
Nutricote 17-7-8 (270 day) {11.5g N/Pot)	2.0ab	2.0a	1.1ab	1.4bc	2.4a	1.6ab	0.9	0.6
Nutricote 17-7-8 (360 day) {12.8 g N/Pot}	2.5a	1.8a	1.3ab	1.6abc	2.6a	2.1a	0.9	0.6
Control (no fertilizer)	0.3d	0.5b	0.4c	0.8	1.2b	0.6b	0.5	0.4
Irrig. Water	-.-	0.3	0.4	0.3	0.3	0.1	0.3	-.-

[z]Mean separation within a column followed by the same letter or letters are not significantly different using the Waller-Duncan k-ratio t-test at k-ratio=100.

[y]Suggested guidelines for EC 0.5-2.0 millimhos/cm.

Evaluating the Phytotoxicity of Insecticidal Oil Sprays on Selected Container Grown Plants

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Alabama

Nature of Work: Increased government regulation, concern for workplace safety, environmental issues, and the need for economically effective methods of pest management are compelling growers of ornamental plants to seek “novel” and more benign methods of pest control. The use of petroleum oil as an insecticide is not, *per se*, a novel pest control tool. Oil sprays have been used in insect pest control for over 100 years (1). However, due to their reputation for causing damage to growing plants, they have not been a tool selected by the growers of ornamental plants. Insecticidal oil, however, has several characteristics that make it attractive for use in pest management programs. Insecticidal oil has a wide range of activity against common ornamental pests such as, mites (all stages), whiteflies (all immature stages), aphids, scales, and mealybugs. Little or no resistance to insecticidal oil by target pests has been observed. Short residual activity makes them less harmful to beneficial insects than pesticides with longer residuals. Low mammalian toxicity and residues that are readily metabolized by bacteria, make insecticidal oil very safe for humans and the environment. Insecticidal oil products have reduced personal protective equipment (PPE) requirements as well as relatively short reentry intervals (REIs) which allow them to fit into nursery situations more easily than many other insecticides. These positive attributes make insecticidal oil a good candidate for use in IPM programs as well as in labor-intensive situations such as those found at most nurseries. Over the years, improvements have been made in insecticidal oil. Narrow range, highly refined, “summer oil” can be safely sprayed on most actively growing crops (1). In spite of this, many ornamental growers are still apprehensive about using insecticidal oil in their spray programs because of their historical use as “dormant only” sprays.

In the summer of 1994, we conducted a demonstration trial at Flowerwood Nursery, Loxley, Alabama to determine the phytotoxicity of insecticide oil sprays on several commonly grown ornamental species. Twenty different ornamental plants were selected for this trial (Table 1). These plants were chosen because they are preferred hosts of insects oil sprays are known to control (i.e., mites, aphids, scales, whiteflies). We tested two different oil products, Sunspray Ultra Fine Spray Oil and Target Oil at a 1% rate (one gallon oil per one hundred gallons of spray solution). Six treatments, consisting of a morning spray (the recommended time to spray) and a midday spray (when phytotoxicity is most likely to occur) for each of the two oil products and two water controls were tested. Six single plant replicates were arranged in a completely randomized design for each of the 20 plants tested. All plant surfaces were sprayed until runoff. Spraying was conducted by Flowerwood Nursery personnel using Flowerwood Nursery equipment. Plants were sprayed using a hand-held Green Garde JD9-C spray gun at approximately 200 psi at the by-pass valve. Plants were sprayed August 9 and again on September 6. Temperatures and relative humidities were 78ºF and 83% and 87ºF and 67% for the morning and midday sprays respectively on August 9. Temperatures and relative humidities were 84ºF and 80% and 91ºF and 71% for the morning and midday sprays respectively on September 6. Weather on both dates was partly cloudy. Plants were evaluated for signs of phytotoxicity three and seven days after the first spray and three and seventeen days after the second spray. Phytotoxicity was determined by comparing oil sprayed plants with water sprayed controls. Two judges rated the degree of phytotoxicity using a scale of 1-5, where 1=death and 5=no visible phytotoxicity.

Results and Discussion: No phytotoxicity was observed following the first spray application. On the first observation date, September 9, following the second spray application, phytotoxicity was observed on rose, compacta holly , carissa holly and gumpo azalea. Symptoms of phytotoxicity included water-soaked spotting on a few leaves of carissa holly, faint water spotting on leaves of compacta holly, chlorosis of growing tips of gumpo azaleas, and marginal burn and curling on rose leaves. Due to an oversight, roses were sprayed while under considerable water stress; this may explain the observed phytotoxicity. On the second observation date, September 23, following the second spray, phytotoxicity could only be discerned on the compacta holly. As with observations made September 12, symptoms consisted of water spotting on leaves.

It was the opinion of the evaluators that none of the observed phytotoxicity would have rendered the damaged plants unsalable. (Table 2)

Significance to Industry: Our tests confirmed the relative safety of insecticidal oil use over a wide range of species. For reasons previously stated: efficacy, environmental and human safety, compatibility with other pest management tactics, short REIs and reduced PPE requirements; insecticidal oil has (will) become an integral part of many nurseries' pesticide arsenals.

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Table 1 Plants Used in Oil Phytotoxicity Trial

Dwarf Burford Holly	Dwarf Nandina 'Fire power'
Crepe Myrtle 'Centennial Spirit'	Cotoneaster 'Scarlet Leader'
Dwarf Yaupon Holly	Japanese Boxwood
Camellia japonica	Hino Azalea 'Hinode Giri'
Formosa Azalea 'Judge Solomon'	Girard Azalea 'René Michelle'
Helleri Holly	Golden Euonymous
Spiraea	Barberry 'Crimson Pigmy'
Chinese Privet	Liriope 'Big Blue'
Rose*	Carissa Holly*
Pink Gumpo Azalea*	Compacta Holly**

* Phytotoxicity observed 9/9/94, ** phytotoxicity observed 9/9/94 and 9/23/94

Table 2 Results of Post Spray Plant Evaluations

Date: 9/9/94	Percentage of Plants Damaged		Mean Score	
Rose	Morning	Midday	Morning	Midday
Target	0	0	5.0	5.0
Sunspray	50	0	4.8	5.0
Date: 9/9/94				
Carissa Holly				
Target	17	17	4.9	4.9
Sunspray	33	67	4.8	5.0
Date: 9/9/94				
Gumpo Azalea				
Target	100	100	4.3	4.4
Sunspray	100	100	4.5	4.5
Date: 9/9/94				
Compacta Holly				
Target	83	100	4.5	4.5
Sunspray	100	100	4.5	4.5
Date: 9/23/94				
Compacta Holly				
Target	83	100	4.5	4.6
Sunspray	100	100	4.4	4.5

Mean score and percentage of plants damaged based on the phytotoxicity ratings of two evaluators evaluating 6 plants per treatment. Rating was on a 1-5 scale with 1=death and 5=no visible phytotoxicity.

Fertilization Treatments of Pot Mums to Increase Efficiency of Nutrient Uptake

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Nature of Work: Fertilization of potted chrysanthemums [*Dendranthema x grandiflurum* (Ramat.) Kitamura] is essential to maximize their vegetative growth (1,2). Nutrient requirements can be met with either a slow release or water soluble fertilizer. Water soluble products can either be applied at each irrigation or applied less frequently at a higher rate. The objectives of this study were: 1) to quantify the levels of soluble salts in leachate from potted mums fertilized by several commercial practices, and 2) to evaluate plant growth response to these practices.

Rooted cuttings of 'Charm' and 'Delano' chrysanthemum were potted singly in 6" azalea pots with a peat-based commercial medium (Pro-Mix BX, Premier Peat Moss Ltd., Stamford, CT) on Feb. 6, 1995. Plants were grown in a glass greenhouse at day/night temperatures of 72/68F. Night interruption (10 P.M.-2 A.M.) was provided for 10 days, after which natural illumination and photoperiod were provided.

The experiment was laid out in a randomized complete block design for each cultivar with 4 blocks, 4 treatments and 3 samples/treatment/block. Fertilizer treatments were initiated 18 days after potting as follows: (1) Alternating Liquid Feed (ALF): 536 ppm (mg/l) N supplied as Peters Pot Mum Special (Grace-Sierra Horticultural Products Co., Milpitas, CA), 15N-4.4P-24.9K (15-10-30) alternated with tap water, (2) Constant Liquid Feed (CLF): 268 ppm (mg/l) N supplied as above at every watering, (3) Slow Release Plastic-Encapsulated Fertilizer (SRP): 0.4 oz (12 g)/pot of Sierra Chrysanthemum Mix + Minors, 12N-4.4P-14.1K (12-10-17), (4) Slow Release Tablets (SRT): 0.3 oz (9 g)/pot (3 0.1oz (3-g) tablets) Sierra Agriform Container Tablets, 14N-1.7P-5.0K (14-4-6). Plants from each treatment were irrigated when they dropped to 60% of container capacity. Sufficient solution was applied to ensure a leaching fraction between 0.1 and 0.2. Leachate was collected from each container at each irrigation and its conductivity and pH determined.

The experiment was terminated at anthesis, 8 weeks after treatments were initiated. Shoot fresh weight, plant height, and plant width in 2 directions were recorded. Shoots were washed in 0.2M hydrochloric acid, rinsed in distilled water, and dried. Following collection of dry weight data, samples were ground and tissue analysis conducted for the range of essential plant elements. Growth and tissue analysis data were subjected to analysis of variance and means separated (lsd=0.05) where appropriate.

Results and Discussion: Over the 8-week period leachate soluble salt readings for the LF treatments increased, whereas they decreased for the SR treatments. Leachate pH values demonstrated the reverse trends. Finished plants in the ALF, CLF and SRP treatments were of high quality with no differences in shoot fresh weight, dry weight or plant width. The SRT treatment resulted in reduced plant growth. Nutrient concentrations fell generally within the standards for uppermost leaves from mature flowering shoots of chrysanthemum. Values for the macronutrients nitrogen, phosphorus and potassium were higher for the LF treatments than for the SR treatments.

Although the ALF, CLF and SRP treatments all produced high quality plants, only the SRP treatment did so at a relatively low concentration of soluble salts in the leachate. This supports previous findings that slow release fertilizers reduce waste of excess nutrients from leaching (3), and that high quality plants can be produced at relatively low nutrient levels (4).

Significance to Industry: With proper management of fertilization practices, commercial greenhouse operators can reduce greenhouse effluents without reducing crop quality. Slow release fertilizers are especially appropriate for greenhouse operations with nonrecirculating irrigation systems due to the low concentration of nutrients in container leachate.

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Effect of Cold Storage and Wax Covering on Shoot Water Potential of Bare-Root Washington Hawthorn and Norway Maple Trees

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Virginia

Nature of Work: Desiccation of bare-root nursery stock during storage and after transplanting can result in poor regrowth and is considered to be the main cause of post-transplant tree death (3). Studies have shown that tree species differ widely in their response to storage conditions (4), temperature and duration (5). Bates and Niemiera (1) found that, following storage and transplanting into a moist substrate, stem xylem water potentials (Ψ_s) increased (became less negative) for Norway maple (*Acer platanoides*), but decreased for Yoshino cherry (*Prunus x yedoensis*), which resulted in more stem dieback and reduced survival for cherry than maple. These results suggested species differences in stem water loss rates. However, there are no reports on the contribution of stem water loss to decreasing Ψ after transplanting. Objectives of this study using bare-root trees were to determine 1) the influence of storage duration on the post-transplant Ψ_s of desiccation sensitive *Crataegus phaenopyrum* and desiccation tolerant *Acer platanoides*, and 2) if post-storage stem wax coating influenced Ψ_s and bud break.

On January 14, 1993, 2-yr-old bare-root *Acer platanoides* and *Crataegus phaenopyrum* seedlings 60-90 cm (24-36") tall were received in Blacksburg, VA, from Lawyer Nurseries, Plains, MT. Upon arrival, trees were enclosed in storage bags (Union Camp Corp., Tifton, GA) to reduce water loss and placed on wooden racks in a cooler at 70% _ 5% relative humidity and 2°C (35°F). On January 28, February 11, February 28, March 11, March 28, and April 11, (2, 4, 6, 8, 10, and 12 weeks in storage, respectively) 16 hawthorn and 16 maple trees were randomly selected and removed from cold storage. Stem water potential was measured between 1200 and 1400 HR the same day using a portable pressure chamber (Model 3005, SoilMoisture Equipment Corp., Santa Barbara, CA) on a 10.2 cm (4 in) stem section excised from 8 trees of each species. Remaining trees were transferred to a greenhouse ventilated at 24°C (75°F) and heated at 18°C (64°F), transplanted into 100% pine bark-filled 3.8 l (1 gal) plastic containers and thoroughly irrigated. Stem water potential was then measured between 1200 and 1400 HR for these trees five days after transplanting. Storage duration and time of measurement factors were applied in a completely randomized design with eight single plant replications. Data were subjected to analysis of variance (ANOVA) and mean comparisons were made using a *t* test. Species (maple and hawthorn) data were analyzed separately.

Dormant 2-yr-old *Crataegus phaenopyrum* bare-root seedlings were received from Lawyer Nurseries on February 16, 1994, and placed in cold storage at 90% relative humidity and 2°C (35°F). Within storage, 78 trees were enclosed in storage bags (approx 10 trees/bag) and 78 trees were unbagged. On February 24, 78 seedlings from each group (bagged and unbagged) were removed from storage and Ψ_s was measured between 1200 and 1400 HR on six trees of each group. The entire shoot system of 36 trees per storage treatment group were submerged in melted TissuePrep (Fisher Scientific Co., Fair Lawn, NJ) paraffin and then dipped into cold water to solidify the wax. The remaining 36 uncoated trees from each group served as the control. All seedlings were then immediately transplanted into 100% pine bark-filled 3.8 l (1 gal) containers and placed on raised benches in the greenhouse previously described. Shoot water potentials were measured between 1200 and 1400 HR on six trees from the wax-treated and untreated controls 2, 4, 6, 8, 10, and 12 days after transplanting. Percent bud break (number of growing buds/total bud number) was measured for each tree 8 weeks after transplanting. Plants in the stem wax treatment and time after transplanting treatments were arranged using a completely randomized design replicated six times. Data were subjected to analysis of variance (ANOVA) and mean comparisons were made using the *t* test. Storage treatment (bagged and unbagged) data were analyzed separately.

Results and Discussion: Pre-transplant maple and hawthorne Ψ_s decreased with increasing cold storage duration (Table 1). This affect of storage duration on Ψ_s was the same as found by Bates (2) in a previous study. For the first six weeks in storage, pre-transplant maple Ψ_s were ≥ -1.2 MPa. Post-transplant Ψ_s values were the same as the respective pre-transplant values for the first six weeks in storage. After eight weeks in storage, pre-transplant values were ≤ -1.5 and post-transplant Ψ_s were higher than the respective pre-transplant values. For hawthorn, Ψ_s decreased more rapidly during storage than maple, reaching a low of -2.25 MPa after twelve weeks (Table 1). Also in contrast to maple, post-transplant Ψ_s were lower than respective pre-transplant values for four of the six durations. In a similar study, Bates and Niemiera (1) reported post-transplant recovery from water stress for Norway maple and lack of recovery for the desiccation sensitive Yoshino cherry.

Stem water potential for unwaxed hawthorn seedlings that were unstressed (covered) during storage decreased 69% during the 12 days after transplanting compared to only 28% for the wax covered seedlings (Table 2). Thus, the wax covering greatly ameliorated post-transplant water stress. Bud break (percent of total buds emerging) for unstressed trees with wax-coated stems was 26% higher than for trees without the wax coating (Table 2). Stressed hawthorn seedlings (uncovered in storage) exhibited the same Ψ_s trends as unstressed seedlings (Table 2) although values were lower and differences between wax and no wax treatments occurred four days after transplanting compared to eight days for unstressed trees. The wax coating data of the current work indicated that water exiting through hawthorn stem tissue was responsible for increasing water stress. The low bud break percentages for the unwaxed trees of both stressed and unstressed experiments demonstrated the lack of desiccation tolerance of hawthorn. From a commercial standpoint, bud break percentages for the unwaxed treatments are unacceptable.

Significance to Industry: During cold storage, bare root trees generally incur water stress. Following storage and transplanting, some desiccation tolerant species such as Norway maple are able to recover from cold storage-induced water stress. In contrast, desiccation sensitive species such as Washington hawthorn have a relatively low recovery capacity. For desiccation-sensitive species, coating stems with wax prior to transplanting alleviates post transplant water stress and and maximizes bud break.

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Table 1. Influence of cold storage duration on shoot water potential of pre- and post-transplant 2-yr.-old Washington hawthorn and Norway maple.

		Shoot Ψ (-MPa)					
		Storage duration (weeks)					
Measurement time	Initial[z]	2	4	6	8	10	12
				Maple			
Pre-transplant	0.90	0.92 ay	1.14 a	1.25 a	1.55 a	1.80 a	1.84 a
5 days post-transplant		0.75 a	0.95 a	1.15 a	1.20 b	1.40 b	1.45 b
				Hawthorn			
Pre-transplant	1.10	1.45 a	1.85 a	1.92 a	1.84 a	1.93 a	2.25 a
5 days post-transplant		1.82 b	2.10 a	2.27 b	2.23 b	2.30 b	2.41 a

[z] Pre-storage Ψ_s.

[y] Mean separation by t test at P=0.05. Same letter within column (by species) indicates no significant difference, n = 8.

Table 2. Influence of wax coating on shoot water potential and bud break of unstressed (bagged in storage) and stressed (unbagged in storage) 2-yr.-old Washington hawthorn after transplanting.

Stem treatment	Shoot Ψ (-MPa)							Bud break[y] (%)
		Days after transplanting						
	Initial Ψ[z]	2	4	6	8	10	12	
Unstressed								
Wax coated	0.76 a[x]	0.72 a	0.69 a	0.70 a	0.60 a	0.57 a	0.55 a	85 a
No wax coating	0.74 a	0.77 a	0.90 a	0.94 a	1.00 b	1.20 b	1.25 b	59 b
Stressed								
Wax coated	1.82 a	1.53 a	1.15 a	1.03 a	0.98 a	1.02 a	1.13 a	71 a
No wax coating	1.77 a	1.79 a	1.88 b	1.95 b	2.02 b	2.26 b	2.25 b	26 b

[z]Stem water potential prior to transplanting.

[y]% bud break 8 weeks after transplanting.

[x]Mean separation within columns by t test, $P = 0.05$. Means followed by the same letter are not significantly different, $n = 6$.

Post-Transplant Growth of Turkish Hazelnut

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Virginia

Nature of Work: Early post-transplant stress, resulting from alterations in plant water status, is the most important factor influencing plant establishment (1,2,3). Since a large percentage of roots may be lost at harvest (8), the ability of the plant to quickly regenerate those roots influences the plant's capacity to overcome water stress and survive transplanting (7).

Sperry et al. (1988) reports freeze-thaw cycles and water stress are primary causes of xylary cavitation leading to embolism. Research (6) indicates that embolism increases as the growing season progresses and may be as great as 89% in mid-winter for some species. Since most field-grown nursery stock is harvested when dormant, plants may be severely embolized before transplanting occurs, No apparent research exists concerning the influence that transplanting plays in embolism recovery, and little agreement exists concerning the effects of immediate fertilization on root regrowth. The objective of this experiment was to evaluate the influence of root severance and rate of fertilization on early post-transplant growth and subsequent recovery from dormant xylary embolism.

Two-year-old bareroot Corylus colurna seedlings were grown in 2 gallon containers from March 15 to June 23, 1995, in a glasshouse using pine bark media. Temperatures were maintained at 86/68° F max/min. Plants received no fertilizer or Osmocote 18-6-12 top-dressed at 14 or 28 grams/container. Additionally, plants were pruned to remove 0, 25, or 50% of the root system based on root length.

Height, caliper and root volumes were recorded at experiment initiation and termination. Root regeneration was calculated by subtracting initial water displacement values from final water displacement values. Branch numbers were determined at the end of the experiment, and all expanded leaves were removed and counted. Total leaf areas were measured using a LI-3000 Leaf Area Meter (LI-COR, Lincoln, NE). Shoot dry weights were also determined. Additionally, percentages of xylary embolism were calculated for dormant and experimental plant material based on the system outlined by Sperry et al. (1987). The experimental design was a factorial consisting of 3 fertility levels (0, 14, or 28 g) and 3 levels of root removal (0, 25, or 50%). The experiment was arranged in a randomized complete block design consisting of 8 single plant replicates. Results and Discussion: Root pruning had no influence on root regrowth, branch number, leaf number, total leaf area, or shoot dry weights (data not shown). Plants having 50% of their root mass removed were taller than plants undergoing 25% root removal, but were similar in height to plants receiving no pruning (Table 1). Root pruning, regardless of severity, reduced stem diameters. Dormant Turkish hazelnuts were 42.5% embolized (data not shown). Removal of 50% of the root system resulted in 34.6% embolism at experiment termination (Table 1). Plants receiving no or 25% root removal had 6.7 and 4.4% embolism, respectively.

Rate of fertilization had no influence on embolism recovery. Plants receiving no fertilizer had reduced height, caliper, branch and leaf numbers, total leaf area, and shoot dry weights compared to plants receiving fertilizer. Fertilization reduced root:shoot ratios. Plants receiving fertilizer at the recommended rate of 14 g/container had greater root regeneration compared to plants receiving no fertilizer or double the recommended rate. Significance to Industry: Survivability and growth of transplanted ornamental tree species is a primary concern for both producers and consumers. The results of this experiment indicate that fertilization using Osmocote 18-6-12 at the recommended top-dress rate results in added top growth compared to no fertilization, but fertilization using double the recommended rate provides no additional benefit. This study indicates that removal of 50% of Corylus colurna roots inhibits the plants' ability to recover from dormant embolism , although early posttransplant growth does not seem to be affected.

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Table 1. Height, caliper, and % embolism for Corylus colurna as influenced by root pruning.

Root pruning (%)	Height (cm)	Caliper (cm)	% embolism
0	52.5ab[z]	0.8a	6.7b
25	49.3b	0.7b	4.4b
50	53.6a	0.7b	34.6a

[z] Means within columns having the same letter are not different according to Fisher's Protected Least Significant Difference (α <O. 05)

Table 2. Height, caliper, root volume increase, branch number, leaf number, total leaf area, and shoot dry weights for Corylus colurna as influenced by fertilizer rate.

	Fertilizer rate (g)		
	0	14	28
Height (cm)	43.5b[z]	56.Oa	55.9a
Caliper (cm)	0.6b	0.8a	0.8a
Root volume increase (mg)	19.2b	39.Oa	25.8b
Branch number	3.Ob	4.6a	4.2a
Leaf number	19.9b	35.8a	37.2a
Total leaf area (cm2)	231.Ob	865.2a	839.1a
Shoot dry weight (g)	5.2b	12.8a	12.1a
Root: shoot ratio	1.2a	0.8b	0.7b

[z] Means within rows having the same letter are not different according to Fisher's Protected Least Significant Difference (a<0.05).

Growth Responses of Nuttall Oak to $Cu(OH)_2$-Incorporated Fiber Containers and DCPTA Seed Soaks

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Texas

Nature of Work: Plastic nursery containers painted on interior surfaces with $Cu(OH)_2$ (2, 3) or $CuCO_3$ (1) or with $CuCO_3$ incorporated in fiber pots during manufacturing (8) have effectively reduced root circling and matting at container wall : media interfaces. Increased growth has been associated with some species produced in Cu-treated containers (1, 2, 3, 8). The chemical bioregulator, DCPTA (2-(3,4-dichlorophenoxy) triethylamine) improved growth of blue spruce (*Picea pungens* var. *glauca*), radish (*Raphanus sativus*), heliconias (*Heliconia stricta*), and various genera of orchids following seed (6, 7) or tissue (4, 5) treatments. The objectives of this study were to determine the effects of $Cu(OH)_2$-incorporated fiber containers and DCPTA seed soaks on the growth of *Quercus texana* Buckley (syn. *Q. nuttallii* Palmer) during container nursery production.

On March 2, 1992, stratified (3 months at 4 C (39(F)) *Q. texana* seeds were soaked at 20 C (68(F) for 6 hr. in water containing 0.1 % tween 80 and 0, 1, 10, or 100 ppm DCPTA (courtesy Dr. Henry Yokoyama, USDA, Pasedena, CA). After soaking, seeds were rinsed in running water for 5 min. and planted in a 3 pine bark : 1 sand : 1 peat moss (by vol.) media in propagation flats. Flats were placed in a greenhouse maintained at 24/18 C (75/65(F) day/night with natural photoperiods. On April 24, seven seedlings of each DCPTA treatment were transplanted to 3.6 liter (#1) fiber nursery pots (Keiding, Inc., Milwaukee, WI) containing 3,000 ppm Cu (as $Cu(OH)_2$, Griffin Corp., Valdosta, GA) incorporated during manufacturing. Media was 3 pine bark : 1 sand (by vol.) ammended with 3.5 kg dolomite/m^3 (6 lb/yd^3), 1.7 kg 0N-20P-0K/m^3 (3 lb/yd^3), and 0.68 kg Micromax (Sierra Chemical Co., Milpitas, CA)/m^3 (1.5 lb/yd^3). Seven seedlings treated with 0 ppm DCPTA were transplanted to non-treated 1gal. fiber nursery containers (Keiding, Inc., Milwaukee, WI). Seedlings were returned to the greenhouse and arranged in a completely random statistical design. An application of 16 g (0.56 oz.) 18N-3.1P-8.3K-1Fe (18-7-10-1) Sierrablen Nursery Mix 8-9 month slow release fertilizer (Sierra Chemical Co., Milpitas, CA) was applied to the media surface of each container.

Seedlings were moved from the greenhouse to an open-air shade structure (55 % light exclusion) on May 14. Seedling height, trunk caliper (6 cm (2") above the container), and number of growth flushes were recorded. After two weeks, seedlings were placed at 0.5 m (21 in.) spacings in a gravel covered outdoor growing area (Cookeville, TN). Daily applications of 3 cm (1 in.) overhead irrigation and fertigated weekly with 200 ppm N from a 20N-8.7P-16.7K (20-20-20) water soluble fertilizer (W.R. Grace Co., Fogelsville, PA). On October 13, all seedlings were harvested to determine height, caliper, leaf number, leaf area, number of growth flushes, foliage, stem, and root fresh and dry (4 days at 70 C (158(F)) weights. Rootballs were rated for degree of peripheral circling and matted root formation on a scale of 0 = no inhibition of root elongation to 3 = no elongation of root tips after contact with container surfaces. Data were analyzed using analysis of variance and Duncan's multiple range test.

Results and Discussion: No significant interactions (*P* (0.05) among container type and DCPTA treatments were found (data not presented). DCPTA had no significant effects for any measured growth characteristics (data not presented) except height at the end of the greenhouse phase (Fig. 1). Soaking seeds in 1 ppm DCPTA increased seedling height over that of non-DCPTA treated seedlings at the time seedlings were removed from the greenhouse, but no significant effects of DCPTA were measured at the end of the growing season.

Seedlings grown in $Cu(OH)_2$-treated fiber containers had greater caliper, leaf area, foliage, stem and root dry weights than seedlings grown in containers without $Cu(OH)_2$ (Table 1). Copper-treated fiber containers provided a substantial reduction in root circling and matting at the periphery of the rootball (Table 1) and the root systems of $Cu(OH)_2$-treated seedlings were visibly more fibrous than those from non-treated containers (Fig. 2B). Similar results have been reported for other species grown in plastic nursery containers treated on interior surfaces with $Cu(OH)_2$ (2) or $CuCO_3$ (1) or in $CuCO_3$ incorporated fiber containers (8). Roots of seedlings grown in non-treated containers adhered to the bottoms of the fiber pots. When these seedlings were removed from the containers a layer of fiber was pulled from the container (Fig. 2B), making container removal more difficult and often damaging the roots at the bottom of the container. Non-treated fiber containers had begun to degrade by the end of the growing season while $Cu(OH)_2$-treated fiber pots remained predominantly intact (Fig. 2A). This would be an advantage during shipping and handling. However, the effects of slowed degradation of the $Cu(OH)_2$-treated fiber pots following planting of seedlings in intact pots to the landscape or disposal of pots in landfills is unknown.

Significance to Industry: Cupric hydroxide-incorporated fiber containers provided similar root growth control as Cu-painted plastic containers and degraded less during crop production than did fiber containers without $Cu(OH)_2$. DCPTA seed soaks did not result in commercially significant improvements in growth of Nuttall oaks in this study.

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Figure 1. Effect of 6 hour seed soaks in 0, 0.1, 1, or 10 ppm DCPTA on the height of Nuttall oak seedlings at transplant from propagation flats to one gallon containers. Means with the same letter are not significantly different at *P* (0.05.

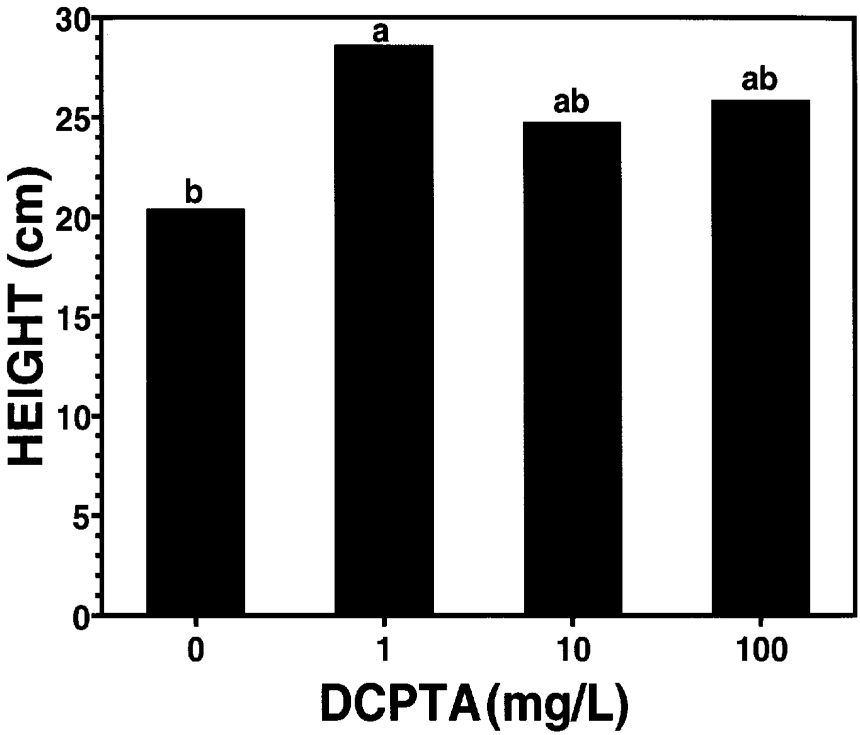

Figure 2. Typical one gallon fiber containers with (A) or without (B) the 3,000 ppm Cu as $Cu(OH)_2$ incorporated. Root systems of Nuttall oak seedlings grown in the fiber containers with (C) or without (D) Cu incorporated. Note adherence of fiber to the base of non-treated root system.

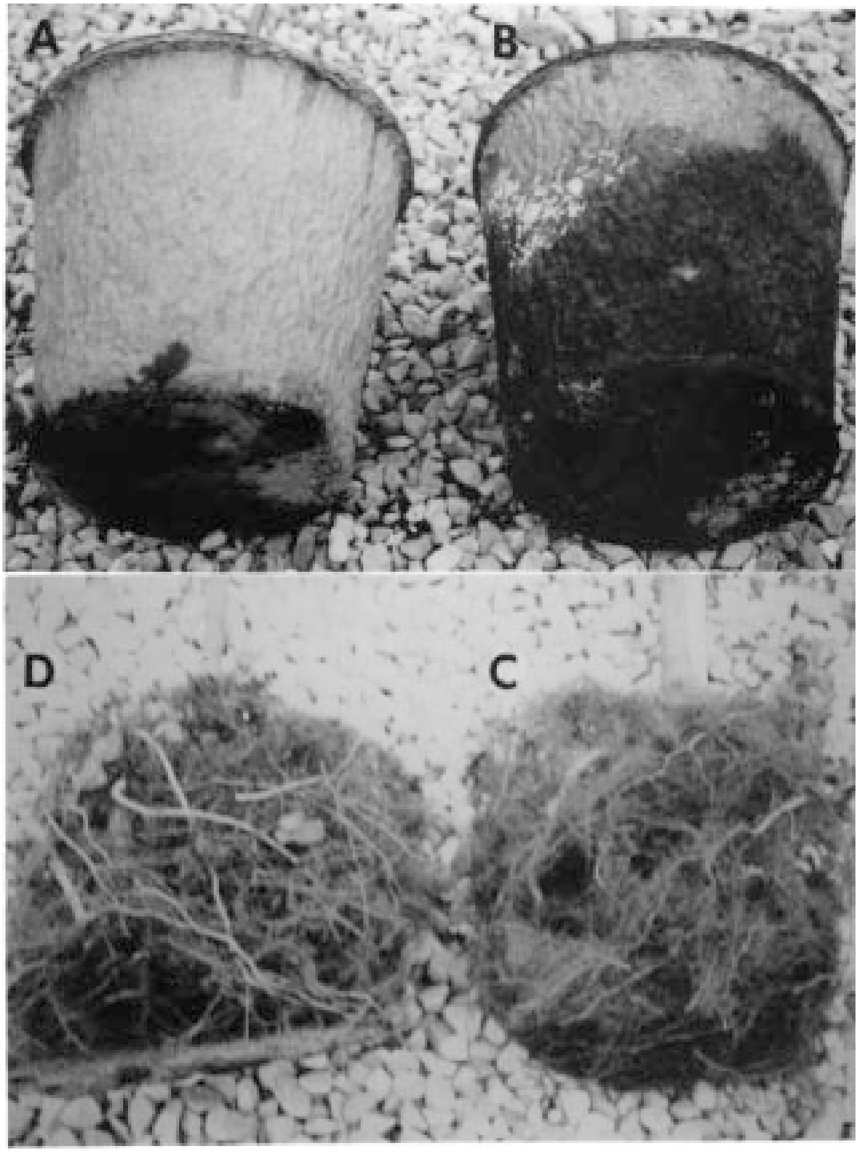

Table 1. Growth responses of Nuttall oak seedlings after one growing season in one gallon fiber containers with 3,000 ppm Cu as $Cu(OH)_2$ incorporated or no $Cu(OH)_2$.

Container	Trunk caliper (mm)	Dry weight Foliage (g)	Stems (g)	Roots (g)	Plant (g)	Total Leaf Area (cm^2)	Root Rating[z]
Non-treated	9.0 b[y]	8.53 b	13.50 b	28.93 b	50.96 b	1,008 b	0 b
$Cu(OH)_2$	10.5 a	11.88 a	21.12 a	37.44 a	70.44 a	1,394 a	2.2 a

[z]Ratings of the extent of inhibition of root elongation at the container wall : rootball interface, ranging from 0 = no inhibition of root elongation to 3 = no elongation of root tips after contact with container surfaces.

[y]Means within a column followed by the same letter are not significantly different using Duncan's multiple range test, $P \leq 0.05$.

Effects of Copper Hydroxide-Treated Containers and Water-Reservoir Containers on Root and Shoot Growth of Four Tree Species

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Nature of Work: Copper hydroxide-treated containers have been reported to reduce root circling within containers and in some cases have enhanced shoot growth (1,3). Containers with water reservoirs have been reported to increase plant growth by providing an even supply of water to the plants between irrigation cycles (4). The objective of this study was to evaluate the effects of these container modifications on shoot and root growth of four tree species.

In April 1994, 40 plants each of Acer rubrum 'Franksred' Red Sunset™, Franklinia alatamaha, Prunus x 'Snofozam' Snow Fountains(g), and Ulmus parvifolia 'Emer I' Athena™ were potted into 3 gallon, black polyethylene containers with pine bark media. Media was amended with 4 lb. dolomite, 1.5 lb. KNO3, 2.0 lb. 017-0, and 5.0 lb. Esmigran micronutrients per cubic yard. Four treatments included; 1) standard containers, 2) standard containers with an interior coating of copper hydroxide, 3) water reservoir containers and, 4) water reservoir containers with copper interior coating. The copper compound was a latex paint base containing 7.1% Cu(OH)2 (SpinOutTM, Griffin Corp., Valdosta, GA) and was applied with a paint brush. The standard containers' (IEM Plastics, Reidsville, NC) drain holes consisted of six 0.75 inch diameter round holes equally spaced around the bottom edge of the container plus one 0.75 inch diameter hole in the bottom center. Water reservoir containers were made by obtaining standard 3 gallon containers without drain holes and then drilling six 0.75 inch diameter holes on the sides of the container. Four of the holes were centered 1.38 inches above the container bottom and two of the holes were centered 3.5 inches above the container bottom. This configuration is the design of Environmentally Friendly Containers, Pursley/Rigsby Inc., Palmetto, Fla. All plants were grown in full sun on a gravel pad in a randomized complete block design, n=10. Plants received daily waterings for 15 min. at 15 psi with 180 degree pattern emitters (avocado color spray stakes, Rogers Irrig. Products, San Marcos, CA.) providing approximately 0.7 gallons/day/plant. This was sufficient water to provide leaching from all containers. A slow release fertilizer was applied twice during the growing season.

Stem diameter (1 inch above the media surface) and plant height were measured in May, 1994 (following planting) and again in November, 1994 (after leaf fall). On the latter date, root systems were visually rated based on the percent of the rootball surface covered by roots or root tips and to the degree of root circling; 1) < 20% of the rootball covered with roots, with no root circling; 2) 2040% of the root ball covered with slight root circling; 3) 40-60% root coverage with moderate root circling; 4) 60-80% root coverage with moderate to extensive root circling and 5) 80-100% root coverage with extensive root circling. Plant height was measured from the media surface to the highest bud on the plant with the exception of Prunus x Snow Fountains, a weeping form, in which case the weeping shoot which would extend the highest was measured.

Results and Discussion: Copper hydroxide-treated containers significantly reduced or eliminated circling roots on the perimeter of the rootballs for all taxa (Table 1.). Shoot growth was not effected by the copper hydroxide for any taxa. Copper hydroxide had a slight positive effect on stem diameter growth of Prunus x Snow Fountains and a slight negative effect for Franklinia alatamaha. For Ulmus parvifolia Athena, copper hydroxide increased stem diameter growth slightly for plants in water reservoir containers but decreased stem diameter growth slightly for those in conventional containers.

Water reservoir containers, alone, had no significant effect on shoot growth, stem diameter growth, or root circling (root index). However, the water reservoir containers did stimulate root circling for Prunus x Snow Fountains, but only in containers without copper hydroxide. Most of this root circling was observed in the water reservoir portion of the container - a surprising result as many Prunus spp. are intolerant of wet conditions (2). Reports of positive effects of water reservoir containers on growth of some species may depend on container size, species, and environment. At our site the rainfall for the growing season months of 1994 was: 6.3", 6.9", 7.8", 5.9", and 4.7" for June, July, August September, and October, respectively. This considerable rainfall may have contributed to the negligible beneficial effect of containers with water reservoirs on plant growth in our study. Also, in a 3 gallon container, as used here, a one inch reservoir in the bottom of the container (assuming a 50% pore space) would only hold approximately 0.13 gallons when saturated. Larger reservoirs may be needed to buffer transient water deficits or significantly improve irrigation efficiency with daily waterings.

Significance to the Industry: Copper coated containers virtually eliminated root circling on these species with no substantial undesirable side effects. No apparent benefits were observed from containers with water reservoirs under our conditions.

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Table 1. Shoot and root growth of four tree species as influenced by copper hydroxide-coated containers and water-reservoir containers.

		Acer rubrum Red Sunset			*Prunus* Snow Fountains			*Franklinia alatamaha*			*Ulmus parvifolia* Athena		
Copper	Water reservoir	Shoot Growth (mm)	Stem Growth (mm)	Root Index	Shoot Growth (mm)	Stem Growth (mm)	Root Index	Shoot Growth (mm)	Stem Growth (mm)	Root Index	Shoot Growth (mm)	Stem Growth (mm)	Root Index
Yes	No	397	7.0	1.2	701	12.6	1.1	487	7.1	1.0	451	6.2	1.0
No	Yes	512	7.6	3.4	1015	12.0	4.1	509	7.9	2.9	383	6.3	2.2
Yes	Yes	451	8.4	1.1	953	12.3	1.0	570	7.5	1.0	516	7.3	1.0
No	No	493	8.5	3.5	888	11.3	3.6	548	9.5	2.8	611	7.7	2.8
Statistical Analysis													
Copper		NS	NS	**	NS	*	**	NS	*	**	NS	NS	**
Water Res.		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Cu X WR		NS	NS	NS	NS	NS	*	NS	NS	NS	NS	*	NS

*,**, and NS indicate significance at 5%, 1% or not significant, respectively.

Pine Bark Growth Media Amended with Coir Pith

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Nature of Work: Coir pith is the material left over after the long fiber has been removed from coconut husks. The long fiber can be used to make rope, mattresses, mats and brushes; while the sponge material or coir pith can be used as a potting medium (2,3). EZ Peat™ is coir pith compressed into block form. Each block is approximately 8 inches X 4 inches X 2 inches and weighs approximately 1.5 lb. When water is added EZ Peat™ will expand approximately 9 times to a ready-to-use form (1). Growth of two subtropical ornamentals was found to be significantly better in coir-based medium compared to sedge peat based medium (4). The objective of this study was to evaluate EZ Peat™ coir pith as a growth medium component for container nursery plants. Ilex crenata 'Compacta' liners in 3 inch pots were planted in 3 qt containers on April 13, 1993 in treatments of 5 ratios of the organic components of pine bark:coir pith and 2 rates of 17-7-12 (Osmocote) slow release fertilizer. An inorganic component, sand, was included at 20% in all gtowth media blends (Table 1). Two pounds of dolomitic limestone, 1 lb each of 0-20-0 and MicroMax, and 17-7-12 at either 7 or 11 Ib/yd3 were incorporated in all growth media blends. Coir pith, obtained as highly compressed blocks, was prepared for use by adding water at the rate of 2 gallons per block. Plants were grown in full sun and irrigated as required with an overhead system. Treatments were arranged in a randomized complete block design in 6 replications with 1 container plant as an experimental unit.

The study was terminated on November 5, 1993. Shoot height, width and fresh weight, root ratings and growth medium leachate pH and electrical conductivity were taken and statistically analyzed. Plant height was taken from the rim of the container, and plant width was taken in two directions perpendicular to each other and averaged. Shoots were severed at the growth medium surface to obtain fresh weight. Root visual ratings were 10=excellent and 0=very poor. Leachate pH and electrical conductivity measurements were taken on June 25, August 24, and October 11, 1993 using the Virginia Tech Extraction Method (5).

Results and Discussion: Shoot width and fresh weight, but not shoot height and root ratings, of Ilex 'Compacta' increased at 11 Ib/yd3 compared to 7 Ib/yd3 of 17-7-12 fertilizer. Shoot height, width, fresh weight and root ratings increased linearly as the amount of coir pith in the growth medium increased (Table 1).

There were no significant differences in pH among treatments obtained from leachates taken in June, August, or October (Table 2). There was a trend for pH to decrease with time for all treatments and ranged from 6.2 to 5.9 in June, 5.9 to 5.6 in August, and 5.1 to 4.7 in October (Table 2).

Higher electrical conductivity levels were obtained at the 11 Ib/yd3 fertilizer rate compared to the 7 Ib/yd3 fertilizer rate in June and October. Also, electrical conductivity levels increased linearly as the amount coir pith in the growth medium increased in June and October, but not in August. Electrical conductivity levels in August and October were very low (Table 2).

Growth, based on fresh weight, increased as the amount of coir pith increased and the amount of pine bark decreased. Growth of Ilex crenata 'Compacta' in media of 80% and 60% coir pith was substantially more than growth obtained in media of 80% and 60% pine bark.

Significance to Industry: Results of this study, evaluating coir pith as an organic component of container plant growth media, indicates that coir pith can be used as a substitute for pine bark. More research is needed using a wide range of woody landscape plants to determine the merits of this material as a cost effective growth media component.

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Table 1. Evaluation of coir pith as a growth medium component and fertilizer rate on the growth of Ilex crenata 'Compacta'.

	Media components				Shoot		
Pine bark	coir pith	17-7-12 sand	fresh rate	root height	width	weight	rating[1]
(v/v/v)	(lb/yd3)	(in)	(in)	(oz)			
4 :	0 :	1	7	10.1	11.2	2.98	8.2
3 :	1 :	1	7	11.7	12.5	4.16	8.7
2 :	2 :	1	7	13.5	13.5	4.23	8.5
1 :	3 :	1	7	12.2	14.7	5.03	9.0
0 :	4 :	1	7	12.3	14.8	5.19	9.3
4 :	0 :	1	11	12.5	14.3	4.47	8.6
3 :	1 :	1	11	11.7	13.4	4.08	8.7
2 :	2 :	1	11	12.9	14.5	4.65	8.5
1 :	3 :	1	11	14.0	16.5	6.40	9.3
0 :	4 :	1	11	12.8	16.2	6.06	8.8
LSD				2.0	1.5	0.96	-

Significance				
17-7-12 rate	NS	**	**	NS
Pine bark:coir pith ratio	*	**	**	NS
Linear	*	**	**	*
Quadratic	NS	NS	NS	NS
Rate x pine bark:coir pith	NS	NS	NS	NS

[1] - Root quality rating - 10=excellent, 0=very poor.

Table 2. Effects of the percent coir pith and fertilizer rate on growth media leachate pH and electrical conductivity.

Media components				PH			Electrical conductivity		
Pine bark	coir pith	sand	17-7-12 rate	6/25	8/24	10/11	6/25	8/24	10/11
			(lb/yd)					(mmhos/cm)	
4 :	0 :	1	7	6.0	5.8	4.7	0.15	0.09	0.05
3 :	1 :	1	7	5.9	5.7	5.1	0.23	0.10	0.07
2 :	2 :	1	7	6.0	5.9	5.1	0.24	0.10	0.07
1 :	3 :	1	7	6.1	5.9	4.9	0.25	0.10	0.09
0 :	4 :	1	7	6.2	5.8	4.9	0.21	0.09	0.08
4 :	0 :	1	11	5.9	5.9	4.8	0.35	0.07	0.08
3 :	1 :	1	11	6.1	5.7	4.7	0.23	0.12	0.09
2 :	2 :	1	11	6.2	5.7	4.8	0.28	0.11	0.10
1 :	3 :	1	11	5.9	5.6	4.7	0.53	0.14	0.12
0 :	4 :	1	11	6.0	5.7	4.7	0.58	0.14	0.11
LSD				--	--	--	0.20	--	0.02
Significance:									
17-7-12 rate				NS	NS	NS	**	NS	**
Pine bark:coir pith ratio				NS	NS	NS	*	NS	**
Linear				NS	NS	NS	*	NS	**
Quadratic				NS	NS	NS	NS	NS	NS
Rate X Pine bark:coir pith				NS	NS	NS	NS	NS	NS

Water Relations, Growth and Development of Three *Rosa Hybrida* L. Groundcover Rose Cultivars

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Nature of Work: Differences in drought resistance have been reported in greenhouse roses (*Rosa hybrida*) (7), but research concerning potential drought resistance mechanisms of landscape roses is limited (2,4). Several low-spreading, prostrate, ground cover cultivars that are being marketed for exhibiting disease tolerance, drought resistance and winter hardiness have recently been released. These cultivars are considered low-maintenance since less pesticide, fertilizer, irrigation and pruning are necessary to maintain a desirable plant than with most rose cultivars currently used for landscaping. Research is needed to determine morphological and growth characteristics of these low maintenance cultivars that might contribute to drought resistance.

There are various morphological and physiological changes in response to drought that confer some measure of drought resistance (5). Decreased stomatal density has been associated with reduced transpirational water loss in barley (6), and increased osmotic adjustment for greater turgor maintenance and growth at lower leaf water potential in greenhouse roses (1). Stomatal density and leaf epicuticular wax content effect transpirational water loss and drought resistance of sorghum (7). Drought resistance in mycorrhizal landscape rose plants was in part attributed to a greater carbon partitioning to the roots and a higher root:shoot ratio than nonmycorrhizal plants (3).

The objectives of this research were to determine morphological and growth characteristics of selected, low maintenance roses that enhance drought resistance.

Results and Discussion: *Rosa hybrida* L. cvs. Meiflopan, Meiplatin and Meineble are from a new selection of ground cover roses, which are considered to be low maintenance for their reduced cultural and chemical establishment needs in the landscape. Little has been documented on their drought resistance characteristics. Glasshouse grown, containerized plants were established from rooted cuttings and exposed to five drought cycles (during peak stress of a given cycle, maximum predawn leaf water potentials Ψ_{leaf} were -l.2 to -l.3 MPa). Drought decreased leaf number, leaf area, absolute shoot growth rate (cm d^{-1}), shoot dry weight, leaf area ratio ($cm^2\ g^{-1}$), leaf stomatal density, relative growth rate (g d^{-1}) and net assimilation rate (g $cm^{-2}\ d^{-1}$), and increased the epicuticular wax content, root dry weight and root:shoot ratio of all cultivars. Drought also decreased leaf relative water content and stomatal conductance (g_s), but their was no difference among cultivars. Meiflopan potentially has the greatest drought resistance characteristics as evidenced by highest root:shoot ratio, greatest % reduction in leaf area via leaf abscission and reduction in shoot dry weight during drought exposure, smallest individual leaves (greater boundary layer resistance), lowest leaf stomatal density, lowest relative growth rate, yet greatest absolute shoot growth rate (cm d^{-1}) during drought. Meineble had the least desirable growth characteristics for drought resistance, such as the highest leaf stomatal density, lowest root:shoot ratio during drought, lowest % reduction in leaf area, yet greatest total leaf area and shoot weight and the lowest root weight among the cultivars; Ψ_{leaf} of Meineble was lowest (most negative) during the later drought cycles. Important drought acclimation characteristics among the three cultivars include increased leaf epicuticular wax content, reduction in transpirational surfaces and increased carbon partitioning to the root system.

Significance to Industry: The three landscape rose cultivars responded to drought with a decrease in Ψ_{leaf}, RWC, g_s and a decrease in whole plant transpiration. The levels reported correspond with other landscape roses (3).

Meiflopan potentially has the greatest drought resistance characteristics as evidenced by a root mass 1.7-fold greater than Meineble, the highest root:shoot ratio, greatest leaf abscission to avoid drought, greatest % reduction in leaf area and shoot dry weight, smallest individual leaves (greater boundary layer resistance), lowest leaf stomatal density, lowest relative growth rate, yet greatest absolute shoot growth rate (cm d^{-1}) during drought. Meineble may have more drought susceptible characteristics such as the highest leaf stomatal density, lowest root:shoot ratio during drought, lowest %reduction in leaf area, yet greatest total leaf area and shoot weight and the lowest root weight among the cultivars; Ψ_{leaf} of Meineble was lowest (most negative) during the later drought cycles.

Important drought acclimation characteristics of the three cultivars for future rose breeding programs include an increased leaf epicuticular wax content, reduction in transpirational surfaces and increased carbon partitioning to the root system.

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Shredded Waste Tires Used as a Media Amendment for Greenhouse Production

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Nature of Work: Growing media for ornamentals production may be comprised of many different materials. Organic components such as peat moss and pine bark are becoming increasingly expensive and alternatives are being examined. Waste tires can be found in abundance in most parts of the country and can be shredded to obtain a product of uniform particle size. Bowman, Evans, and Dodge (1994) examined the use of ground waste tires combined with sawdust as a growing medium for chrysanthemum production. Shredded tires as a medium component resulted in an increased zinc concentration in the foliage. The use of course shredded tires resulted in some reduced growth when the tire material was the majority component of the growing medium (Bowman, Evans, and Dodge, 1994). While they report a potential for zinc toxicity due to high zinc concentrations in the foliage, no toxicity symptoms were observed. Corn (Zea maize) grown in shredded tires combined with peat moss grew slowly and were chlorotic (Milbocker, 1974). An application of chelated iron was effective in restoring the green color and increasing the growth rate of the plants. Zinc and iron are competitively taken up by plants with zinc more easily absorbed. Milbocker (1974) found that increased temperatures, acidity, and fineness of particle size increased the available zinc in media containing shredded tires.

Gladiolus 'Wig's Sensation' were grown in a greenhouse in raised beds, 42x32x6 inches. Shredded waste tires at a 1/4 inch particle size were used t o replace pine barl< at 0, 20, 40, 60, 80, or 100 percent from a standard mix of 2:1:1, pine bark, peat moss, and sand by volume. The media was amended with 1 lb. dolomitic lime per cubic foot of peat moss added to the mix. The treatments consisted of 2 replications of 40 corms in a randomized complete block experimental design. The beds were watered as needed with a constant liquid feed at 200 ppm nitrogen from a 20-10-20 source. Data collected included the date of emergence, date of harvest, height to first floret, total height, number of leaves, and number of florets. Stems were harvested when the first floret was fully open. The growing medium combinations were tested before planting for bulk density, porosity, percent air space, water holding capacity, pH, and soluble salts.

Results and Discussion: The initial media varied in soluble salt content ranging from .32 to .54 mmhos (Table 1). The media with a higher waste tire content tended to have the higher salt readings. This may result from a low cation exchange capacity of (CEC) the waste tire material (Zhao, 1995). A low CEC would lead to greater leaching of media additives including lime. There were no significant differences between the treatment media in bulk density, percent pore space, percent air space, percent water holding capacity, or pH.

There was no significant effect of waste tire concentration in the growing medium on flower quality. All treatments averaged stems greater than 38 inches long with 12 florets, standard grade. Waste tire concentration in the growing medium did not negatively affect the days to emergence. However, the harvest date was slightly delayed, 4 days, when 100 percent of the bark was replaced with shredded tires (Table 2). The delay in harvest may have resulted from a possible restriction of available moisture for growth. Although statistically not significant, the water holding capacity of the medium decreased with increasing waste tire content. All treatments were watered whenever about 50% of the plots needed watering.

Significance to Industry: This study has shown that waste tires may be a viable media amendment for use in greenhouse production. Although not statistically significant, there was a trend to decreased water holding capacity with increasing waste tire content. There was no affect on Gladiolus flower quality due to waste tires in the media but there was a delay in harvest at higher waste tire concentrations. Shredded waste tires may be an effective media amendment partially replacing and reducing the use of more expensive organic amendments.

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Table 1: Physical and chemical properties of the media combinations tested before planting .

Media %rubber[Z]	BD	PS (%)	AS (%)	WHC (%)	pH	SS (mmhos)
0	0.73a	42a	5a	41a	5.4b	0.32b
20	0.76a	45a	12a	44a	5.2b	0.37b
40	0.70a	41a	19a	34a	5.5b	0.37b
60	0.71a	38a	4a	45a	5.9a	0.42ab
80	0.69a	44a	11a	33a	6.0a	0.54a
100	0.71a	40a	1 la	30a	6.1a	0.47ab

Base medium was 2:1:1 pine bark: peat moss :sand by volume.

[Z]%rubber equals the amount of rubber replacing the bark in the base medium.

BD=bulk density, PS=pore space, AS=air space, WHC=water holding capacity, SS=soluble salts.

Mean separation within columns using SNK P=0.05.

Table 2: Effects of increasing percent of waste tire material as a growing medium amendment on greenhouse production of Gladiolus.

Media %rubber[Z]	Days to emerge	Days to harvest (	Height inches)	Florets (number)	Scape length[Y]	Stem length[X]
0	15a	121 b	57a	13a	14a	43a
20	14a	122b	58a	13a	14a	44a
40	15a	123ab	50a	12a	11 a	39a
60	16a	124ab	55a	13a	13a	42a
80	16a	124ab	55a	13a	13a	42a
100	17a	128a	53a	12a	11 a	42a

Base medium was 2:1:1 pine bark:peat moss:sand by volume.

[Z]%rubber equals the amount of rubber replacing the bark in the base medium.

[Y]Scape length equals the length of the inflorescence in inches.

[X]Stem length equals the height to the first floret in inches.

Mean separation within columns using SNK P=0.1.

Growth Response of Nandina as Influenced by Substrate Temperature and Limestone Amendment

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Virginia

Nature of Work: Summer heat stress reduces growth and increases chlorosis of certain species of container-grown plants. Nandina (*Nandina domestica*) is among those plants most susceptable to this problem. Heat-induced ammonium toxicity related to high substrate temperature has been proposed as a factor contributing to summer heat stress (4). Limestone amendment (3) influences nitrification and subsequently the level of NH_4-N in a pine bark substrate. We investigated the influence of container substrate temperature and limestone amendment on growth of nandina .

This study was conducted on an outdoor gravel nursery bed. Single-stem liners were grown in 1 gallon containers in a substrate of 5 bark:1 sand amended with 0 or 6.7 lbs dolomitic limestone/yd^3. On June 25, limed and unlimed plants were divided into uninsulated or insulated container temperature treatments. The uninsulated treatment consisted of containers on gravel. The insulated treatment consisted of containers on gravel which were enclosed by a pallet of aluminum-covered insulation board. Plants were spaced on 12 inch centers and arranged in randomized complete blocks with a split-plot design. Container temperature treatment comprised the main plots. There were four plants per subplot in each of four blocks. Plants were fertilized at 7 to 10 day intervals with a complete nutrient solution containing 300 ppm NH_4-N and 100 ppm NO_3-N as well as 40 ppm Ca and 20 ppm Mg. Substrate temperatures one inch from the southwest container sidewall were recorded on several clear, hot days. Substrate solution extracts (VTEM) obtained on August 8 were analyzed for pH, NH_4-N, and NO_3-N. On September 26, plants were rated for chlorosis and harvested for dry weight determination and leaf tissue analysis.

Results and Discussion: The highest mean maximum recorded substrate temperature in uninsulated containers was 115F. Substrate temperatures in the insulated containers did not exceed 90F. On August 8, limestone amendment had increased substrate solution pH from 4.0 to 5.3. The NH_4-N:NO_3-N ratio was _8 times higher in the unlimed substrate than in the limed substrate. Plants grown in uninsulated containers had lower shoot and root dry weights (Table 1). Shoot dry weight was also influenced by an interaction of container temperature treatment and limestone addition. Higher root-zone temperatures in the uninsulated containers reduced shoot dry weight by 59 and 28% in the unlimed and limed substrates, respectively. Limestone addition increased shoot dry weight in the uninsulated containers but had no influence on shoot dry weight in the insulated containers. Root dry weights exhibited a similar trend. Chlorosis ratings were higher for plants grown in the unlimed substrate (Table 1) but were not influenced by container temperature treatment. Chlorosis ratings were positively correlated ($r=0.68^{**}$) with leaf tissue Mn levels which ranged from 52 to 128 ppm. This relationship was due to significantly higher (P=0.05) leaf tissue Mn concentrations in unlimed treatments. An inverse relationship between medium pH and tissue Mn levels has been demonstrated for plants grown in pine bark substrates (2). Leaf tissue Mn levels were within the sufficiency range for woody nursery crops and well below levels associated with toxicity symptoms (1). There were no other significant correlations between chlorosis ratings and leaf tissue nutrient concentrations.

Chlorosis ratings suggest a sensitivity of nandina to the higher NH_4-N:NO_3-N ratio in the unlimed substrate. At moderate root-zone temperature (insulated containers), the substrate NH_4-N:NO_3-N ratio did not influence shoot dry weight. In the uninsulated containers, however, higher root-zone temperatures apparently enhanced the toxicity of NH_4-N in the unlimed substrate, decreasing shoot dry weight in comparison to that in the limed substrate.

Significance to Industry: These results indicate that mid-summer growth reductions and chlorosis of nandina may be partially due to NH_4-N toxicity, which can be avoided by substrate amendment with limestone in amounts sufficient to encourage nitrification.

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Table 1. Influence of container temperature (CT) treatment and limestone addition (LA) on dry weight and chlorosis of nandina.

	Lime (lbs/yd^3)					
	0	6.7	0	6.7	0	6.7
CT treatment	Shoot wt		Root wt.		Chlorosis[z]	
		g				
uninsulated	8.0	13.6	2.2	3.6	2.9	1.1
insulated	19.5	19.0	4.7	4.6	2.2	1.1
CT	**		***		NS	
LA	NS		NS		***	
CTxLA	*		NS		NS	

NS,*,**,***Nonsignificant (NS) or significant at P = 0.10, 0.05, or 0.01, respectively.
[z]Chlorosis rating on a scale of 1 to 5 (1=no chlorosis, 5=most chlorosis)

Growth of Southern Magnolia in Pot-in-Pot and Above-Ground Production Systems

John M. Ruter
Georgia

Nature of Work: Growth of *Magnolia grandiflora* 'St. Mary' is known to be influenced by container volume and time of transplanting (1). Improved growth in larger containers was partially attributed to lower root-zone temperatures in the center of the container. One of the advantages of growing plants using the pot-in-pot production system is lower root-zone temperatures (2). Copper hydroxide may also be useful for reducing root circling and keeping more roots in the center of the container where root-zone temperatures are lower (3). Therefore, the purpose of this study was to look at the effects of two production systems (pot-in-pot and above-ground) and the treatment of containers with and without copper hydroxide on the growth and root development of southern magnolia.

Research was conducted outdoors under full sun at the University of Georgia Coastal Plain Experiment Station in Tifton. Uniform plants of *Magnolia grandiflora* 'St. Mary' grown in #3 containers were shifted to #7 containers in April, 1993. Half of the containers in the study were treated with copper hydroxide (SpinOut, Griffin Corp.) on the inside of containers. Potting substrate consisted of milled pine bark and sand (6:1 by volume) amended with Micromax (1.5 lbs. cu. yd.) and dolomitic limestone (5.0 lbs. cu. yd.). Plants were topdressed with 5.3 oz. of Sierra 17-7-12 per container in May, 1993 and again in February, 1994.

For the pot-in-pot (PIP) system, holder pots were placed in the ground with 1 inch at the top of the container remaining above grade. Above-ground (AG) containers were placed on the soil surface. All plants were irrigated daily at the rate of 1.0 gallons per container using low volume spot spitters.

The experiment was a randomized complete block with two production systems (PIP and AG), two copper treatments (with and without) and 14 replications. At the termination of the study in May, 1994, measurements of shoot dry weight, root dry weight, height and stem diameter were taken. A root coverage rating (1 = <20% of the rootball surface covered with white root tips, 3 = about 50% of the rootball surface covered with white root tips, and 5 = >80% of the rootball covered with white root tips) was recorded.

Results and Discussion: Plants grown in the PIP system had 16% more root dry weight and 12% more combined root and shoot dry weight compared to AG plants. Production system had no effect on shoot dry weight. With the PIP system, plants were 6% taller and had 10% greater stem diameter compared to AG plants. Treatment of containers with copper hydroxide resulted in no differences in root and shoot growth compared to plants grown in non-treated containers.

Root coverage was greater for plants grown PIP (4.5) compared to plants in AG (3.1) containers. Copper hydroxide reduced root coverage (3.3) compared to non-treated containers (4.3). Loss of root control when copper hydroxide was used was evident on the bottom but not the side of treated containers.

Significance to Industry: This work is in agreement with previous research which showed that *Magnolia x Soulangiana* had increased root dry weight and combined biomass when grown in a PIP system compared to AG (2). Copper hydroxide reduced root coverage but treatment of containers did not result in increased plant growth. Future research on the heat tolerance of roots and shoot physiology of plants grown in PIP and AG systems is planned to discern the growth benefits observed in this study.

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Growth Performance of Air-Pruned Tomato Seedlings

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North Carolina

Nature of Work: There are many excellent merits of plant root air-pruning (Huang, 1994; Huang and Ai, 1992), however actual mechanisms of root development during the air-pruning process are not well understood. Little information available on this subject in the fields of crop sciences, horticulture sciences, or forestry. In fact very little research has occurred in this area except for chemical root pruning. Production of air-pruned seedlings have demonstrated many advantages including: elimination of root-binding, promotion of properly oriented root-branching for vigorous growth, shorter propagation period, increased yields, savings on growth media, energy and fertilizer, and adaption to fully automated transplanting (Huang and Liang, 1987; Huang and Kato, 1985; Huang and South, 1982). New understanding on use of the root air-pruning process is needed as it relates to accelerated and superior plant growth.

A study was conducted to quantitatively and qualitatively evaluate growth performance and yields of root air-pruned tomato seedlings. Initial root development was measured immediately after germination. Effects of the air-pruning process on growth and yields were investigated using conventional styrofoam trays. Plant growth performance for tomatoes was studied based on seedling size comparison and on yield results. Conventional styrofoam trays were used as a control while other conventional trays were inverted and detachable screens were attached to the now large open bottom.

Results and Discussion: Growth of a biological system or component normally can be described by a S-shaped curve. The growth process starts at a slow pace, following an exponential curve; then gradually slows down to cease the growth. Growth of an individual leaf follows the similar pattern of a S-shaped curve. Total growth is then described by the superimposition of each S-shaped curve, resulting in a S-shaped plant growth curve for the life of the plant (Huang, 1994). Root growth can also be described by discrete growth periods (emergence of new roots), within which growth is continuous (elongation of roots). Maximum periodic growth rate is reached in the early stage of growth following an exponential curve, and from that point steadily declines until the root reaches its late growth stage of slow growth. Therefore, development of root growth can also be described as S-shaped curves superimposed at different development levels in different historical periods to form a larger S-shaped curve. Figure 1 illustrates root length versus time curves over a 51 hour period for a tomato plant, two weeks after seeding. Root-#1 and -#2 curves clearly show that they are in the later stage of a S-shaped curve, while other roots are in the various early stages of a S-shaped growth curve. Proper application of air-pruning to a root tends to suspend the root's growth at the exponential portion of the growth stage and facilitates new branching. As each branched root is air pruned, new branching is initiated. As the suspension of root growth in the exponential growth stage and accelerated branching is repeated, the upper portion of S-shaped curves are effectively eliminated, resulting in faster root growth, larger root mass, and accelerated superior plant growth.

Figure 2 shows the qualitative comparison of seedlings grown in the conventional non-air-pruning tray (4 left) and inverted conventional tray, modified to be an air-pruning tray (4 right), six weeks after seeding and maintained under the same environmental conditions. Superior growth of air-pruned seedlings was obvious. As the air-pruned seedling was ready for transplanting, one could observe that the cell bottom was full of root tips which were ready to produce new roots as soon as the seedling was transplanted. For the conventional or non-air-pruning tray cell, the first root continues to elongate, spiraling around the inside of a container cell at the bottom following the entire S-shaped curve. Therefore, branching and sub-branching occur at much slower rates near the lower part of the main root. Most branched roots continue to elongate, again spiraling around near the cell bottom, to complete the entire S-shaped growth periods. Growth media in the upper part of the cell is not fully utilized, resulting in root-binding.

Seedlings were transplanted on 6/28/94. In order to minimize growth variables affecting growth rates of the plants, no fertilizer was added during the test. Yield data was taken from 8/30/94, when the first tomato was harvested, to 10/20/94 when the first frost appeared. Yield results were analyzed using the average accumulated number of tomatoes and the average accumulated weight of tomatoes. Field observations showed that, in general, air-pruned seedlings grew faster, resulted in larger plants, and bore fruits earlier than non-air-pruned plants. Curves for the average accumulated number of tomatoes show that air-pruned plants grew significantly more tomatoes than non-air-pruned plants (Figure 3). Similarly, curves for the average accumulated weight of the harvested tomatoes indicate that the air-pruned plants produced nearly twice the amount of tomatoes in weight (Figure 4). Tomato size was about the same between the two treatments.

Significance to Industry: Traditionally, agricultural and forestry fields are very conservative in accepting new methodologies even when clear-cut advantages have been demonstrated. Technology transfer from research to market usually takes much longer as compared to industrial sectors. Results indicate that clear understanding of root air-pruning process and proper application of the process to container/tray-grown seedlings would significantly increase plant production and effective greenhouse utilization. Nursery and greenhouse growers can use the research information as a guideline to improve their cultural practices.

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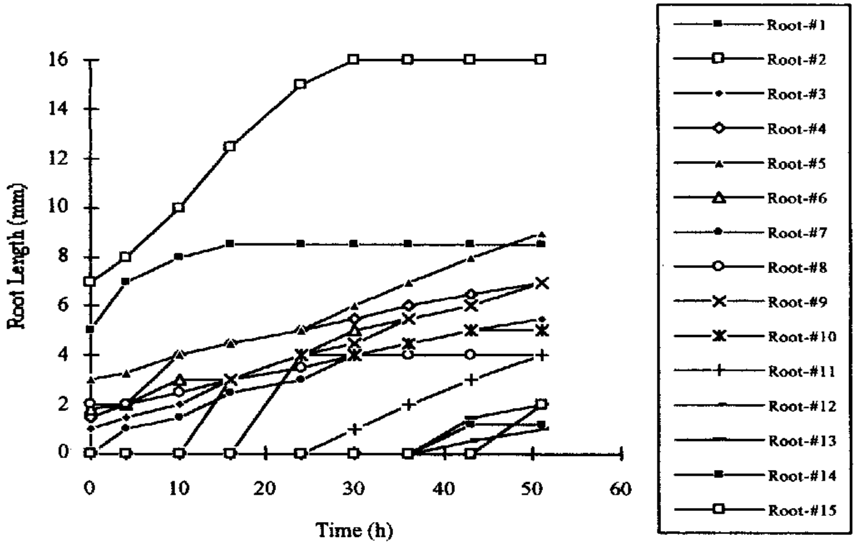

Figure 1. Root Development versus atime curves for a small tomato seedling over a 51-hour period.

Figure 2. Comparison of tomato seedlings grown in a conventional non-air-pruning tray (4 left) and inverted conventional tray, used as an air-pruning tray (4 right), six weeks after seeding and maintained under the same environmental conditions.

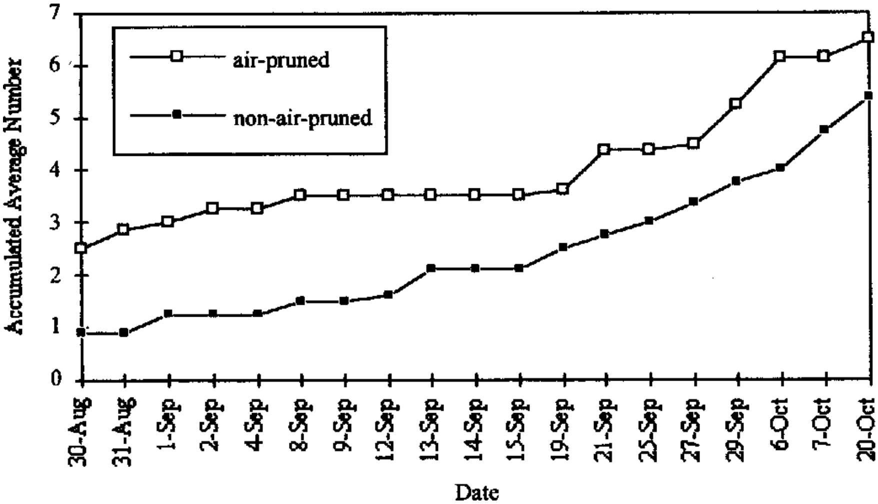

Figure 3. Accumulated average number of tomatoes versus time.

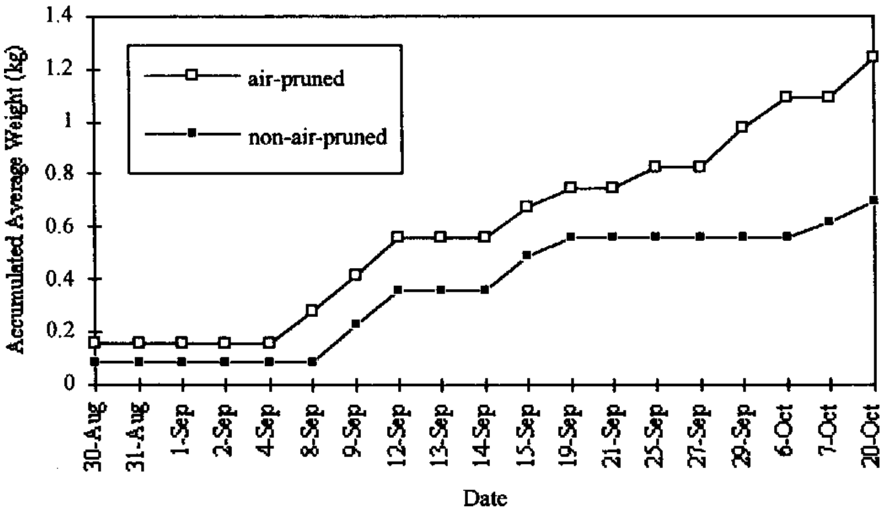

Figure 4. Accumulated average weight of tomatoes versus time.

Climate Alters Growth and Foliar Nutrient Levels of Crapemyrtle

Chris A. Martin and John M. Ruter
Arizona and Georgia

Nature of Work: High container root-zone temperatures result mostly from an interaction of solar radiation striking container walls and other climatic variables such as air temperature, wind speed, and relative humidity (3). Temperatures above 40°C (104°F) for extended durations in rooting medium in outdoor production nurseries can cause indirect or direct injury of roots and subsequent reductions in shoot growth and market quality (2). Supraoptimal temperatures in pine bark media can reduce rates of nitrification and for some species might result in foliar nutrient imbalances (5). Therefore, our objective was to investigate the influence of two disparate climates [central Arizona (arid, Sonoran desert) and southwestern Georgia (humid, temperate)] on container plant growth and foliar nutrient levels.

Research was conducted outdoors under full sun at the Arizona State University Horticultural Resource Center in Tempe (33.5N 112W) and the University of Georgia Coastal Plain Experiment Station in Tifton (32N 83W). Uniform rooted liners of *Lagerstroemia indica* x *fauriei* 'Muskogee', trimmed to 0.2 m (8") height, were potted into #7 black polyethylene containers on May 1, 1994. The rooting medium consisted of pine bark and sand (8:1 by vol.) amended with micronutrients at 0.9 kg/m^3 (1.5 lb/yd^3) and grown at a spacing distance of 0.9 m (36") between exterior walls. Plants were also top-dressed with 16N-3.0P-10.0K controlled-release Osmocote fertilizer formulated for a 10-month release at 360 g/pot (23 lb/yd^3). Plants at both locations were irrigated to container capacity each day in the early morning. Weather variables of daily maximum and minimum air temperatures and rainfall were collected at each location and averaged for each month. Rooting medium temperatures were also recorded with a 21X micrologger (Campbell Scientific, Inc., Logan, Ut.). Copper constantan thermocouples were positioned one-half way down the container profile at the cardinal coordinates, 0.02 m (0.8") from the rooting medium/container wall interface, and at the center location. The experiment was terminated after five months and shoot and root dry weights and foliar nutrient levels determined.

Results and Discussion: Average daily maximum temperatures in Arizona ranged from 5.9 to 11.2°C (10.7 to 20.1°F) higher than in Georgia, while minimum daily temperatures were 0.6 to 7.0°C (1.0 to 12.6°F) higher in Arizona. In Arizona, the highest recorded rooting medium temperature was 63°C (145°F) at the west exposure and remained above 40°C (104°F) for 6.3 hours. In contrast, the highest recorded rooting medium temperature at the Georgia location was 45°C (113°F) at the west exposure and remained above 40°C (104°F) for only 1.5 hours. Rainfall for the five months totaled 62 mm (2.48") in Arizona and 714 mm (28.58") in Georgia.

After five months, growth indices [(width + width + height) / 3] of crapemyrtle in Georgia were 1.9 times higher (Pr>F = 0.0001) than for those in Arizona. Shoot dry weights of plants in Georgia were 6.0 times greater (Pr>F = 0.0001) than for those in Arizona, while root dry weights of Georgia-grown plants were an astonishing 11.0 times greater (Pr>F = 0.0001) than for those in Arizona.

Nutrient levels in foliage of crapemyrtle at both locations were at least sufficient for normal plant growth (1). Moreover, foliar levels of N, K, P, Fe, and Cu were all significantly higher for plants in Arizona compared with those in Georgia. For example, total N level in Arizona crapemyrtle leaves was 4.0%, while N level in Georgia crapemyrtle leaves was 2.8% (Pr>F = 0.0001). In contrast, foliar tissue levels of Ca and Zn were significantly higher for plants grown in Georgia. Foliar levels of Mg and Mn were not affected by growing location.

Significance to Industry: These data indicated that *Lagerstroemia indica* x *fauriei* 'Muskogee' growth reductions attributed to extremely high root-zone temperatures were not related to plant nutrition and, except for Ca and Zn, resulted in a foliar nutrient concentrating effect, as evidenced by foliar nutrient levels of plants in Arizona. Thus, container plant nursery growers might not be able to ameliorate the negative effects of supraoptimal root-zone temperatures on plant growth through increased fertilization.

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