Container-Grown Plant Production

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Screening Landscape Plants for Their Ability to Accumulate Nitrogen and Phosphorus

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Index Words: Phytoremediation, Nutrient contaminants, Constructed wetlands, Nursery runoff, Nitrogen, Phosphorus, Water quality

Significance to Industry: The woody and herbaceous landscape species used in this study thrived and absorbed N and P in a gravel-based screening experiment. They performed well at nutrient rates equivalent to the concentrations of N and P found in nursery runoff, which suggests that some of these plants may be useful in a constructed wetland remediation system. Bilderback et al. (1993) reported on an aquatic plant production system designed to use nutrients from catfish production ponds to produce salable plants. The plants in this study could also be commercially produced with nursery runoff without supplemental fertilization. The production area occupied by these plants would have the dual function of remediating runoff and providing a saleable product.

Nature of Work: Commercial nurseries use large amounts of water and nutrients to produce container-grown plants. Excess water contaminated with N and P can impact the quality of surface water and groundwater. Earlier work by the authors found that constructed wetlands at a commercial nursery were highly efficient at removing N. However, phosphate (PO_4) removal was highly variable with uptake coinciding with periods of heavy nursery use and net loss often occurring during other periods. Landscape plants that remediate nutrients, especially P, would be very useful in constructed wetlands or production systems for commercial nurseries and greenhouses.

Porous gravel-based constructed wetlands have been of interest to Clemson University researchers as a way of remediating pesticide contaminated runoff from nurseries and golf courses (Wilson et al., 1999). Gravel-based systems were used successfully for treating sewage sludges (Lewis et al., 1982; Cooper and Boon, 1987). However, a drawback to these gravel-based systems is their longevity as they have a relatively short life span (10 to 15 yr) before replacement due to clogging and surface-ponding (Lewis et al., 1982; Cooper and Boon, 1987). To design a constructed wetland system to remediate both N and P contaminants for horticultural business, golf courses, and residential areas, we needed a suite of aesthetically attractive plant varieties that would thrive under anaerobic conditions and remediate levels of N and P found in runoff. To this end, we developed a screening test of commercially available landscape plants for their phytoremediation potential and their ability to thrive in a non-aerated pea gravel-based test system. Pea gravel was chosen as a medium because it has high hydraulic conductivity and low cation exchange capacity. We examined 19 species and cultivars in 18 genera of woody and herbaceous landscape plants.

Liners of selected species were washed free of planting medium and transplanted to 6.5 inch azalea pots in pea gravel. Potted plants were placed in 1 gallon aquatic pots with rims even and watered with approximately 1.4 qts. (1350 mL) of 10% Hoagland's solution until water was visible through the gravel. After an acclimation period of 2 to 4 weeks, plants were washed with deionized water, and placed in a randomized complete block design with 6 replicates and five treatment levels of concentrations of Hoagland's solution. Experiments were replicated twice for each species. These treatment levels (concentrations given are nominal values) corresponded to a 0.1% solution (0.93 ppm NO_3; 0.095 ppm PO_4); 1% (9.3 ppm NO_3; 0.95 ppm PO_4); 5% (46.5 ppm NO_3; 4.75 ppm PO_4); 10% (93 ppm NO_3; 9.5 ppm PO_4); and 20% solution (186 ppm NO_3; 19 ppm PO_4). These concentrations fall within the range of nutrients used for nursery irrigation, those found in nursery runoff, and those found in constructed wetland discharge. Plants were watered as required every two days for 8 weeks for herbaceous species and 13 weeks for woody species. Total water usage, final fresh weight of shoots and roots, final dry weight of shoot and roots, and nitrogen and phosphorus content of shoot and root dry matter were measured. Data were analyzed using SAS (SAS Institute, Cary, NC) GLM procedure for the experimental model and LSD t-test for differences among treatment groups.

Results and Discussion: Shoot and root N and P showed significant treatment effects for all landscape species for which analyses have been completed (Table 1). Silky dogwood (*Cornus amomum*) root dry weight (data not shown) showed no significant treatment effect and shoot dry weight was similar except at the 20% Hoagland's treatment level. Stargrass (*Rhyncospora colorata*) had no differences for root dry weight and little difference in phosphorus uptake at environmentally relevant concentrations. Red stemmed alligator flag (*Thalia geniculata* f. *ruminoides*) produced greater biomass at levels above 5% Hoagland's and accumulated N and P in shoots and roots above 5% Hoagland's except root nitrogen was greater only at 20% Hoagland's. Root dry weight of miniature cat-tail (*Typha minima*) did not vary by treatment but shoot and root nutrient concentrations were higher at concentrations above 10% Hoagland's. Shoot and total dry weight of blue flag (*Iris* 'Full Eclipse') did not vary by treatment but shoot and root nutrient concentrations were generally higher at concentrations above 10% Hoagland's. Canna (*Canna* 'Bengal Tiger') produced large quantities of biomass but N and P accumulation for the lowest concentrations of Hoagloand's generally showed no differences from the highest concentrations.

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Table 1. Nitrogen and phosphorus tissue concentrations (mg/g dry weight) for six woody and herbaceous landscape species following exposure to varying levels of Hoagland's solution for 8 and 13 weeks, respectively.

Landscape species	Nutrient	Plant part	Percent Hoagland's solution (%)				
			0.1	1.0	5.0	10	20
Silky dogwood	N	shoot	5.76[a]*	5.51[a]	6.18[a]	8.88[a]	9.13[a]
Cornus ammonium		root	7.12[a]	8.59[a]	9.37[ab]	11.95[ab]	14.97[b]
	P	shoot	1.00[a]	0.83[a]	1.03[a]	1.38[a]	1.35[a]
		root	1.37[a]	1.53[a]	2.20[b]	2.81[c]	3.36[d]
Stargrass	N	shoot	7.10[a]	7.76[a]	10.02[b]	13.00[c]	18.03[d]
Dichromena colorata		root	5.63[a]	5.58[a]	7.44[a]	11.43[b]	21.46[c]
	P	shoot	0.85[a]	0.98[a]	1.29[b]	1.81[c]	2.58[d]
		root	1.05[a]	1.13[a]	1.32[a]	1.81[b]	2.83[c]
Red-stemmed	N	shoot	6.96[a]	6.96[a]	7.45[b]	8.69[c]	10.99[d]
alligator flag		root	6.48[a]	6.19[a]	6.10[a]	6.63[a]	8.45[b]
Thalia geniculata	P	shoot	0.90[a]	1.03[ab]	1.06[b]	1.20[c]	1.83[d]
f. *ruminoides*		root	0.73[a]	0.71[a]	0.78[ab]	0.89[b]	1.24[c]
Minature cat-tail							
Typha minima	N	shoot	9.30[a]	9.87[a]	11.85[b]	14.80[c]	20.93[d]
		root	6.60[a]	6.91[a]	7.72[ab]	9.28[b]	13.04[c]
	P	shoot	1.19[a]	1.33[a]	1.27[a]	1.58[b]	2.23[c]
		root	2.00[a]	2.02[a]	2.40[ab]	2.72[b]	4.00[c]
Blue flag iris	N	shoot	9.13[a]	10.15[ab]	12.22[b]	15.53[c]	19.81[d]
Iris 'Full Eclipse'		root	9.30[a]	10.47[ab]	11.05[ab]	11.76[b]	16.12[c]
	P	shoot	1.38[a]	1.53[a]	1.76[ab]	2.22[b]	2.89[c]
		root	1.09[a]	1.37[ab]	1.64[bc]	1.97[cd]	2.32[d]
Canna lily							
Canna 'Bengal Tiger'	N	shoot	11.74[a]	11.12[a]	12.40[a]	14.29[ab]	17.18[b]
		root	11.05[a]	10.41[a]	9.41[a]	9.43[a]	10.46[a]
	P	shoot	3.03[bc]	2.54[abc]	2.45[a]	2.48[ab]	3.06[c]
		root	2.29[a]	2.17[a]	1.92[a]	1.94[a]	2.18[a]

*Different letters indicate differences among nutrient treatment levels within a plant part at $P < 0.05$.

Rate of Calcined Clay Incorporation Influences Phosphorus Retention in a Pine Bark Substrate

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Index Words: Calcined Clay, Controlled Release Fertilizer, Phosphorus

Significance to Industry: Calcined clays are stable products capable of reducing the amount of phosphorus which leaches from a pine bark based container substrate. Optimal reduction (54-58%) of Ortho-P leaching from containers was obtained using Hi-Dri clay at a rate of 5.0% to 7.5% by vol. At a retail cost of $0.10 per pound, the 5.0% by vol. treatment would cost an additional $0.02 per #1 (2.8 L) container. Further research is needed to evaluate the influence of calcined clays on growth of different plant species, the influence of irrigation rate and leaching fraction on leaching of Ortho-P from substrates amended with calcined clays, and to determine why some calcined clays from different manufacturers differentially bind phosphorus.

Nature of Work: Previous research has shown that calcined clay is an effective substrate amendment for reducing the leaching of phosphorus from container substrates (1,2). When incorporated at 10% by volume, particle size of a calcined clay product had little influence on leaching of phosphorus, indicating that it may be possible to utilize less product and still retain P in the substrate (2). A study was initiated on 22 April, 2003 using a 8:1 pinebark:sand (by vol) substrate (control) amended with a calcined clay product (Hi-Dri Clay, Sud-Chemie, Meigs, GA) at the following volumes: 1) 2.5%, 2) 5.0%, 3) 7.5%, and 4) 10.0% per #1 (2.8 L) container. Two products included for comparison and incorporated at 7.5% by vol. were a calcined clay (Coarse Cat Litter) and a non-calcined clay (Flowability Aid) both manufactured by Oil-Dri (Chicago, IL). Dolomitic limestone (2.0 lbs/cu. yd.) and Micromax (1.0 lbs/cu. yd.; The Scotts Co., Marysville, OH) were incorporated into the substrate. The substrate mixes were then placed into leachate collection buckets as previously described (2). All containers were topdressed with 25 g/pot Osmocote Plus 15-9-12 Southern Formula (12 month formulation, The Scotts Co.). Overhead irrigation was applied daily as needed at 0700 hr. Irrigation volume was 1.0 cm (0.3 in) per irrigation event, applied at a rate of 1.39 cm/hr (0.55 in/hr) with a coefficient of uniformity of 92%. Total volume of leachate was collected and measured every two weeks for a 24 week trial period. Ortho-P was measured using a molybdovandate procedure and a Brinkmann PC 920 probe colorimeter (Brinkmann Instruments, Inc., Westbury, NY). Total Ortho-P leaching from the containers was determined by multiplying total volume of leachate by concentration of Ortho-P collected during the entire study.

Data for the experiment were subjected to analysis of variance using PROC GLM (SAS version 8.0 for Windows, Cary, NC). The experiment was a randomized complete block design with four replicates per treatment. Data were evaluated using Dunnett's t Test.

Results and Discussion: Total mg of Ortho-P leached from the control substrate over a 24 week period was 198 or approximately 1.2 mg/day. At a density of one plant per sq. ft., the rate of 1.2 mg/day would equate to 19.3 lbs. of Ortho-P lost per acre of production over a 24 week period. In 2002, a leaching rate for Ortho-P was 1.7 mg/day using the same substrate and controlled release fertilizer (1). However, irrigation was applied at the rate of 0.4 in per irrigation event in 2002, compared to 0.3 in per event in 2003, indicating that irrigation volume influences leaching of Ortho-P from the substrate. For the four Hi-Dri clay treatments, leaching of Ortho-P was reduced in the range of 44% to 58% (Table 1). The two clay products from Oil-Dri did not reduce leaching of Ortho-P. Why the Oil-Dri products did not reduce leaching of P is not understood at this time. Based on this research it appears that Hi-Dri clay incorporated at 5% to 7.5% by vol. is optimal for reducing phosphorus losses from pine bark based container substrates.

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Table 1. Percent Ortho-P leached from #1 containers during a 24 week period compared to the non-treated control.

Treatment	Percent leaching of Ortho-P (+/-)
Hi-Dri 2.5%	-44%
Hi-Dri 5.0%	-54%
Hi-Dri 7.5%	-58%
Hi-Dri 10.0%	-57%
Oil-Dri (calcined)	+4.0%
Oil-Dri (non-calcined)	-2.0%

Response of River Birch (*Betula nigra*) to Foliar and Drench Applications of Nickel

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Index Words: *Betula nigra* 'BNMTF' Dura-Heat, Mouse-ear, Nickel Deficiency

Significance to Industry: Nickel has been shown to cure mouse ear disorder on river birch. Plants are tolerant of a wide range of concentrations applied as foliar sprays. Applied in late June in south Georgia, foliar sprays resulted in a quicker response compared with drench applications. Rates as low as 250 ppm Ni applied as a foliar spray were effective in this study. Lower rates have been effective as well (Ruter, unpublished data). Further work is needed to refine methods of application, rates of application, evaluate formulations of nickel, as well as timing of applications. Caution should be used when handling nickel as it can cause skin dermatitis and is recognized as a carcinogen. Efforts are under way to have nickel recognized as an essential element so fertilizer products can be developed.

Nature of Work: Mouse ear (leaf curl, little leaf, squirrel ear) has been a problem in container-grown river birch (*Betula nigra*) since the 1970's and has been a serious problem since the mid 1990's. Mouse ear disorder on pecan (*Carya illinoinensis*) has been corrected by the application of nickel salts and has been associated with a deficiency of nickel at budbreak (3). Foliar spray and substrate drench applications of nickel sulfate cured mouse ear symptoms on river birch plants growing in a pine bark substrate in #15 containers (1,2). Further work is needed to determine optimal rates of application and to determine if phytotoxicity occurs at higher rates of nickel application.

A study was initiated on June 25, 2003 at a commercial nursery in south Georgia. River birch (*Betula nigra* 'BNMTF') in their second growing season in #15 containers were selected for uniformity of size and mouse ear disorder. Plants were treated between 11am to 12 pm EST under partly cloudy skies with an air temperature of 85F. Treatments included a 1) control, 2) 2.0 lbs./100 gal urea + 4.0 ml/gal SilEnergy surfactant (Brewer International, Vero Beach, FL), 3) treatment 2 + 250 ppm Ni spray, 4) treatment 2 + 500 ppm Ni spray, 5) treatment 2 + 750 ppm Ni spray, 6) treatment 2 + 1000 ppm Ni spray, 7) 0.005 lbs. Ni/cu.yd. drench, and 8) 0.01 lbs. Ni/cu.yd. drench. Nickel sulfate (22.3% Ni) from Fisher Scientific (Pittsburg, PA) was utilized. Spray treatments were applied at ~100 gal/acre. The drench treatment was applied with a volume of 500 ml/pot. Plants were arranged utilizing a completely randomized design with five single plant replicates.

Plants were rated for mouse ear (percentage of canopy showing mouse ear symptoms) and samples were collected 30 days after treatment. Five stems from each plant were cut back to the point where new growth had initiated in 2003. Stem length was recorded, then leaves from the five stems were removed, counted, and run thru a LI-COR 3000 (LI-Cor, Inc., Lincoln, NE) leaf area meter to determine leaf area for the composite sample. Leaves were dried for three days at 150F in a forced-air dryer and dry mass was determined. Specific leaf area was calculated as leaf area/leaf dry mass. Number of leaves per unit stem length was calculated as number of leaves/mean stem length. Foliar nutrient analysis was conducted using an ICP. Data was analyzed using SAS and mean separations compared utilizing Dunnett's t test.

Results and Discussion: After 30 days, all plants treated with nickel sulfate had 100% normal growth, except the low rate of drench which had 79% of the canopy with normal growth. No phytotoxicity was noted for any treatment. Number of leaves per stem was not influenced by treatment. Plants receiving foliar sprays of nickel had a 66 to 72% increase in leaf area, a 64 to 68% increase in leaf dry weight, a 31 to 44% increase in stem length, and a 9 to 17% increase in specific leaf area compared to the non-treated control plants. Number of leaves per unit stem length decreased up to 40% for plants treated with nickel, indicating that internode elongation increased. Foliar application of Ni at rates as low as 250 ppm was effective for correcting mouse ear disorder on container-grown river birch.

For the drench treatments with nickel, leaf area increased up to 62%, leaf dry weight increased up to 55%, and specific leaf area increased up to 18% over the non-treated control. Mean stem length increased up to 29% while the number of leaves per unit stem length were similar to the foliar spray applications.

Nickel concentrations in the foliage of mouse-eared control plants was 2.3 ppm. For the spray treatments, foliar Ni ranged from 5.5 ppm for the 250 ppm Ni treatment to a high of 9.3 ppm for the 1000 ppm Ni treatment. Though the plants at the highest rate of drench treatment resumed normal growth, the Ni concentration in the foliage was not different from the non-treated control. A drench rate of 0.005 lbs. Ni/cu.yd. applied in late June did not totally correct the mouse ear problem, while a drench at this rate applied in early June resulted in 100% normal regrowth, indicating that timing and rate will be critical. In general, if plants were treated with Ni, then B, Fe, and Zn in the tissue decreased. Manganese in the foliage showed a similar trend to B, Fe, and Zn but treatment was not significant and Cu was below detection limits in the samples. There was a negative correlation between Ni and Zn and Ni and B in the foliage.

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Response of Container-grown *Acer rubrum* and *Quercus rubra* to Foliar Application of a Kaolin Particle Film

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Index Words: Maple, Oak, Nursery Production, Particle Film

Significance to Industry: Kaolin particle film application is easy, safe, and relatively inexpensive. Reduced heat stress and increased plant growth in production and holding areas where temperatures exceed 86 ˚F for extended periods may lead to increased production efficiency and more vigorous plants as end products. However, our studies indicate further investigation into carbon partitioning is needed.

Nature of Work: According to the American Horticultural Society Plant Heat-Zone Map, much of the Southern half of the United States east of the Rocky Mountains averages 60 to 180 days annually with high temperatures exceeding 86 ˚F (30 ˚C). At this temperature many plants begin experiencing heat stress with damage to cellular proteins. Heat stress often results in reduced growth rate, chlorosis, wilting, abnormal branching, root injury or death, and reduced flowering (Ingram, et al., 1989). Nursery stock is exposed to extended periods of heat stress in many nurseries and on postharvest sales lots resulting in extended production times and a larger percentage of unsalable plants due to poor quality or death. These losses directly affect profitability.

Foliar application of kaolin particle films (KPF) has been shown to reduce leaf temperatures and increase stomatal conductance of apple leaves, thus reducing heat stress and in turn expressed as increased yield and/or fruit weight in 7 of 8 trials (3). Other recent studies supporting reduced heat stress benefits of KPF include Glenn et al. (1, 2), Jifon and Syvertsen (5), and Tworkoski et al. (8). To date, published studies have focused primarily on fruit crops and a few vegetable and grain crops. This study was conducted to determine the effects of foliar application of KPF on *Acer rubrum* (Red Maple) and *Quercus rubra* (Red Oak).

Acer rubrum 'Red Sunset' and *Quercus rubra* trees in 5-gallon containers were obtained from Bailey Nursery, Newport, MN in May 2003. Trees were 6 to 9 ft tall, 3⁄4 to 1 inch in caliper, and were fully leafed out. Upon arrival trees were repotted into 7-gallon containers and allowed to acclimate for 2 weeks prior to treatment application and data collection. Tree canopies were sprayed bi-weekly with a highly reflective hydrophilic kaolin particle film (Surround WP, Engelhard Corp., Iselin, NJ), or not sprayer (control). Surround WP was tank mixed a rate of 8 oz per gallon of water and applied with a hand-held garden sprayer at a rate of 1 gallon per 6 trees. A randomized complete block design was used with 3 blocks and 2 trees per species per treatment. Plants were spaced on 8 ft centers on a flat, open field in Manhattan, KS. Daily water use was determined using weights of the plants at field-capacity minus weights 24 hours later. This data was collected 3 times weekly for 8 weeks beginning June 26, 2003. Fresh weight gain was determined using the mean of the first 2 field-capacity weights per plant minus the mean of the last 2 field-capacity weights after 14 weeks. Additionally, plant height and caliper at 6 inches above soil line were recorded at the beginning and end of the experiment in 14 weeks. Data were subjected to analysis of variance and means separation by LSD0.05.

Results and Discussion: Maples tended to lose more water than the oaks and daily water loss varied considerably due likely to varying temperatures, humidity, light levels, and wind speed (Fig. 1). Application of Surround WP did not alter water loss significantly (Fig. 1). These results concur with findings of Jifon and Syvertsen (5) where KPF-sprayed grapefruit trees had similar leaf transpiration and whole-tree water use compared to untreated controls. However, studies with apple by Glenn et al. (1, 3) found increased stomatal conductance and reduced water use efficiency associated with foliar applications of KPF. Differences in outcomes may be attributable to species-specific responses, temperature (1), and/or number of treatment applications [This study (every 2 weeks), Glenn et al., 2003 (weekly, then every 2 weeks), and Jifon and Syvertsen, 2003 (twice a week)].

When averaged over species, Surround WP-treated trees increased twice as much in height compared to control trees (Fig. 2A). However, overall fresh weight gain was less for Surround WP trees and caliper increase was not significantly different between treatments (Fig. 2B, 2C). There were significant differences in growth between the maples and oaks (Fig. 2D, 2E). Maples gained more height and weight over the 14-week period than oaks. Maples also tended to increase more in caliper than oaks though differences were not significant (Fig. 2F).

Increased carbon assimilation and/or fruit yield from KPF application was documented in several studies with apple (1, 3), grapefruit (5), grain sorghum (7), and tomato (6). Our results had significant increases in height with KPF application over non-treated trees. However, this additional height was not reflected in additional fresh weight gain over controls. In a study with bean, Tworkoski et al. (8) reported no KPF effect on stem and leaf dry weight but root dry weights were reduced compared to non-treated plants, suggesting KPF may alter dry weight partitioning in plants. Follow-up studies are needed to understand the overall carbon partitioning in KPF treated woody plants because this is important to the continued growth and health of these plants.

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Figure 1. Daily water loss of container-grown Red Maple and Red Oak trees as influenced by foliar application of Surround WP particle film or no application (control).

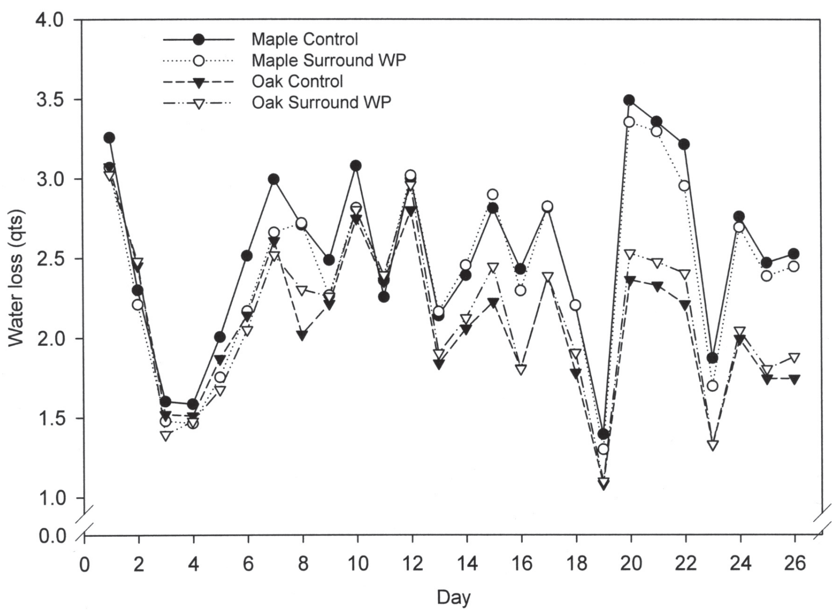
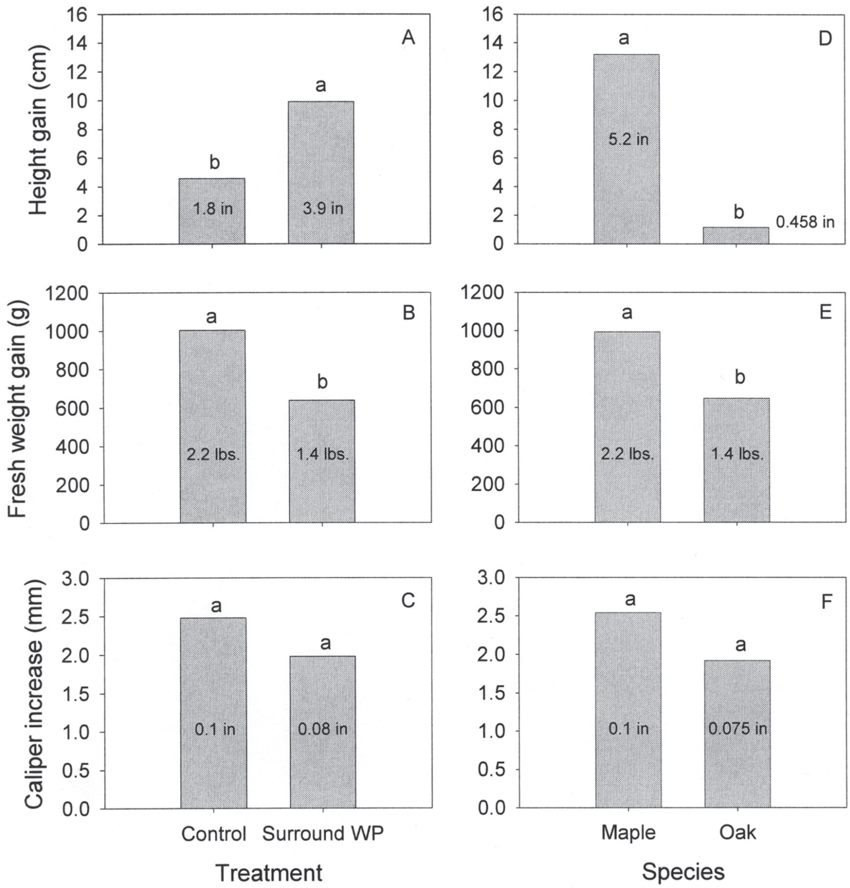


Figure 2. Height, fresh weight and caliper change of container-grown Red Maple and Red Oak trees as influenced by foliar application of Surround WP particle film or no application (control) over 14 weeks. Mean separation by $LSD_{0.05}$.



Effect of Atmospheric Warming on the Growth of Red Maple

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Index Words: *Acer rubrum* L., Heat stress, Gas exchange, Acclimation

Significance to Industry: The results obtained in this study clearly demonstrate that heat affects Summer Red photosynthetic processes. Characterization of these differences may reveal the photosynthetic mechanisms necessary for improved plant performance under elevated temperatures. Identification of such mechanisms could be used to develop a physiologically based evaluation tool for current and newly released cultivars. Most importantly, these results could possibly decipher the mechanism(s) for not only red maple heat tolerance, but other common urban woody species as well. The project will, therefore, provide a physiological measure for future cultivar evaluations and breeding programs on a regional level with potential national and international recognition.

Nature of Work: High temperatures usually limit crop yields because the rate of photosynthesis is heat sensitive. Leaves, grown at contrasting temperatures, can have different photosynthetic rates due to a change in the temperature dependent balance of the following two key photosynthetic processes: (1) the activity of ribulose-1,5-bisphosphate carboxylase-oxygenase (RuBP carboxylation) and (2) the regeneration rate of ribulose-1,5-bisphosphate (RuBP regeneration). We hypothesize that evolutionary adaptation underlies the response to atmospheric warming and that temperature interactions directly affect the balancing of RuBP carboxylation and RuBP regeneration. If this type of leaf photosynthesis response to atmospheric warming is to be understood, then we need to elucidate the potential for a species, cultivar, and/or clone to further adapt to new selection pressures by deciphering the functional importance of intraspecific genetic variation (Rice and Emery, 2003).

Predicted temperature increases are well documented within the literature, with estimated mean land surface temperatures rising from 3 to 6°C (5.3 to 10.8° F) for temperate regions within the century (Houghton et al. 1996). Therefore, we must aspire to understand the leaf-level feedback mechanisms that regulate whole plant carbon fixation and the factors that limit photosynthetic rates at elevated atmospheric temperature by investigating the genetic control on photosynthetic temperature acclimation (Hikosaka et al. 1999).

Plant Production. We investigated ‘Summer Red’, a genotype native to southern portions of the USA. Trees were transplanted into 56.7-L (15 gallons) Spin Out treated plastic pots containing a mixture of 20 pine bark: 1 sand (by vol), fertilized with 8.3 kg m^{-3} (18.25 lbs) of Nutricote™ 20N-3.0P-8.3K type 360 (Chiso-Asahi Inc., Japan), and placed on an outdoor gravel pad. Each tree was fit with pressure-compensating micro emitters (ML Irrigation Inc., Laurens, SC) at a spacing of 1.5 x 1.5 m (5 x 5 ft.).

Effect of Heat on Photosynthesis. Four subdivided whole crown chambers were used to control atmospheric temperature on four replicate trees by dividing each crown into three equal area layers per tree. Photosynthesis was measured using a portable steady state gas-exchange system (CIRAS-I, PP Systems, Haverhill, Mass.) equipped with a light and temperature controlled cuvette (model PLC5 (B); PP Systems). Measurements were made on fully expanded leaves at three canopy positions per crown. On the branch tip, measurements were taken on the youngest fully expanded non-damaged leaf from 0900 to 1430 HR. The leaves were tagged and on any given day, measurements were taken in random order to compensate for any effects caused by time of sampling.

Results and Discussion: Leaf temperatures of nursery grown red maple were measured over the course of 7 d in early-July 2003 after nearly 50 d of exposure to atmospheric treatment temperatures of 25°, 33°, and 38° C (77°, 91.4°, and 100.4° F). As air temperature increased, leaf temperature increased and lowered the maximum rate of Rubisco-catalyzed carboxylation (V_{Cmax}). Surprisingly, however, the rate of maximum noncyclic electron transport (J_{max}) increased as growth temperature increased from 25° to 38° C (77° and 100.4° F) (Figure 1). In this preliminary study, a genotype native to southern environmental conditions (‘Summer Red’) showed a lower Rubisco activity in response to temperature, indicating the activity of RuBP carboxylation was lower as temperature increased. However, J_{max} increased in response to elevated temperature, signifying the rate of RuBP regeneration was higher as temperature escalated to 38° C (100.4° F). The increase in J_{max} could indicate acclimation to elevated growth temperature and bring into question the generalization that elevated temperature reduces crop yield. In our study, the genotype was native to the location of the study site and therefore, could already be preadapted and/or able to acclimate to the range of treatment air temperatures.

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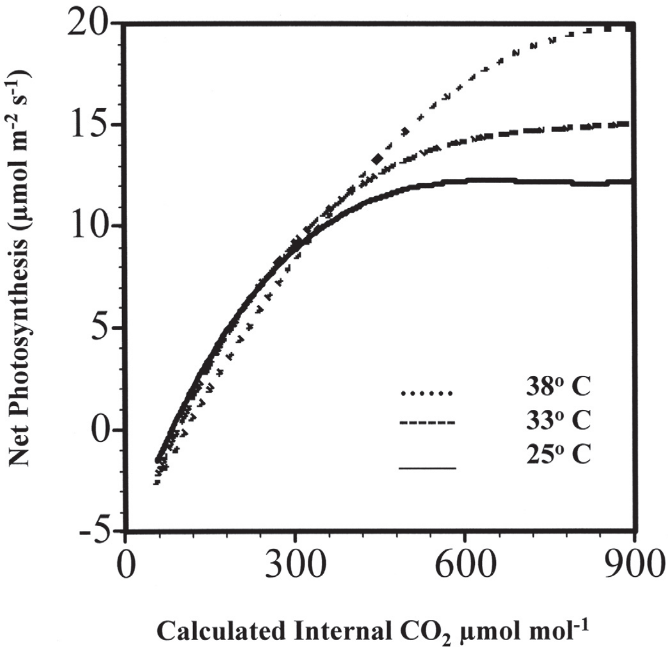
Figure 1. Representative net photosynthesis versus calculated internal CO_2 curves for leaves grown at 38, 33, and 25° C. Each curve shows the rate of carboxylation allowed by the amount, activity, and kinetic properties of Rubisco (i.e. V_{cmax}) at moderate temperature and the transition of this limitation to one allowed by the rate of RuBP regeneration via electron transport (i.e. J_{max}) at higher atmospheric temperatures. The red maple genotype depicted is 'Summer Red'.



Incorporation of Clay Amendments to Reduce Fertilizer Use in Poinsettias

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Index Words: Fertilization, Water Quality, Container Production, Euphorbia pulcherrima

Significance to Industry: Calcined clays incorporated into the substrate reduced discharge of nutrients from container-grown poinsettias early in the production cycle. However, controlled release fertilization did not ensure adequate substrate nutrient solution concentrations for poinsettias in clay-amended substrates. Regardless of growers' specific nutrient management techniques, frequent monitoring of nutrient concentrations in the substrate solution is essential to achieve adequate growth while minimizing nutrient loss.

Nature of Work: Various clays have been used as amendments to soilless substrates, since heterogeneous substrates offer the combined advantages of their components. When arcillite, a montmorillonite and illite clay, was added to gravel/vermiculite and pine bark substrates, available water holding capacity and nutrient retention were increased (4,6). Growth of 'Carolina Sapphire' smooth Arizona cypress grown in arcillite was maximized at a relatively low nitrogen concentration (20 ppm) (5). Arcillite incorporated into a peat-based substrate at 10 or 20% (v/v) reduced discharge of excess nutrients from container-grown chrysanthemum without reducing plant quality (1); however, it reduced plant height and shoot dry weight. In another study, shoot dry weight was reduced when arcillite (10% v/v) was layered at the bottom of containers, but not when it was incorporated (2). Fuller's earth, another 2:1 clay, reduced nutrient discharge without negative effects on growth of poinsettia (Euphorbia pulcherrima) (3).

The objective of this study was to determine whether calcined clay amendments to peat and bark + peat substrates decreased discharge of excess nutrients from containers without limiting growth or quality of poinsettias.

Rooted cuttings of 'Freedom Red' and 'Prestige' poinsettia (Euphorbia pulcherrima Willd. ex Klotzsch) were grown in 15 cm (6 inch) azalea containers in a glass greenhouse during autumn 2003. Peat-based (Fafard 2) and pine bark/peat-based (Fafard 52) commercial substrates (Conrad Fafard Inc., Agawam, MA) were used alone or amended with 10% (v/v) Agsorb (16/30 mesh size), an attapulgite-type clay from Georgia (Oil-Dri, Chicago, IL). Plants were otherwise grown according to standard commercial practices. Plants were arranged in a randomized complete block experimental design with 6 three-pot replicates and 4 treatments. Plants were topdressed with Osmocote (Scotts Co., Marysville, OH) 19N-2.6P-10K (19-6-12, 3-4 month release, 9.3 g/pot) and then irrigated by treatment each time container weight decreased by 45% of container capacity.

Sufficient irrigation with tap water was applied to attain a leaching excess near 20% of the volume applied. Leachate was collected at each irrigation and analyzed for pH and electrical conductivity (EC). Plant heights were collected weekly. Final growth data (plant height, width, fresh and dry weight), were collected as each cultivar reached anthesis. Shoot tissue analysis was performed to determine nutrient concentrations.

Results and Discussion: Shoot dry weight comparisons revealed that plant growth was higher in the peat substrate than in bark + peat. However, due to differences in chemical and physical properties between peat and bark, direct comparisons between substrates are not valid. Leachate EC data showed that nutrient concentrations were higher in peat than in bark + peat throughout the studies. Furthermore, irrigation frequency was probably less than optimal for the bark + peat (55-60% bark).

Within substrates, the presence of clay decreased growth in some instances. Dry weight of 'Freedom Red' grown in bark + peat + clay was 34% lower than in bark + peat. Dry weight of 'Prestige' grown in peat + clay was 11% lower than in peat-based substrate alone.

Leachate EC from both cultivars was initially 2 dS/m. Values decreased gradually for the first 7 to 9 weeks of the studies, but increased thereafter. This may suggest that plant demand for nutrients declined as plants shifted from vegetative to reproductive growth, and that no additional sorption occurred on clay surfaces once they were saturated. Tissue nutrient concentrations of finished plants grown with clay tended to be lower for some nutrients, including phosphorus. Thus, EC and nutrient analysis data suggest that clay may be sorbing certain ions and making them less available for plant uptake. Since surface charges on clays can be positive or negative, depending on substrate solution pH, clays may be sorbing nitrogen, phosphorous or potassium. Speciation studies would be required to determine which nutrients are most limiting.

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The Effect of Cyclic Irrigation and Herbicide on Plant and Weed Growth in Production of *Magnolia grandiflora* 'Alta'

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Index Words: Oxyfluorfen, Oryzalin, Oxidiazon, Regal O-O, Rout, Snapshot, Trifluralin, Isoxaben, Chamaesyce, Spurge

Significance to Industry: This research shows that cyclic irrigation reduces the efficacy of all the herbicides evaluated. However, despite increases in weed infestations, dividing the plants daily water allotment into six applications produced larger Magnolia grandiflora 'Alta'. Growers should be aware that a possible side effect of converting to cyclic irrigation is a reduction in herbicide longevity and efficacy. This may result in an increase in the amount of hand weeding needed or an increase in the frequency of herbicide applications.

Nature of Work: Cyclic irrigation is the practice of dividing the plants daily water allotment into multiple irrigation events with a prescribed resting interval between events. Past research has shown the benefit of cyclic irrigation in production of nursery plants. Research has indicated that the proper use of cyclic irrigation can increase water and fertilizer use efficiency as well as increasing plant growth (1,2,3,4). However no research has been conducted to indicate what effect cyclic irrigation might have on herbicide efficacy.

An experiment was conducted to evaluate the effect of cyclic irrigation (dividing the plants daily water allotment into more than one application with resting intervals between applications) and herbicide formulations on plant and weed growth in production of Magnolia grandiflora 'Alta'. On March 21, 2003, one quart Magnolia grandiflora 'Alta' liners were potted into #7 containers (Nursery Supplies Inc.) using an 8:1 (v:v) pinebark:sand medium amended with 3.0 kg•m^{-3} (5 lb/yd^3) of dolomitic limestone and 0.9 kg•m^{-3} (1.5 lb/yd^3) of Micromax (The Scotts Co.) micronutrients. Polyon (Purcell Technologies Inc.) 17N-2.9P-9.8K (17-7-12) was dibbled (placed 7.6 cm (3 in) below the surface of the container media at potting) at 210 g (7.4 oz) per container. Irrigation was applied using a spray stake (Bowsmith, Inc. model JS-52) attached to an 11.4 liter (3 gal) per hour pressure compensating drip emitter (Plastro model 3245-0012). The experimental design was a randomized complete block with 8 single plant replicates. There were three irrigation and three herbicide treatments.

Irrigation was applied in a single application, divided into three applications with a two hour resting interval between applications, or divided into six applications with a one hour resting interval between applications. All plants received approximately 2.3 liters (2.4 qt) of water daily. Herbicides were Rout®

(oxyfluorfen + oryzalin, The Scotts Co.), Snapshot® (trifluralin + isoxaben, Dow AgroSciences), or Regal O-O® (oxyfluorfen + oxidiazon, Regal Chemical Company). All herbicides were applied at the label recommended rate. Herbicides were applied on March 28. On March 31 containers were over-seeded with 20 prostrate spurge seed (Chamaesyce prostrata). Weeds were harvested on June 26 (data not shown) and containers were retreated and reseeded as before. Data collected monthly was plant height and caliper as well as percent weed coverage. Weed top dry weight was determined at study completion on October 20 [90 days after second herbicide treatment (DAST)].

Results and Discussion: Herbicide formulation had no effect on plant or weed growth. Irrigation treatment had a significant effect on plant height and caliper increase. On October 20 plants receiving six irrigation applications had on average a 21% greater height increase and a 14% greater caliper increase than those receiving one or three applications. Irrigation treatment also had a significant effect on weed top dry weight. At 90 DAST plants receiving three and six irrigation applications had 261% and 285% greater weed top dry weight respectively than those receiving one application. Growers using cyclic irrigation should be aware of its effect on herbicide efficacy. Dividing the plants daily water allotment into six applications produced larger Magnolia grandiflora 'Alta' despite the increase in weed infestation.

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Table 1. The effects of cyclic irrigation weed control and growth of Magnolia grandiflora ‘Alta’.

	Magnola grandiflora ‘Alta’		*Chamaesyce prostrata* Spurge		
	Height increase (cm)	**Caliper increase (mm)**	**Weed #**	**% Coverage**	**Dry weight (g)**
Cyclic Irrigation[z]	90 DAST[y]	90 DAST	90 DAST	90 DAST	90 DAST
one	61.7a[x]	10.3 a	4.0 b	15.2 b	3.9 b
three	61.5 b	10.2 a	6.5 ab	24.6 a	10.1 a
six	74.7 b	11.8 b	8.1 a	27.9 a	11.1 a
Herbicide Type					
Regal O-O	66.0 a	10.9 a	6.3 ab	17.5 a	9.0 a
Rout	71.0 a	11.4 a	4.3 b	26.0 a	6.6 a
Snapshot	70.2 a	11.4 a	8.6 a	29.4 a	9.4 a

[z]Plants daily water allotment applied in one, three (amount from one divided into three equal amounts applied at 10:00 am, 12:00 pm, and 2:00 pm), or six (beginning at 9:00 am with one hour resting intervals between applications).

[y]Ligustrum growth index = (height + width + width)/3. days after second herbicide treatment.

[x]Means (within a column and for each factor) with different letters are significantly different, according to Duncan’s Multiple Range Test (a = 0.05).

Slab Production of Asiatic Jasmine for Instant Landscape Appeal

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Index Words: Groundcover Production, Trachelospermum asiaticum, Water Conservation

Significance to Industry: There appears to be a solid demand for ground covers that can be installed as easily and rapidly as turf sod. Production in small containers discourages wide spread use of ground covers due to labor involved in transplanting into a landscape, and the "grow-in" period to establish complete coverage. The method described here produced slabs of asiatic jasmine that can be handled like turf sod and produce instant coverage. Production costs are included.

Nature of Work: Substituting ground covers for turf grass is recommended in XeriscapeTM landscape guides and promoted in the University of Florida's Florida Yards and Neighborhoods Program as a way to reduce landscape irrigation and non-point pollution. Many woody plants are more drought tolerant than grasses, and are able to maintain a normal appearance under water stress where grasses would die back as a survival mechanism. Thus many woody ground covers, once established, would require no irrigation during normal rainfall years, and limited irrigation during droughts. Ground covers not only require less irrigation once established, but also fewer, if any, pesticide applications compared to turf grass. Maintenance of groundcover areas is also greatly reduced compared to turf.

Adoption of ground covers as a turf replacement has been slow. Two main reasons for this are: 1) ground covers are produced in small containers, and 2) they are installed one hole at a time. Costs to produce a #1 container of groundcover is the same as a shrub. On a square foot basis installed in a landscape, ground covers cost 5 to 10-fold more than the same area of turf. The more defeating aspect is installation. Turf grass is purchased as 400 ft^2 palletized stacks of 1 ft x 2 ft slabs and installed by throwing down 2 ft^2 sections at a time. Container-grown ground covers are installed one at a time into holes dug into the ground. One 1 ft centers, that is almost 400 holes. After installation, turf sod generally forms a solid canopy of grass blades. In contrast, ground covers installed from containers may require 4 to 12 months to form a solid canopy. In the meantime, weed growth can ruin a groundcover's appearance and appeal. In addition to landscape installation, slab production holds several production benefits also. Thus the objectives of this research were to evaluate a production scheme and estimate a cost per ft^2 to produce asiatic jasmine as slabs.

In late March 2003, commercial liners of asiatic jasmine (*Trachelospermum asiaticum* 'Minima') were transplanted into 10.5 x 20 inch polyethylene nursery trays in a 7 pine bark fine: 3 Fla. sedge peat: 1 sand substrate amended with dolomite and micronutrients. Trays were transplanted with 2, 3 or 4 liners and placed on TexR propagation liner (Texel Inc., Saint Elzear de Beauce, Quebec, CA) or elevated on1 x 4 inch treated lumber frames to inhibit root growth through underlain black woven ground cloth. Treatments were arranged as a randomized complete block, with 6 blocks per root pruning treatment and 13 reps (trays) per liner density per block. Trays were overhead irrigated with 0.20 in. nightly the first 2 months, then increased to 0.25 in. thereafter. Each tray received about 3 oz of a 350 ppm liquid fertilizer (20-10-20, Scotts Co., Marysville, OH) per liner and an broadcast application of Ornamental Herbicide II (Scotts Co.) within a week after transplanting. Polyon (18-6-12, Purcell Technologies, Sylacauga, AL) a 9 month fertilizer was also applied the first week. After 24 weeks, plants in 3 tray replicates per liner treatment per block were lifted to evaluate root knitting on 1 to 4 scale, with 1 being no root entanglement and 4 being a solid, root-knitted, harvestable slab. Plants were pruned by hand to promote branching 4 times and hand-weeded 8 times. Weeding and pruning were concurrent twice. Trays were sprayed once with glyphosate in October. All labor and materials for the plot was recorded. Analysis of the root knitting rating used ANOVA in SAS (SAS Inc, Cary, NC).

Results and Discussion: The 'Minima' cultivar is a well-known ground cover tolerant of full sun to shade conditions, and the post-emergent herbicide glyphosate (without surfactant) at rates of 0.33% active ingredient. Previous research found it to be tolerant of stacking on a pallet like turf (Beeson, unpubl. data).

There were no differences in the root knitting rating between the use of TexR liner or treated lumber. Both systems prevented root growth into the ground cloth below. However root growth beneath a tray was visibly less massive on the TexR liner than the treated lumber. Root knitting rating was significant (P<0.01) for the interaction of time after transplanting and number of liners per tray (Table 1). Trays with 2 liners never achieved sufficient root knitting to be considered harvestable within the time frame of the experiment. Statistically, knitting ratings were similar for both 3 and 4 liners per tray at both 30 and 36 weeks after transplanting. At 30 weeks, both 3 and 4 liners per tray had sufficient shoot growth. Based on experience in transporting and laying the slabs in the spring of 2004, ratings of 3.5 or higher would be commercially acceptable. Thus we conclude that commercially harvestable slabs could be produced in a 30 week growing season with 3 or 4 liners per tray.

Cost to produce the slabs included an accounting of all labor input, materials, irrigation and an average overhead cost of 20% of input cost (Haydu, pers. comm.). Using simple accounting, lumber treatments were \$0.07 per ft^2 cheaper than using the TexR fabric. Cost for 4 liners per tray was \$2.94/ ft^2 at 30 weeks and \$2.61/ ft^2 for 3 liners. The most expensive items were the liners (\$0.38 each), follow by labor (\$0.39/ft^2) and trays (\$0.32 each). Recycling trays, mechanical pruning and wider use of glyphosate would lower cost.

Table 1. Root knitting rating for each evaluation event for trays with 2, 3 or 4 asiatic jasmine liners per tray. Ratings ranged from 1 - root systems independent, to 4 - well-knitted and harvestable. Each mean represents 36 tray replicates.

Number of liners per tray	Weeks after transplanting		
	24	30	36
2	1.75 d [z]	2.55 cd	3.00 bc
3	2.29 cd	3.5 ab	3.68 ab
4	3.07 abc	3.79 ab	3.92 a

[z]Means with the same letters are not significantly different ($P>0.05$) based on F-Protected LSD.

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Application of Nickel Cures "Mouse-Ear" Disorder on River Birch

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Index Words: *Betula nigra* 'BNMTF' Dura-Heat, Mouse-ear, Nickel Deficiency

Significance to Industry: Foliar spray and substrate drench applications of nickel sulfate cured mouse ear symptoms on river birch plants growing in a pine bark substrate in #15 containers (1). Further work is needed to refine methods of application, rates of application, evaluate formulations of nickel, as well as timing of applications. Caution should be used when handling nickel as it can cause skin dermatitis and is recognized as a carcinogen. Efforts are under way to have nickel recognized as an essential element so fertilizer products can be developed.

Nature of Work: Mouse ear (leaf curl, little leaf, squirrel ear) has been a problem in container-grown river birch (*Betula nigra*) since the early to mid 1990's. I have been working on the problem since 1996 when it first showed up at a south Georgia nursery. Mouse ear has been noticed in several southeastern states as well as Minnesota, Ohio, Oregon, and Wisconsin. The problem has caused considerable economic impact in the southeast with some growers saying that they will never grow river birch again.

The disorder is easy to detect in nurseries as the plants appear stunted and may appear to have been "sheared" into their stunted form. The leaves are small, wrinkled, often darker green in color, commonly cupped, and have necrotic margins. Interveinal chlorosis is generally lacking in symptomatic leaves. New growth also has severely shortened internodes which gives a witches-broom appearance.

Plant pathogens and mites have been suggested as possible causes of mouse ear. Myself and other researchers have never detected any pathogens or mites which could be causing the problem. Non-detectable concentrations of sulfonyl-urea herbicides have even been suggested as the cause. I have seen problems on plants from tissue cultured liners to large containers. Health of the root system is important. The problem appears to be correlated with plants that have been in containers for too long and are rootbound. The problem occurs in plants grown using the pot-in-pot system. I first saw the problem when I tried controlling rooting-out of river birch with Lerio's moat pots. Every plant growing in the moat pots had mouse ear, the plants in the control pots did not have it. Water stress is also related to the problem. One very good grower I work with generally has the problem on his border rows near the road where the sprinklers do not provide enough overlap to adequately water the plants. This usually occurs later in the summer when the roots have filled the container. Containers on border rows are also exposed to increased solar radiation.

I have seen the problem on Dura-Heat, Heritage, and seedlings from several sources. The problem occurs on plants fertilized with controlled release fertilizers and plants receiving fertigation. Symptoms have been seen on plants with high and low soluble salt readings, high and low substrate pH, with or without healthy root systems, and early, mid, and late season. Plants may appear fine in the fall and have the problem when growth resumes in the spring. Strangely, some plants may only show the problem on one branch, or only certain plants in a block may show the problem. Symptoms may be uniform thru an entire block or appear randomly.

I have only encountered two cases of plants growing in the field where the problem occurred. Growers have noted symptoms on field grown plants in Oregon. Plants that are transplanted into the landscape generally grow out of the problem within one season. Plants growing in containers which root into native soil do not express the problem or grow out of the disorder. This leads me to believe there is an element in the native soil that we are not supplying via pine bark based substrates and highly refined fertilizers commonly in use today.

Mouse ear disorder on pecan (*Carya illinoinensis*) has been corrected by the application of nickel salts and has been associated with a deficiency of nickel at budbreak (2). A study was initiated on June 9, 2003 at a commercial nursery in south Georgia to determine if nickel sulfate would cure mouse ear on river birch. River birch (*Betula nigra* 'BNMTF') in their second growing season in #15 containers were selected for uniformity of size and mouse ear disorder. Plants were treated between 11am to 12 pm EST under partly cloudy skies with an air temperature of 90F. Treatments included a 1) control, 2) 789 ppm Ni spray, 3) 394 ppm Ni spray, 4) 0.005 lbs Ni/cu. yd. as a drench, 5) 26 g/pot triple superphosphate (0-46-0), and 6) 130 g/pot Milorganite (Milwaukee, WI). Both superphosphate and Milorganite contain nickel. Spray treatments were applied at ~100 gal/acre and included 4.0 lb/100 gal urea and 4.0 ml/gal SilEnergy surfactant (Brewer International, Vero Beach, FL). The drench treatment was applied with a volume of 500 ml/pot. Both triple superphosphate and Milorganite were applied to the surface of the substrate. Plants were arranged utilizing a completely randomized design with six single plant replicates.

Plants were rated for mouse ear (percentage of canopy showing mouse ear symptoms) and samples were collected 30 days after treatment. Five stems from each plant were cut back to the point where new growth had initiated in 2003. Stem length was recorded, then leaves from the five stems were removed, counted, and run thru a LI-COR 3000 (LI-Cor, Inc., Lincoln, NE) leaf area meter to determine leaf area for the composite sample. Leaves were dried for three days at 150F in a forced-air dryer and dry mass was determined. Specific leaf area was calculated as leaf area/leaf dry mass. Number of leaves per unit stem length was calculated as number of leaves/mean stem length.

Results and Discussion: Plants treated with sprays of nickel began to resume normal growth within one week of treatment. After 30 days, all plants treated with nickel sulfate had 100% normal growth, where as plants treated with superphosphate, Milorganite and the control still suffered from severe mouse ear. Plants treated with nickel had an 80 to 83% increase in leaf area, a 76 to

81% increase in leaf dry weight, a 53 to 60% increase in stem length, and a 16 to 21% increase in specific leaf area compared to the non-treated control plants. Number of leaves per unit stem length decreased up to 60% for plants treated with nickel, indicating that internode elongation increased. Superphosphate and Milorganite, which both contain small amounts of nickel, did not correct the problem on plants with severe mouse ear symptoms.

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Chlorophyll Fluorescence of Fir (*Abies* spp.) Seedlings in Response to pH

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Index Words: Conifers, Chlorosis, Liming, Christmas Trees

Significance to Industry: Increasing media pH significantly reduced F_v/F_m and needle chlorophyll concentration in all of the species tested. The effect of pH on photochemistry was due to depressed nutrient uptake of P, Mn, B, and Cu. Among the species examined, *A. veitchii* and *A. lasiocarpa* were most tolerant of increased pH based on F_v/F_m and needle chlorophyll concentration. Because photosynthetic quantum yield may be related to deficiencies of several elements affected by pH, F_v/F_m may serve as criteria to select for improved pH tolerance.

Nature of Work: Evergreen conifers are an important component of landscapes in the upper Midwest. Conifers fulfill an important design function by providing year-round color, form and texture in landscapes as well as providing cover for wildlife. However, horticulturists are recognizing that many of the principle conifers planted in the central United States are becoming overplanted and suffer from an increasing number of pest problems.

True firs (*Abies* spp.) include a number of species that may add diversity to the conifers available for landscape planting. However, in the upper Midwest, the use of true firs in landscapes is limited by their fairly exacting site requirements. In general, most *Abies* grow best on sites with good drainage, adequate moisture and low soil pH. For example, Fraser fir (*Abies fraseri*) is native to mountainous sites with extremely acid soils (2). In contrast, concolor fir (*A. concolor*) may grow on sites with considerably higher pH (6) indicating that *Abies* spp. vary in their pH tolerance. However, most information on the pH tolerance of firs is based on observational studies of soils in forest stands.

Increasing soil pH may induce chlorosis in plants due to reduced uptake of one or more nutrients particularly phosphorus, manganese, boron, and copper (7). All of these nutrients are involved, either directly or indirectly, in photosynthetic processes. Therefore, understanding the effect of increasing soil pH on photosynthetic function may provide an opportunity for identifying species or genotypes that are adapted to relatively alkaline conditions. The efficiency with which photosystem II captures light energy may be rapidly and non-destructively estimated as the ratio of variable to maximal chlorophyll fluorescence (F_v/F_m) (3). Because the function of the photosynthetic system is related to foliar nutrition, variable chlorophyll fluorescence may provide a rapid means to identify physiological response of plants to nutrient imbalances (8).

The objectives of this study were to: 1) compare the response of five diverse species of true firs (*Abies* spp.) to varying soil pH and 2) determine the utility of chlorophyll fluorescence as a tool to quantify this response. Seedlings of sub-alpine fir (*Abies lasiocarpa*), Veitch fir (*A. veitchii*), Sakhalin fir (*A. sachalinensis*), Siberian fir (*Abies sibirica*), and Macedonian Fir (*A. borisii regis*) were grown in 8 liter containers filled with a mixture of sphagnum moss and perlite (3:1, v:v) in the Plant Science Greenhouses at Michigan State University. Soil media pH was modified using liquid flowable dolomitic limestone resulting in five pH levels (3.4, 4.0, 5.4, 6.0, and 6.8). After 30 weeks exposure to the pH treatments, dark-adapted variable chlorophyll fluorescence (F_v) and maximum chlorophyll fluorescence (F_m) were measured on newly formed randomly selected needles using a portable chlorophyll fluorescence system (Plant Efficiency Analyzer, Hansatech Instruments Limited, Norfolk, England). The ratio of variable fluorescence (F_v) to Fm was then calculated. After determining F_v/F_m, foliage from each seedling was collected to determine chlorophyll content (4).

The experiment was a completely randomized design and the effect of dolomitic lime treatment on media pH was determined by repeated measures analysis of variance based on 26 periodic measurements during the study. Species and pH treatment effects on F_v/F_m and needle chlorophyll concentration were determined by analysis of variance using a fixed effects model.

Results and Discussion: Photosynthetic quantum efficiency, as indicated by variable chlorophyll fluorescence (F_v/F_m), declined with increasing pH, especially at the highest pH level (Fig. 1, Table 1). Analysis of covariance indicated a significant ($P = 0.05$) interaction between species and pH. At the highest pH level, F_v/F_m of *A. lasiocarpa* was significantly higher than *A. borisii regis*. A Bonferoni-adjusted comparison among coefficients indicated a significant difference in F_v/F_m response to pH between *A. veitchii* and *A. borisii regis*. Also, needle chlorophyll concentration decreased with increasing pH (4). This effect reflected visible chlorosis symptoms, which were evident in seedlings at 1:50 lime:water ratio and higher pH treatments.

Lime treatment and lime x species interaction effects on seedling height growth were not significant ($P>0.1$). However, species varied significantly in height growth (Table 1). *Abies sachalinensis* grew more than all the other species except *A. sibirica*. Foliar concentration of several nutrients differed among treatments and species (Table 1). Nutrient concentrations were generally lower in *A. borisii regis* relative to the other species. Foliar concentrations of N, P, Mn, B, and Cu declined in response to increasing pH. Foliar Mg and Ca increased with pH, due to increased availability of these ions with the dolomitic limestone treatment. Foliar Fe, S, Zn, and K were not significantly affected by lime treatment. Chlorophyll concentration and F_v/F_m were highly correlated ($r = 0.72$, $P<0.001$)(4). Correlation analyses suggest that photochemical response of *Abies* to increased pH is related to depression of P, Mn, and Cu uptake (4).

The results of this study indicate that the photochemistry of seedlings of *A. lasiocarpa* and *A. veitchii* is more tolerant of increasing soil alkalinity than the other species tested. Since these species have evolved in distant regions of the world, they likely have adapted to varying edaphic conditions. Although we have no specific information on the soils from which these species were selected, other *Abies* species occur on diverse soils and differ in pH tolerance. Among North American *Abies* species, optimum pH varies widely. Fraser fir and Pacific silver fir grow on strongly acid soils (pH 3.3 to 4.2) (2). Balsam fir grows under a wide range of soil pH conditions and achieves its best growth on soils with pH between 6.5 and 7.0 (5). *Abies lasiocarpa*, which was relatively insensitive to increasing pH in this study, has an extensive native range and occurs across a range of soil pH levels from 4.5 to 5.9 (1).

Increasing chlorosis and reduced photosynthetic activity in firs in response to pH is attributed to reduced uptake of several key elements, particularly Mn, P, B, and Cu. This nutritional response closely follows the classic pattern for organic soils depicted by Lucas and Davis (7). Their graphic representation of nutrient availability indicates that B, P, Zn, and Cu are severely reduced as pH increases above 6 and that Mn availability declines sharply at pH higher than 5.5. All of these nutrient elements affected by pH are involved with photosynthetic processes and may be associated with the decreases observed in F_v/F_m and/or chlorophyll content. Variable chlorophyll fluorescence appears to provide a rapid and effective mechanism to identify pH tolerance among *Abies* species.

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Table 1. Variable chlorophyll fluorescence, chlorophyll content, height growth, and foliar nutrition of seedlings of five *Abies* species grown in peat:perlite under varying levels of flowable dolomitic limestone.

Species[1]	F_v/F_m	Chl a+b ($mg\ cm^{-2}$)	Height growth (cm)	N ($g\ kg^{-1}$)	P ($g\ kg^{-1}$)	K ($g\ kg^{-1}$)	Mg ($g\ kg^{-1}$)	Ca ($g\ kg^{-1}$)	S ($g\ kg^{-1}$)	Mn ($mg\ kg^{-1}$)	Fe ($mg\ kg^{-1}$)	Zn ($mg\ kg^{-1}$)	B ($mg\ kg^{-1}$)	Cu ($mg\ kg^{-1}$)
A. borisii regis	0.73ab[†]	0.95a	1.56a	28.9a	2.3a	19.9a	1.9a	3.9a	2.0a	224a	74a	43.0a	18.6a	5.2a
A. lasiocarpa	0.77a	1.76b	0.90a	32.5ab	2.7ab	17.7a	2.2ab	4.4ab	2.5ab	499a	105a	45.0a	21.6ab	4.8a
A. sachalinensis	0.75ab	0.93a	3.82c	37.8b	3.0b	25.0b	2.8b	6.4b	3.0b	320a	108a	46.0a	29.2bc	5.2a
A. sibirica	0.70b	1.16a	3.14bc	36.5ab	3.0b	24.4b	2.2ab	5.3ab	3.0b	420a	104a	59.8a	31.4c	4.8a
A. veitchii	0.74ab	1.21a	1.87ab	34.5ab	2.9b	21.3ab	2.4ab	4.4ab	2.5ab	390a	88a	41.2a	20.4ab	4.4a

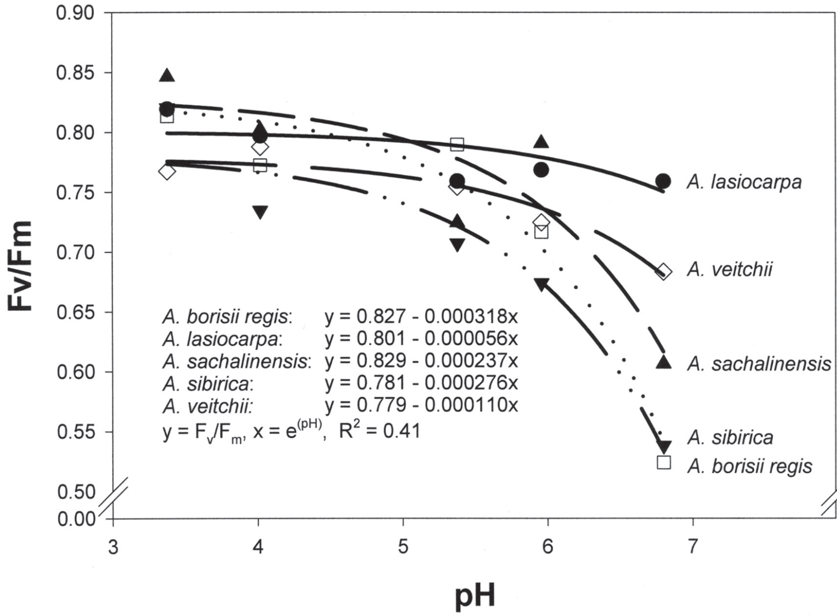
Treatment[2] (lime:water)	F_v/F_m	Chl a+b ($mg\ cm^{-2}$)	Height growth (cm)	N ($g\ kg^{-1}$)	P ($g\ kg^{-1}$)	K ($g\ kg^{-1}$)	Mg ($g\ kg^{-1}$)	Ca ($g\ kg^{-1}$)	S ($g\ kg^{-1}$)	Mn ($mg\ kg^{-1}$)	Fe ($mg\ kg^{-1}$)	Zn ($mg\ kg^{-1}$)	B ($mg\ kg^{-1}$)	Cu ($mg\ kg^{-1}$)
Control	0.81x	1.65x	2.25x	39.9x	3.1xy	20.5x	1.8x	3.6x	2.8x	449xy	100x	43.0x	28.2xy	5.6xy
1:100	0.77xy	1.39xy	2.38x	40.9x	3.4x	23.3x	2.2xy	4.1x	2.9x	528x	104x	50.2x	32.2x	6.8x
1:50	0.74xy	1.15y	2.07x	30.7y	2.6xy	22.7x	2.5xy	5.2xy	2.5x	342xy	98x	51.4x	21.6yz	4.4xy
1:20	0.73y	1.10y	2.27x	28.0y	2.5z	20.8x	2.3xy	4.6x	2.3xy	183y	89x	38.4x	15.6z	4.2xy
1:10	0.62z	0.62z	2.43x	30.8y	2.4z	21.1x	2.7y	6.9y	2.5x	351xy	88x	52.0x	23.6xyz	3.4y

[†] Mean separation within each variable by Tukey's Studentized Range test, $P \leq 0.05$.

[1] Species means averaged across treatments.

[2] Treatment means averaged across species.

Figure 1. Relationship between variable chlorophyll fluorescence and soil media pH of seedlings from five *Abies* species.



Use of Air-Root-Pruning Containers in Pot-in-Pot Systems

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Index Words: ARP, Girdling Roots, Modified Containers, PIP, Root circling

Significance to Industry: The results of this trial suggest that RootMaker Root Trappers will work in a pot-in-pot production system to achieve air root pruning or root modification. However, further research needs to be conducted with controlled water applications in order to optimize plant growth for each container treatment, and to determine ease of production and cost considerations for modified containers.

Nature of Work: The pot-in-pot (PIP) system is a popular production method used by commercial nurseries. With PIP, a planted container is placed into a holder or socket pot that has been permanently placed in the ground, or placed on the surface and bermed around for insulation (2). The PIP system has many benefits. It reduces container-grown plant blow over, allows for proper plant spacing, keeps plant roots cooler in summer heat, helps plants over winter more readily without supplement protection, and can be used with drip irrigation to help conserve water (3).

Root circling has been determined to cause long term damage to tree roots and trunks well after trees have been planted into the landscape (1). Air-root-pruning (ARP), accomplished by using containers with holes in the container wall, or containers made of synthetic fabrics, have been demonstrated to minimize root circling by modifying or killing root tips (4). However, most specialty ARP containers are manufactured for above ground production, while an increasing number of large container-grown trees produced in Virginia are grown in PIP systems. The purpose of this research was to determine if ARP containers could be used effectively for root modification in a PIP system.

In June 2003, uniform *Quercus phellos* (willow oak) and *Quercus rubra* (red oak) seedlings were potted into seven different 3-gallon containers using a 3:1 (v:v) course pine bark to sand substrate amended per yd^3 with 4 lb Harrell's CRF 18-4-8, 4 lb lime, and 2.5 lb Micromax. The seven container treatments were: Nursery Supplies Grip Lip 2000 (plastic – no holes - control), RootMaker (plastic), Accelerator (plastic), RootMaker Root Trapper (fabric), Root Control Smart Pot (fabric), Terra-Cell ARPACC (plastic), and Texel Tex-R Agroliner (fabric). Due to available seedlings, willow oak treatments were replicated 20 times and the red oak treatments eight times in a randomized complete block design. All potted trees were installed in a drip-irrigated PIP site of Lancaster Farms, Suffolk, VA, and received 0.66 gal/day. Trees were harvested in November 2003, and shoot and root dry weight data subjected to statistical analysis.

Results and Discussion: There were no significant differences in root or shoot dry weights for red oaks regardless of container treatment, and therefore no data is presented. Willow oak shoot and root dry weights were affected by the ARP containers. Trees grown in RootMaker Root Trappers had statistically significant higher root and shoot dry weights than the ARPACC containers. All other treatments were not significantly different (Table 1).

Low root and shoot dry weights for the willow oaks grown in ARPACC containers may have been a result of faster substrate drying due to the large side and bottom holes in the ARPACC. The ARPACC container walls had more open space than any other container, and therefore potentially less than adequate water reserves for plant growth.

The opposite was true for RootMaker Root Trappers. Those fabric (polypropylene) containers have solid sides and bottoms and only allow water to drain from the sewn seams. Substrate in these containers probably held more water, resulting in higher root and shoot weights. Though the Root Control Smart Pots and the Texel Tex-R Agroliners are fabric containers similar to the RootMaker Root Trappers, those containers are constructed in such a way that they drained faster than the Root Trappers. Substrate water holding capacity needs to be determined for all of these containers to further investigate these preliminary results.

Table 1. Root and shoot dry weights for willow oak.

Container	Root dry weight (g)	Shoot dry weight (g)
RootMaker Root Trapper	74.0 a^{z}	60.6 a^{y}
Nursery Supplies Grip Lip	68.2 ab	51.2 ab
RootMaker	66.2 ab	50.2 ab
Accelerator	65.4 ab	41.8 ab
Texel Tex-R Agroliner	56.8 ab	43.6 ab
Root Contro Smart Pot	49.2 ab	42.0 ab
Terra-Cell ARPACC	38.6 b	23.8 b

^{z}Mean separation within columns by Tukey's multiple comparison, $P \leq 0.05$.

^{y}Mean separation within columns by Tukey's multiple comparison, $P \leq 0.10$.

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Rate of Phosphorus Application Influences Growth of Four Ornamental Species

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Index Words: fertigation, *Ilex cornuta* 'Dwarf Burford', *Juniperus chinensis* 'Nick's Compact', Liquid Feed, *Loropetalum chinense* var. *rubrum* 'Blush', *Rhododendron* 'Tradition'

Significance to Industry: As there were no interactions between taxa and P rate, this indicates that all four species responded similarly to changes in rate of P application. Differences in plant growth parameters by taxa were expected since some species like 'Blush' loropetalum are going to be faster growing than a compact plant like 'Tradition' rhododendron. Likewise, one would expect width growth of 'Nick's Compact' juniper to be greater than height. Differences in plant width due to late season growth was particularly evident on 'Nick's Compact' and 'Dwarf Burford' holly as P rate increased. On 'Dwarf Burford', approximately half of the plants in each treatment had flushed again at the 26 September harvest date, but only plants in the 15 mg L-1 P treatment showed any substantial shoot elongation. At the high P rate this extra shoot elongation may very well need to be pruned off for the plant to keep its shape. Growth of 'Blush', 'Nick's Compact', and 'Tradition' was more uniform at 10 mg L^{-1} P than at 15 mg L^{-1} P. All four species had fewer "long shoots" which would normally be pruned off when grown at the 10 mg L^{-1} P rate. Plant growth was insufficient at 5 mg L^{-1} P. Compared to 15 mg L^{-1} P, shoot dry mass for all four taxa at 5 mg L^{-1} P decreased 20%, 9%, 14%, and 17%, respectively. Based on this study, P rates could be reduced 33% from 15 mg L^{-1} P to 10 mg L^{-1} P without significantly affecting plant growth of the species tested.

Nature of Work: Phosphorus is the primary limiting nutrient in aquatic systems. While phosphorus runoff from agronomic and animal sources has received considerable attention, phosphorus runoff from container nurseries has received little attention. Some states have implemented the need for nutrient management plans for nurseries due to concerns over nitrogen and phosphorus runoff from nurseries. Many growers still utilize liquid feed systems (fertigation) due to uniformity of application, ability to apply known concentrations of nutrients, ability to control EC levels, and labor saving aspects. However, the environmental impacts from fertigation can be undesirable due to poor application efficiencies and eutrophication of surrounding bodies of water. An informal survey of the nursery industry in the southeastern United States indicated that P levels in liquid feed systems ranged from 15 to 40 ppm. Due to environmental concerns, a study was initiated to determine if P levels could be reduced without influencing plant growth and quality.

On 6 April, 2001, liners of the following plants: *Ilex cornuta* 'Dwarf Burford', *Juniperus chinensis* 'Nick's Compact', *Loropetalum chinense* var. *rubrum* 'Blush', and *Rhododendron* 'Tradition' were repotted into 2.8 L (#1) containers.

The substrate consisted of an 9 aged pine bark : 1 #6B gravel mix (by volume) amended with the following per cubic meter of substrate: dolomitic limestone (1907 g), urea formaldehyde (38.0N-0.0P-0.0K, 1200 g), ferrous sulfate (272 g), copper sulfate (8.2 g), zinc sulfate (13.6 g), manganese sulfate (35.4 g), sodium borate (2.7 g), sodium molybdate (0.27 g), and 1300 g of Talstar nursery granular insecticide (FMC Corporation, Philadelphia, PA). All plants were pruned to a height of 12 cm (4 in) on 26 April, 2001. Plants were grown outdoors in full sun at a 15 cm (6 in) spacing between pots on top of black woven ground cloth. Overhead irrigation was applied daily as needed at 0700 hr. Irrigation volume was 1.0 cm (0.4 in) per irrigation event, applied at a rate of 1.39 cm/hr (0.55 in/hr) with a coefficient of uniformity of 92%.

Treatments were initiated on 1 May 2001 and consisted of phosphorus (P) applied at 15, 10, and 5 mg L^{-1} (ppm). Phosphorus was supplied from fertilizer solution grade ammonium polyphosphate (11.0N-16.3P-0.0K, PCS Nitrogen Fertilizer, L.P., Memphis, TN). Nitrogen, potassium and iron were supplied at the constant rate of 100 mg N L^{-1} using a 12.0N-0.0P-6.6K + 0.03% Fe liquid fertilizer (Big Bend Supply Inc., Cairo, GA). The nitrogen source was 5.98% nitrate-N and 6.02% ammoniacal-N. Fertilizer was injected using a Dosatron Model DI 16 (Dosatron International Inc., Clearwater, FL). The pH and electrical conductivity (EC) of the three P rate fertilizer solutions ranged from 7.0 to 7.4 and 1.15 to 1.07 dS/m, respectively.

After final growth measurements were made on 25 September, 2001, plants were harvested for dry mass determination. Plants were separated into shoots and roots (except for Rhododendron) and the roots were shaken free of substrate. Shoots and roots were dried to a constant dry mass in a forced-air oven at 80C (175F). After separation, foliage was ground in a Wiley mill to pass a 20-mesh sieve. Tissue nitrogen (N) was analyzed using the Kjehdahl method. Tissue P, K, Ca, Mg, Cu, Fe, Mn, and Zn were analyzed with a microwave digestion method (1). Phosphorus was determined using a molybdovandate colorimetric method whereas the other elements were measured using a Perkin Elmer Aanalyst 300 Atomic Absorbance spectrophotometer (Perkin Elmer, Inc., Norwalk, Conn.). Plant width was calculated as (width 1 + width 2)/2. Biomass was calculated shoot dry mass + root dry mass. Root:shoot ratio was calculated as root dry mass/shoot dry mass. Canopy density was calculated as shoot dry mass/ (height + plant width/2).

Data for the experiment were subjected to analysis of variance using PROC GLM (SAS version 8.0 for Windows, Cary, NC). The experimental design was a split-plot, with P rate as the main plot and taxa as the subplot, and 10 single plant replicates. Data were evaluated using the Waller-Duncan K-ratio t-test or linear and quadratic regression, where appropriate.

Results and Discussion: Final plant height across species was not influenced by P rate, while plant width decreased linearly as rate of P decreased. Shoot dry mass was greatest for Nick's Compact' juniper and least for 'Tradition' rhododendron. Root dry mass was greatest for 'Dwarf Burford' holly and least for 'Blush' loropetalum. Root dry mass could not be determined for 'Tradition' rhododendron due to the fibrous nature of its root system which could not be separated from the substrate. Total plant mass was greatest for ‘Dwarf Burford’ and ‘Nick’s Compact’ and least for ‘Blush’. With intermediate shoot dry mass and high root dry mass, ‘Dwarf Burford’ had the greatest root:shoot ratio among the three species. Canopy density was greatest for ‘Dwarf Burford’ and ‘Nick’s Compact’ and least for ‘Blush’ loropetalum. The low canopy density of ‘Blush’ can be attributed to its increased height and width in conjunction with intermediate shoot dry mass relative to the other species. Shoot dry mass and total plant mass showed a curvilinear response to P rate with optimal growth occurring at 10 mg P L^{-1}. Rate of P application had no influence on root dry mass, root:shoot ratio or final canopy density.

Tissue N was influenced by taxa and P rate. In general, foliar N decreased as rate of P decreased. All other elements were influenced by a taxa x P rate interaction. Phosphorus in the tissue ranged from a low of 0.18% for ‘Blush’ at the medium rate of application to 0.35% for ‘Nick’s Compact’ at the high rate of P. Foliar potassium was usually greatest at the low rate of P application. Calcium decreased as P rate decreased. ‘Nick’s Compact’ juniper had the highest concentration of magnesium, followed by ‘Dwarf Burford’ holly. Manganese and zinc were higher in ‘Dwarf Burford’ than in the other species. Foliar copper ranged from 0.7 ppm to 10.0 ppm, while iron ranged from a low of 99.3 ppm in ‘Blush’ to a high of 205.0 ppm in ‘Tradition’ rhododendron at the highest rate of P application.

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Pruning Effects on Nursery Crop Production

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Index Words: Soft-pruning, Hard-pruning, Pruning frequency

Significance to Industry: Our research shows that species respond differently to pruning severity and frequency. Compared to infrequent, hard pruning the soft pruning produced a higher quality rating in three of six species. Only with *Cephalotaxus* was both size and quality similar for the two pruning treatments. While the time required for frequent soft pruning of plants is greater, a shortened production cycle may more than offset the increased labor cost.

Nature of Work: Most nursery crops require pruning once or more during container production to produce marketable plants. Pruning can improve marketable quality of nursery stock through the promotion of a uniform shape and compact growth habit. Typical pruning practices are to prune infrequently into hardened-off wood, removing about 30% of the canopy. Pruning into hardened wood results in a delay in regrowth of 2 1⁄2 weeks or more when plants would normally be actively growing, which increases production time (1). An alternative approach being practiced by Fairview Evergreen Nurseries in Fairview, PA is to begin pruning early and frequently, removing only soft tissue. The nursery produced 11.4 L (# 3) *Ilex verticillata* in four months using this method. The shrubs were cut back to 30 cm (12 in.) and, beginning in June, were pruned every 10-14 days when there was 7.5 cm (3 in.) of new growth. Pruning involved pinching new growth back to 2.5 cm (1 in.), yet never cutting back into hardened off tissue. Latent buds broke and began aggressively growing in less than one week (1). Pruning early and frequently may eliminate the need to prune many species later, and create a fuller, more marketable plant in less time. Shortened production time equates to a more rapid crop turnover and the potential for increased revenue. Our objective was to compare frequent soft pruning to less frequent hard pruning in the production of several deciduous and evergreen shrubs.

The study evaluated six species and cultivars of container-grown nursery crops: Gardenia jasminoides 'August Beauty', *Gardenia jasminoides* 'Radicans', *Cephalotaxus harringtonia* 'Prostrata', *Itea virginiana* 'Henry's Garnet', *Illicium anisatum*, and *Rhododendron* 'Cavendish'. All plants were in 3.4 L, 7.6 L, or 11.4 L (#1, 2, or 3) pots containing a 7:1 pinebark:sand substrate by volume amended per m^3 (yd^3) with 8.3 kg (14 lb) of 17N-2.2P-9.13K (PolyOn 17-5-11, Pursell Industries, Sylacauga, AL), 0.9 kg (1.5 lb) Micromax (The Scotts Company, Marysville, OH) and 3 kg (5 lb) dolomitic limestone. Plants were spaced in full sun or under 47% shade and irrigated daily. All plants were hard-pruned about 50% on March 24, 2003. Treatments included an unpruned control, hard pruning, and frequent soft prunings replicated with ten plants per treatment and placed in a completely randomized design within species. Soft pruning was performed by removing about 1/3 of the soft new growth, when new shoots were about 7.5 cm (3 in.) long. The soft pruning treatment was performed as needed beginning on April 25 and continuing until August 6, 2003. On August 7, 2003, the hard pruning treatment was applied by removing about 30% of the canopy. A growth index [(height + width 90° to first width) / 3] was determined in September 2003 and a quality rating based on compaction, fullness, and plant size relative to container size was made in February 2004. Treatments were compared using the Waller-Duncan K-ratio T-test, *P=0.05*.

Results and Discussion: Soft pruning 'August Beauty' gardenia produced plants 56% larger than hard pruning, and similar in size to the control (Table 1). The quality rating for the soft-pruned 'August Beauty' gardenia was 59% greater than that of hard-pruned plants. The dwarf gardenia control was 23% and 41% larger than plants in the hard and soft-pruned treatments, respectively. The quality rating of dwarf gardenia was 26% greater than that of hard-pruned plants and 63% greater than that of the control. Soft-pruned 'Henry's Garnet' sweetspire was 28% smaller than controls but 35% larger than hard-pruned plants, while quality rating was 35% and 14% higher, respectively. Soft and hard pruned 'Cavendish' azaleas were 15% smaller than the controls (Table 2). However, the quality of soft-pruned plants was 26% higher than that of the controls and 83% higher than that of the hard-pruned plants. Soft-pruned prostrate plum yews were 46% smaller than the controls and similar in size to the hard-pruned plants. The quality rating for the soft-pruned and hard-pruned yews were similar but 102% higher than that of the controls. Soft-pruned anise was 22% smaller than the controls, but 43% larger than hard-pruned anise. Quality rating for the soft-pruned plants was 38% higher than that of the controls and hard-pruned plants.

Pruning severity and frequency affected growth and quality of all species tested, however response varied with species. Unpruned controls of five of six species in the study were larger than the hard or soft pruned plants, and three of six hard pruned plants were the smallest. Quality ratings of four out of six soft-pruned species were higher than that of hard pruned plants and similar for the other two species. With no species was quality rating higher than that of plants receiving soft pruning.

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Table 1. Growth and quality of *Gardenia jasminoides* 'August Beauty', *Gardenia jasminoides* 'Radicans', and *Itea virginiana* 'Henry's Garnet' in response to pruning severity and frequency.

	Gardenia jasminoides 'August Beauty'		*Gardenia jasminoides* 'Radicans'		*Itea virginiana* 'Henry's Garnet'	
Pruning Treatment	GI[z]	Quality[y] Rating	GI	Quality Rating	GI	Quality Rating
Control	62.8a[x]	4.3a	48.1a	2.4c	83.9a	3.1b
Hard Prune	38.7b	2.9b	38.9b	3.1b	48.9c	3.7ab
Soft Prune	60.5a	4.6a	34.1b	3.9a	65.8b	4.2a

[z]Growth Index = (height + width 90° to first width) / 3, taken in September 2003.

[y]Quality rating taken in February 2004 and based on compaction, fullness, and plant size relative to container size; ratings ≥3 indicate marketable plants.

[x]Mean separation by Waller-Duncan K-ratio T-test, P=0.05.

Table 2. Growth and quality of *Rhododendron* 'Cavendish', *Cephalotaxus harringtonia* 'Prostrata', and *Illicium anisatum* in response to pruning severity and frequency.

	Rhododendron 'Cavendish'		*Cephalotaxus harringtonia* 'Prostrata'		*Illicium anisatum*	
Pruning Treatment	GI[z]	Quality[y] Rating	GI	Quality Rating	GI	Quality Rating
Control	44.4a[x]	3.5b	51.8a	2.1b	52.0a	2.7b
Hard Prune	38.6b	2.4c	31.6b	4.2a	29.7c	2.8b
Soft Prune	38.5b	4.4a	35.6b	4.3a	42.5b	3.8a

[z]Growth Index = (height + width 90° to first width) / 3, taken in September 2003.

[y]Quality rating taken in February 2004 and based on compaction, fullness, and plant size relative to container size; ratings ≥3 indicate marketable plants.

[x]Mean separation by Waller-Duncan K-ratio T-test, P=0.05.

How Do Micronutrient Sulfates Increase Pin Oak Seedling Growth?

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Index Words: *Quercus palustris* (Münchh), Chelate, Pine Bark, pH, Micromax

Significance to Industry: This work further confirms the benefits of adding micronutrient sulfates to container substrates for growing shade tree seedlings. The increase in growth was primarily due to the additions of sulfur and not micronutrients. Treatments such as sulfuric acid that supplied sulfur without micronutrients resulted in plant growth comparable to Micromax, the latter of which supplied both micronutrients and sulfur. There may be conditions though, high pH for example, where micronutrient additions are necessary due to reduced availability of micronutrients. In such cases, the addition of micronutrient sulfate products like Micromax would be advisable.

Nature of Work: Substrates of container-grown plants are commonly pre-plant amended with micronutrient sulfates with the intention of increasing the supply of micronutrients to the plant. Wright et al. (3) showed that seedling growth of nine container-grown tree species in pine bark was positively affected by the addition of Micromax (Scotts-Sierra, Marysville, Ohio). However, Kelk (2) found that the growth of *Quercus palustris* (Münchh) was increased to the same degree as Micromax by amending pine bark with only one micronutrient sulfate, either Fe_2SO_4, $CuSO_4$, $MnSO_4$, or $ZnSO_4$. This raises the question of whether micronutrients are the cause for increased growth at all. Both Wright et al. (4) and Kelk (2) found that pre-plant amending pine bark with micronutrient sulfates decreased substrate pH by approximately 0.5 units. This is most likely due to the release of H^+ during the hydrolysis of the metallic micronutrient cations (1). Thus, the possibility exists that the positive growth response of *Quercus palustris* to Micromax addition may be due, to either: 1) the acidification of the substrate, 2) the addition of micronutrients, or 3) the addition of sulfur. The objective of this work was to determine which of these factors or combination of factors improves growth of container-grown *Quercus palustris* in a pine bark substrate.

This study was conducted in a glass house in Blacksburg, Virginia using milled pine bark (PB) (*Pinus taeda*) (pH of 4.5), in plastic 2.8 liter (trade 1 gal) containers. On September 9, 2003 three 2.54 cm (1 in) tall *Quercus palustris* (Sheffield's Seed Company, Inc., Locke, NY) seedlings were transplanted into each container. Irrigation frequency was based on plant need for water by lifting containers and assessing container weight. Each container was supplied with 250-mL (8.5 oz) of fertilizer solution of 300 ppm N (NH_4NO_3), 45 ppm P (H_3PO_4), and 250 ppm K (KCl) as needed to maintain an electrical conductivity reading of 1-1.5 dS/m. Treatments included the above fertilizer in addition to the following: 1) unamended PB, 2) PB pre-plant amended per cu/m (cu/yd) with 0.9 kg (1.5 lbs.) Micromax, 3) K_2SO_4 (instead of KCl) supplying 248 ppm K and 100 ppm S, 4) H_2SO_4 supplying 100 ppm S added as needed to reduce container substrate solution pH equal to Micromax, 5) HCl solution as needed to reduce container substrate solution pH equal to Micromax, and 6) Peters Professional Compound 111 micronutrient chelate solution at a rate of 1 ppm Fe, 0.16 ppm B, 0.076 ppm Cu, 0.052 ppm Zn, 0.016 ppm Mo, and 0.52 ppm Mn. Substrate solutions were periodically extracted from containers using the pour-through (PT) method (5) and pH's were determined to gauge the frequency of H_2SO_4 and HCl application. Solutions were extracted on October 1, 2003 and analyzed for S via inductively coupled plasma analysis. On November 7, 2003 plant stems were severed at the soil surface. Shoots were dried for approximately three days at 65 C (149 F) and dry weights were determined. The experimental design was completely randomized with four single container replications per treatment. All data were analyzed using PROC GLM (SAS Institute, Cary, NC) and means separated using Duncan's multiple range test at $P<0.05$ level of probability.

Results and Discussion: Micromax and H_2SO_4 treatments resulted in the largest plants, followed by K_2SO_4 (Fig. 1). These treatments resulted in higher sulfur concentrations in substrate solution than other treatments (Fig. 2). The reason why the K_2SO_4 treatment had less growth than Micromax or H_2SO_4 is unknown. Hydrochloric acid supplied the same amount of acidity as H_2SO_4, but had no influence on growth, ruling out a lowering of pH as a reason for growth increases by micronutrient sulfate additions. Of the treatments that supplied micronutrients, (Micromax and chelate), only Micromax had a significantly higher dry weight than control. These data show that the addition of micronutrients under conditions of this experiment have little influence on growth, but demonstrate the importance of supplying S to shade tree seedlings for vigorous growth. This study also demonstrates the importance of S in a well-balanced nutritional program for nursery crops.

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Fig. 1. Mean dry weights of *Quercus palustris* seedlings as affected by various treatments. Treatments with the same letters are not significantly different.

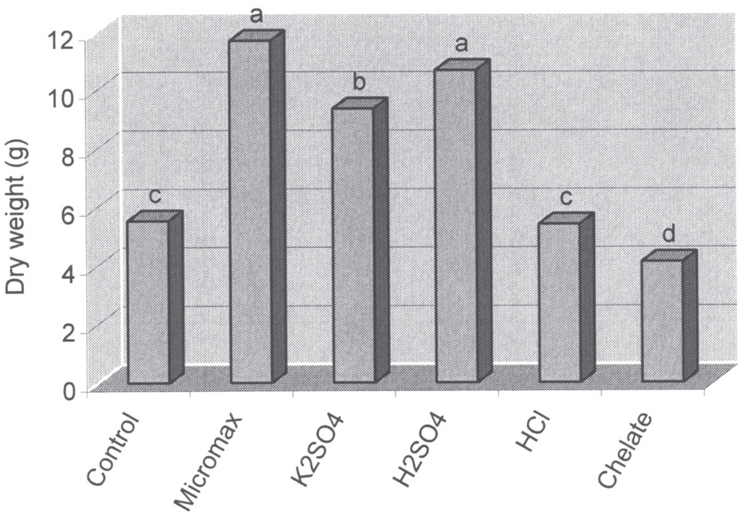
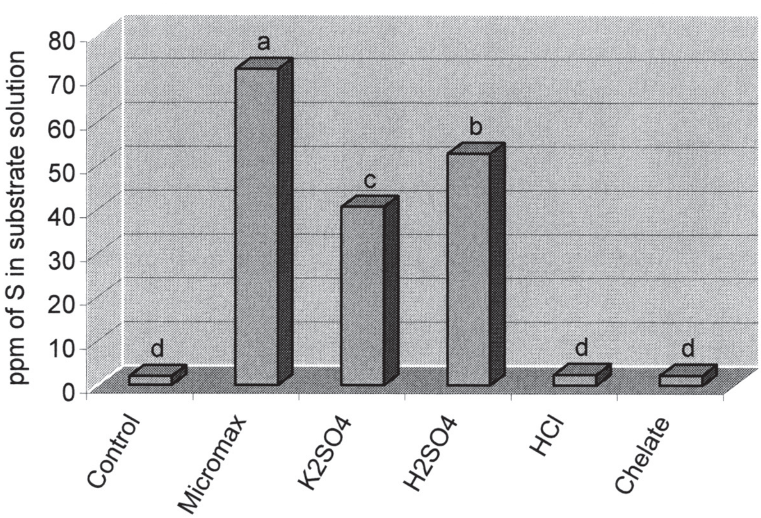


Fig. 2. Sulfur levels in substrate solution of *Quercus palustris* seedlings as affected by various treatments. Treatments with the same letters are not significantly different.



How Do You Manage Aged Versus Fresh Pine Bark?

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Index Words: Irrigation Volume, Nitrogen, Chemical Properties, Physical Properties

Significance to Industry: 'Skogholm' cotoneaster grown in fresh pine bark was significantly smaller than cotoneaster grown in aged pine bark. The reduction in growth did not appear, however, to be due to a competition for N. Additional N did not increase plant growth in fresh bark. The reduction in growth in fresh bark may have been due to differences in container capacity and available water. Container capacity and available water in aged pine bark were significantly greater than fresh pine bark throughout the study. Growers using fresh pine bark do not need any additional fertilizer but may need to be very diligent in maintaining adequate water within the substrate. This may require applying less water more frequently.

Nature of Work: Pine bark is a common substrate for container-grown plant production in the southeastern United States. Research comparing fresh, aged or composted pine bark is limited. Research conducted in Australia by Handreck and Black (2) reported reduced plant growth with fresh bark due to competition for N. They reported that up to an additional 300 mg N/liter per week may be required to support adequate plant growth in fresh pine bark. Cobb and Keever (1), however, grew dwarf Japanese euonymus (*Euonymus japonica* Thunb. 'Microphylla') and Japanese holly (*Ilex Crenata* Thunb. 'Compacta') in fresh and aged (one year) pine bark with no detrimental effects from using fresh pine bark as a growing substrate. Pokorny (4) also supported the use of fresh pine bark when adequate N was supplied. Adequate N, however, was not defined.

Age of pine bark may also affect physical properties which could affect water availability. Laiche (3) reported lower plant quantity in plants grown in fresh pine bark compared to aged pine bark. He attributed the lower quality to difficulty in maintaining adequate moisture levels, especially during the first two to three months after transplanting.

Growers may need, however, to adjust their fertility and/or water regimes based on whether they are growing in fresh or aged pine bark. What adjustments should be made are currently unknown. The objective of this research was to determine the physical and chemical properties of fresh and aged bark and resultant plant growth.

A 2 x 3 factorial experiment in a randomized complete block design with three replications each containing five plants was conducted at the Horticulture Field Laboratory, North Carolina State University, Raleigh. The main factors consisted of fresh or aged pine bark substrates and three rates of a controlled release fertilizer (low, medium, and high). Rooted stem cuttings of *Cotoneaster dammeri* 'Skogholm' were potted May 8, 2003 into 14.2 liter (#5) containers in a pine bark : sand (8:1 by vol) substrate with either fresh or aged pine bark (aged for one year in an unprotected location) amended with 0.9 kg cu m (2 lbs cu yd) dolomitic limestone. Each plant was topdressed at potting with 11.1 g, 22.2 g, or 33.3 g N from a 17N-2.2P-8.2K controlled release fertilizer (17-5-10 with minors, 5 to 6 month, Pursell Technology, Sylacauga, AL). After 160 days, tops were removed and roots were placed over a screen and washed with a high pressure water stream to remove substrate. Shoots and roots were dried at 65 C (150 F) for 5 days and weighed.

Irrigation was applied via pressure compensated spray stakes {Acu-Spray Stick; Wade Mfg. Co., Fresno, CA [200 ml/min (0.3 in/min)]} at 12:00 pm, 3:00 pm, and 6:00 pm. Leachate fraction (leachate volume ÷ irrigation volume) was monitored weekly and irrigation volume was adjusted to maintain a 0.2 leaching fraction within each treatment and replication. Substrate solution samples were collected every three weeks via the pour through extraction method and electrical conductivity (EC) and pH were measured.

All physical property analyses were conducted at the Horticultural Substrates Laboratory N.C. State Univ. on five replicated samples using procedures described by Tyler et al. (5). Root : top ratio (R:S) was calculated as root dry weight ÷ top dry weight. All data were subjected to analysis of variance procedures (ANOVA). Treatments means were separated with Fisher's Protected least significant difference, $P = 0.05$.

Results and Discussion: Age of pine bark and rate of fertilization affected many of the measured parameters, however, age of pine bark X rate of fertilization interaction was not significant for any measured parameter (data not presented). Therefore, data is presented accordingly. Top dry weight and total plant dry weight of cotoneaster grown in aged pine bark were 12% larger than cotoneaster grown in fresh pine bark (Table 1). Root dry weight and root : top ratio were unaffected by age of bark. The reduction in growth in fresh pine bark may have been due to differences in physical properties. Container capacity and available water in aged pine bark were significantly greater than fresh pine bark throughout the study (Table 2). This was also reflected in the volume of irrigation water required to maintain a 0.2 LF in each bark (Fig. 1). With the increase in available water (AW), aged pine bark required greater volume of water. This difference in AW may have been what Laiche (1974) was referring to when he stated that it was difficult to maintain adequate water in fresh pine bark. Plant growth may have been limited by available water content in fresh pine bark.

The lowest rate of N produced significantly smaller tops and total plant dry weight than the medium and high rates of N. The high rate of N did not produce bigger plants compared to the medium rate of N. Thus, similar to the results reported by Cobb and Keever, (1984) plants grown in fresh pine bark did not appear to need additional N to maximize growth. This is in contrast to Handreck's (1992) work in Australia. This may be due to differences in pine bark. Bark in the southeastern United States is most often from loblolly pine

(*Pinus taeda*) and longleaf pine (*Pinus palustris*), whereas most bark in Australia is derived from radiata pine (*Pinus radiata*). On most sample dates, EC increased with increasing rate of fertilization, whereas EC was unaffected by age of bark (data not presented). Age of bark and rates of fertilization had little effect on substrate pH with the pH ranging between 6.1 and 6.4 throughout the study (data not presented).

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Table 1. Effect of age of bark and rate of fertilization on top, root, and total dry weight and root : top ratio.

Bark	Top (g)	Root (g)	Total (g)	Root : Top[z]
Aged	320 ay	55 a	375 a	0.17 a
Fresh	286 b	51 a	337 b	0.18 a
Fertilizer rate (g N/container)				
11.1	277 c	56 a	333 b	0.20 a
22.2	322 a	55 a	377 a	0.17 b
33.3	310 a	48 b	358 a	0.15 c

[z]Root : top ratio = root dry weight ÷ top dry weight

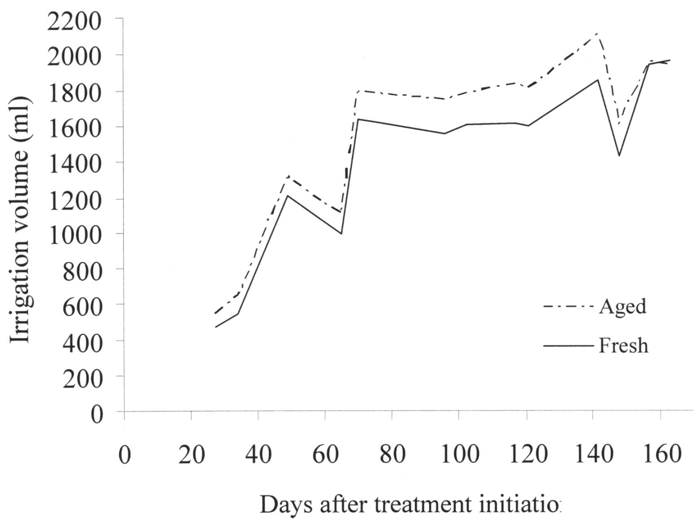
[y]Means within columns and treatments followed by the same letter are not significantly different as determined by Fisher's protected LSD, P = 0.05.

Table 2. Effect of age of bark on physical properties.

Bark	Total porosity (%)	Air space (%)	Container capacity (%)	Available water (%)	Unavailable water (%)	Bulk density (g/cm^3)
Prior to treatment initiation (pine bark substrate)						
Aged	87.3 a	25.2 b	61.1 a	26.3 a	35.8 b	0.19 a
Fresh	88.3 a	39.3 a	49.0 b	9.8 b	39.2 a	0.17 b
56 days after treatment initiation (8 pine bark : 1 sand substrate)						
Aged	82.8 b	25.9 b	56.9 a	22.7 a	34.3 a	0.32 a
Fresh	85.4 a	36.3 a	49.1 b	15.8 b	33.3 a	0.32 a
336 days after treatment initiation (8 pine bark : 1 sand substrate)						
Aged	74.9 b	17.0 b	57.9 a	30.0 a	27.9 b	0.35 a
Fresh	80.1 a	24.9 a	55.2 b	22.3 b	32.6 a	0.35 a

[z]Means within columns and weeks after treatment initiation followed by the same letter are not significantly different as determined by Fisher's protected LSD, P = 0.05.

Fig. 1. Effect of age of bark on irrigation volume required to maintain 0.2 leaching fraction.



Cotton Gin Compost as a Substrate Component in Container Production of Ornamental Plants

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Index Words: *Buxus, Nandina, Rhododendron*, Pine Bark Substitute, Organic Media

Significance to Industry: Growth of 'Winter Gem' boxwood and 'Atropurpurea Nana' nandina were higher in substrates containing higher ratios of CGC that when grown in PB:S only, while no differences in growth were observed for azalea. Additionally, root growth in substrates amended with CGC was similar to that occurring in PB:S suggesting that composted cotton gin by-products can provide a viable alternative substrate for production of containerized ornamental crops.

Nature of Work: Availability and cost of materials used as substrate blends for horticultural crop production are of frequent concern. Pine bark (PB) is one of the most widely used substrate components, yet the supply and cost of PB may be inconsistent or unpredictable (5). Alternative substrates for container production of ornamental plants are therefore important. Use of composted agricultural wastes as a replacement for PB is not a new concept, however, factors such as transportation costs, consistency and reproducibility of product, disease and insect infestation, and availability of composted materials represent concerns for growers (2).

Cotton is a major agronomic crop grown in the southeast United States. As a result of the cotton ginning process a large amount of by-product waste is generated. Cotton gin waste (CGW) is a term used to describe the byproducts of the cotton ginning process that includes leaves, stems, burrs, and some fiber (3). Composted cotton gin waste (CGC) has been shown to be a useful substrate component for production of bedding plants, poinsettias, and floral crops (4, 6). Further evaluation of the potential of this material for use as a substrate component for container production of woody ornamental plants is needed. The objective of this study was to evaluate the effect of substrates containing CGC on the growth of shoots and roots of three commonly produced woody ornamental cultivars.

Treatments were four substrate blends that included by volume 6:1 PB:Sand (S), 4.5:1.5:1 PB:CGC:S, 1:1:1 PB:CGC:S, and 1.5:4.5:1 PB:CGC:S. The percent CGC in each substrate was 0, 21, 33, and 64% respectively. The nursery standard 6:1 P:S substrate blend was used as the control substrate for comparison to CGC amended treatments. Substrates were amended with 8.2 kg•m^{-3} (13.9 lbs•yd^{-3}) Osmocote 18-2.6-9.8, (Scotts-Sierra Company, Marysville, OH), 0.9 kg•m^{-3} (1.5 lbs•yd^{-3}) Micromax™(Scotts-Sierra), and 3.0 kg•m^{-3} (5 lbs•yd^{-3}) dolomitic limestone. Initial pH's of amended substrates 6:0:1 PB:CGC:S, 4.5:1.5:1 PB:CGC:S, 1:1:1 PB:CGC:S, and 1.5:4.5:1 PB:CGC:S were 5.4, 5.5, 5.7, and 5.6 respectively. 'Winter Gem' boxwood (*Buxus microphylla* Sieb. & Zucc. 'Winter

Gem'); 'Atropurpurea Nana' heavenly bamboo (*Nandina domestica* Thunb. 'Atropurpurea Nana'); and 'Renee Mitchell' azalea (*Rhododendron indicum* L. & Sweet 'Renee Mitchell') were transplanted from 3.8 liter (1 gal) containers into 13.5 liter (3 gal) containers. Loose substrate particles were shaken off the roots, and roots were loosened before transplanting into the four substrate blends. At transplanting shoots of all plants were uniformly pruned to 20 cm (8 in.) above the substrate surface of each container. Plants were placed on an outdoor container pad in August 2003 under overhead irrigation at the Paterson Greenhouse Complex, Auburn University, in Auburn, AL. Plants were arranged in a randomized complete block design (RCBD) with four blocks and three single container replications per cultivar per treatment per block.

Initial growth indices (GI's) of each plant were determined at transplanting using the following formula: [(height + widest width + perpendicular width)/3]. A second GI was determined 74 days after the initial (DAI) evaluation and then every 40 days thereafter until the conclusion of the study in April 2004. At the end of the study, root development was evaluated visually using a rating scale of 0-5 (Table 1). All data were subjected to analysis of variance procedures and means were separated using protected least significant difference (LSD) at $P = 0.05$.

Results and Discussion: At experiment termination, GI of 'Winter Gem' boxwood and 'Atropurpurea Nana' nandina was higher when grown in substrates containing CGC than when grown without. These effects of container substrate on GI of 'Winter Gem' boxwood and 'Atropurpurea Nana' nandina were observed at the third and first measurements respectively (data not shown). Container substrate had no effect on GI for 'Renee Mitchell' azalea (Table 2). For all cultivars, substrate had no effect on visual root growth ratings (Table 2). Initial pH was higher in all substrates containing CGC as compared to the PB:S control. The higher GI data that were reported for 'Winter Gem' boxwood and 'Atropurpurea' nandina could be attributed to these plants preferring the higher pH levels present in the CGC amended substrates. Results herein are consistent with previous work reported by Cole (1) showing improved plant growth of 'Winter Gem' boxwood and 'Atropurpurea Nana' nandina in CGC amended substrates.

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Table 1. Visual rating scale for root development.

Rating	Overall quality
0	no root growth
1	root ball falls apart when removed from the container
2	root ball loosely stays intact when removed from the container
3	root ball firmly stays intact but does not fill the container
4	roots reach the edge of the container but are not root bound
5	root bound

Table 2. Effect of container substrate on GI and root rating of *B. microphylla* 'Winter Gem', *N. domestica* 'Atropurpurea Nana' nandina, and *R. indicum* 'Renee Mitchell' azalea on April 23, 2004.

Species	% CGC[z]	PB:CGC:S (by vol)[y]	Growth Index (GI)[x]	Root rating
Buxus microphylla 'Winter Gem'	0	6:0:1	50.6 bw	4.5 a[w]
	21	4.5:1.5:1	52.4 ab	4.4 a
	33	1:1:1	54.0 a	4.6 a
	64	1.5:4.5:1	54.1 a	4.4 a
Nandina domestica 'Atropurpurea Nana'	0	6:0:1	48.8 c	3.1 a
	21	4.5:1.5:1	54.9 b	3.1 a
	33	1:1:1	56.4 ab	3.5 a
	64	1.5:4.5:1	58.0 a	3.5 a
Rhododendron indicum 'Renee Mitchell'	0	6:0:1	49.6 a	2.8 a
	21	4.5:1.5:1	53.3 a	3.1 a
	33	1:1:1	53.8 a	3.0 a
	64	1.5:4.5:1	53.5 a	3.2 a

[z]Percentage of CGC incorporated in each treatment.

[y]PB = pine bark, S = sand, CGC = cotton gin compost.

[x]GI = [(height + widest width + perpendicular width)/3].

[w]Means separation by cultivar and within columns by LSD at P = 0.05.

Effects of Various Compost-amended Substrates on Water Use Efficiency and Leaf Nutrition of *Clethra alnifolia*

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Index Words: Substrate, Compost, Water use, Nutrition, Time Domain Reflectometry, Summersweet

Significance to Industry: Milled pine bark is the most utilized substrate for the production of container grown woody ornamentals in the eastern United States, and the development of this substrate has facilitated the growth of container nursery production. Increasing demand for pine bark, coupled with inconsistent supply, has made current and future availability of milled pine bark uncertain and potentially prohibitively expensive. Research has been conducted on many alternative substrates, but no substitute of suitable quality and availability has been introduced into the ornamental nursery trade (3). Although some ornamental plants have been shown to perform well in compost-amended substrates (1), the physical and chemical properties of various composts must be assessed before practical use of compost as a growing medium can be achieved. Of particular practical importance when evaluating compost-amended substrates are assessments regarding growth, water-use efficiency, and nutrition.

Nature of Work: Four regionally available composts mixed with milled pine bark were assessed. “Panorama Pay Dirt” is a commercially available compost made from chicken litter and leaf feedstock. “Huck’s Hen Blends” is a commercially available compost made from yard trimmings, ground lumber and chicken manure feedstock. “Wolf Creek Compost” is composted biosolids and milled yard waste feedstock, and “Rivanna Solid Waste Authority Compost” is a compost produced from lime-stabilized biosolids and wood chips. Each was mixed 25% and 50% with pine bark and compared to 100% pine bark. Rooted cuttings of summersweet (*Clethra alnifolia* L.) were transplanted into these substrates and top dressed with a low rate of Osmocote 18-6-12 (9 month formulation) fertilizer and grown out for one year. Fresh compost was obtained from the suppliers and three replicates of each treatment were potted up into 3-gallon (11.4 L) containers and allowed to grow out for 3 months. The plants were moved into the Greenhouse Complex at Virginia Tech to monitor water use. Each pot was placed on three 1-inch (2.54 cm) thick sections of polyvinyl chloride pipe in plastic oil pans. A Trase System Model 6050X1 Time Domain Reflectometry (TDR) unit was attached to a multiplexer fitted with buriable wave-guides. Plants were allowed to experience mild drought stress, observed as slight wilt, to establish a baseline TDR measurement of volumetric water content. Future irrigation events consisting of 2000 mL (67.6 oz) of water occurred when TDR measurements were within 5 % VWC of the established baseline. Irrigated plants were allowed to drain for one hour, and leachate volume gathered in the collection pan was measured. On the final day of measurements all plants were irrigated and leachate was collected, regardless of measured VWC. Water use efficiency was characterized by dividing plant dry weight by total water use.

Utilizing mass spectrometry, plant leaves were measured for nutritional status by A & L Laboratories (Richmond, VA). Nitrogen, P, K, S, Ca, Mg, Mn, Fe, Zn, Cu, B, Al, and Na levels were assessed for summersweet leaves from plants growing in pure pine bark and compost-amended pine bark.

Results and Discussion: With the exception of plants grown in 50% lime-stabilized biosolids, summersweet grew as well or had increased dry weight when grown in compost amended substrates (Figure 1). Additionally, water use efficiency was as good or better for plants grown in compost- amended pine bark than plants grown in pure pine bark, with the same exception of the lime-stabilized biosolid compost (Figure 1). Extrapolating this data suggests that plants can be produced as quickly or more quickly in compost amended substrates without a decrease in water use efficiency, thus reducing total water inputs during a production cycle, as well as reducing water losses as potential pollutant carriers.

Analyses of leaf nutrient status indicate that summersweet grown in most compost-amended substrates are able to obtain similar nutritional values when compared to plants grown in pine bark (Table 1). Plants that exhibited increased growth rates showed no signs of nutrient deficiency over the course of the experiment. Symptoms of manganese deficiency were visually obvious on summersweet grown in pine bark amended with lime-stabilized biosolids, and their growth was stunted. Manganese levels were not restrictive in this compost, but pH of 8.0 rendered manganese unavailable (data not shown). Taken in conjunction with other research (2), in the absence of extensive plant response testing we recommend avoiding the use of large volumes (25% or greater) of lime-stabilized biosolid composts as substrate amendments utilized in container production.

Composts made from various feedstocks can provide suitable substrates for growing plants when mixed with pine bark. Water-use efficiency can be improved with the addition of up to 50% compost into the growing medium. This improvement can be utilized to reduce irrigation inputs into a growing system, particularly when used in conjunction with a TDR system.

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Figure 1. Total dry weight (A) and total dry weight per water use (B) of *Clethra alnifolia* grown in various compost-amended substrates. PPD = leaves & poultry litter, HB = wood waste &chicken manure, WC = biosolids & yard waste, RC = biosolids & wood chips. Bars indicate standard error.

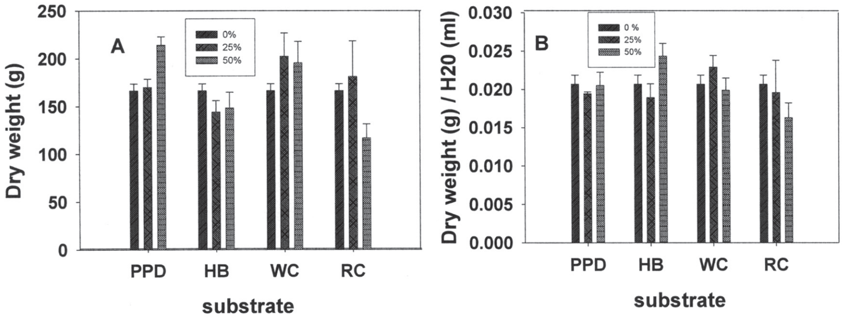

Table 1. Leaf nutrient levels of summersweet grown in various compost-amended substrates. Values in columns followed by the same letter are not significantly different according to Duncan's Multiple Range Test (p = .05). See fig. 1 for substrate description.

Nutrient Content	%				ppm	
Substrate	**N**	**P**	**K**	**Ca**	**Mn**	**Fe**
PB 100	1.32 ab	0.28 a	1.22 a	1.45 a	1431.86 a	127.71 ab
PPD 25	1.4 ab	0.51 a	1.07 a	1.44 a	1253.33 ab	64.67 b
PPD 50	1.68 a	0.79 a	1.39 a	1.57 a	837.67 bc	92.33 ab
HB 25	1.35 ab	0.45 a	1.27 a	1.44 a	590.67 bcd	85.00 ab
HB 50	1.44 ab	0.34 a	1.32 a	1.25 a	606.33 bcd	87.33 ab
WC 25	1.15 b	0.72 a	1.14 a	1.49 a	786.00 bcd	84.00 ab
WC 50	1.46 ab	0.69 a	1.50 a	1.40 a	328.00 cd	106.33 a
RC 25	1.59 a	0.39 a	1.15 a	2.27 b	48.67 d	101.33 a
RC 50	1.67 a	0.16 a	1.43 a	2.61 b	37.00 d	92.33 ab

Finding the Balance: Calcined Clay Rate Effects in Pine Bark Substrates

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Index Words: *Cotoneaster dammeri* ‘Skogholm’, water, growth, photosynthesis, amendments

Significance to Industry: The addition of a 710 μm to 300 μm (24/48 mesh) calcined (LVM) Georgia palygorksite-bentonite mineral at ≈ 11% (by vol.) to pine bark increased ‘Skogholm’ cotoneaster dry weight 39% when compared to a pine bark substrate. When clay was used to amend pine bark at rates greater than 12% (by vol.) plant dry weight decreased. A clay amended substrate engineered to retain water and fertilizers while improving or not affecting growth, allows BMPs to become more attainable without costly infrastructural changes. This, in turn, could reduce watershed impact and water use.

Nature of Work: The nursery industry is the largest crop producing sector in the United States, with 9.4 billion cash sales in 2003 in which ≈ $86 was spent per household. However, the nursery industry is coming under greater environmental scrutiny for the consumption of large amounts of water and fertilizer used to maximize plant growth to quickly produce salable plants. Nurseries have begun to implement Best Management Practices (BMP’s) to increase fertilizer and water efficiency (4). In containerized crop production a substrate composed of pine bark and sand, both relatively inert, are commonly used to grow nursery crops in the southeastern United States. These substrate components offer little water or nutrient retention (2), contributing to a water and nutrient use efficiency ≤ 50%. Therefore, half of the water and nutrients applied are not used by the plant being produced. These nutrients are leached from the production system and contribute to water quality concerns. The use of BMP’s alone still has not proven to increase water and fertilizer efficiency to an acceptable level for local, state, and federal proposed regulation without implementing costly infrastructural changes. Past research has focused on inputs, but has neglected to focus on substrate retention of these inputs to improve water and nutrient efficiency (4).

Our research has focused on the addition of industrial clay aggregate products in soilless substrates to increase water and nutrient efficiency in containerized nursery crop production. The clay component of soil is primarily responsible for water and nutrient retention. However, all “clay” is not created equally. In 2002, we found that amending pine bark with industrial clay aggregates increased water and nutrient efficiency without sacrificing plant growth. Water savings were equivalent to 370,309 liters growing hectare^{-1} year^{-1} (100,000 gallons growing acre^{-1} year^{-1}) whereas, phosphorus and ammonium leaching was reduced ≈ 50% (3). Our past research has shown clay used to amend pine bark based substrates are an effective method of improving nutrient and water efficiency. The objective of this study was to determine at what rate an industrial clay aggregate used to amend pine bark would result in maximum growth.

The experiment was a randomized complete block design with three replications. The clay used was a 710 µm to 300 µm (24/48 mesh) calcined (LVM) palygorksite-bentonite mineral from Georgia (Oil-Dri Corporation of America, Chicago, IL) (1). The palygorksite-bentonite mineral was added to a pine bark substrate at a rate of 0, 8, 12, 16, or 20% (by vol.). Rates were determined with a preliminary experiment that examined the effect of clay amendment rate on substrate physical properties (data not presented). In the preliminary experiment the calcined clay was used to amend pine bark at 0, 4, 8, 12, 16, 20, and 24% (by vol.). These data suggested an optimum rate occurred between 12% and 16% (by vol.).

Two hundred and forty rooted stem cuttings of *Cotoneaster dammeri* C.K. Schneid. 'Skogholm' were potted in a clay amended pine bark substrate at one of the previously mentioned rates in 14 L containers (trade 5 gal). There were 15 plants per replication. Effluent was measured daily from irrigation water that was applied via pressure compensated spray stakes [Acu-Spray Stick; Wade Mfg. Co., Fresno, CA; (200 ml min^{-1})]. Irrigation was applied in a cyclic manner, with three applications daily (1100 HR, 1400 HR, and 1700 HR EST). An irrigation volume to maintain a 0.2 leaching fraction was applied to each plot based on effluent values monitored daily and irrigation volumes that were monitored bi-weekly. All substrate was fertilized with 60 g 17-5-10 6 month controlled-release fertilizer (Harrell's, Lakeland, FL), at the beginning of the study. Substrate was also amended with 0.6 kg m^{-3} (2 lb cu yd^{-3}) blend of crushed and ground dolomitic limestone. To determine substrate water buffering capacity, stomatal conductance and net CO_2 assimilation were measured periodically under normal irrigation. Measurements were conducted from 1130 HR to 1330 HR EST with a LI-6200 computer and LI-6250 gas analyzer (LI-COR, Lincoln, Nebraska) after approximately 50 days of plant establishment. After 122 days, tops from two randomly chosen containers per plot (total of six plants $treatment^{-1}$) were removed. Roots were placed over a screen and washed with a high pressure water stream to remove substrate. Shoots and roots were dried at 65 C (150 F) for 5 days and weighed. All data was regressed using PROC REG (SAS Institute, Cary, NC) to determine best-fit, linear and quadratic models. Terms of the model were evaluated for significance based on a comparison of F values at $\alpha = 0.05$.

Results and Discussion: Plant weight and net photosynthesis both fit curvilinear models when plotted as a function of clay amendment rate (Figs.1 and 2). A 39% increase occurred in total dry weight when the clay amendment rate increased from 0% to 12% (Fig. 1). However, as the clay rate increased from 12% to 20% top dry weight decreased 20% (Fig.1). Clay amendment rates produced a quadratic relationship with maximum net photosynthesis and plant growth at clay rates of 12% and 11%, respectively (Figs.1 and 2).

When combining past and current results we have shown that a 710 µm – 300 µm (24/48 mesh) calcined (LVM) palygorksite-bentonite mineral from

Georgia can reduce phosphorus leaching, reduce water application volumes, and maximize growth when used to amend pine bark at ≈ 11% (by vol.) versus pine bark only substrates.

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Figure 1. Effect of clay amendment rate on total plant dry weight (g) of 'Skogholm' cotoneaster after 122 days.

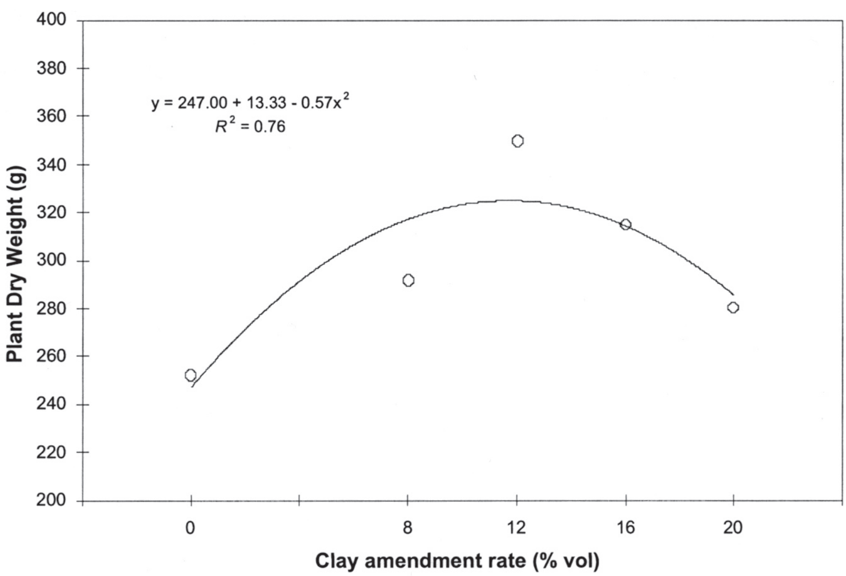
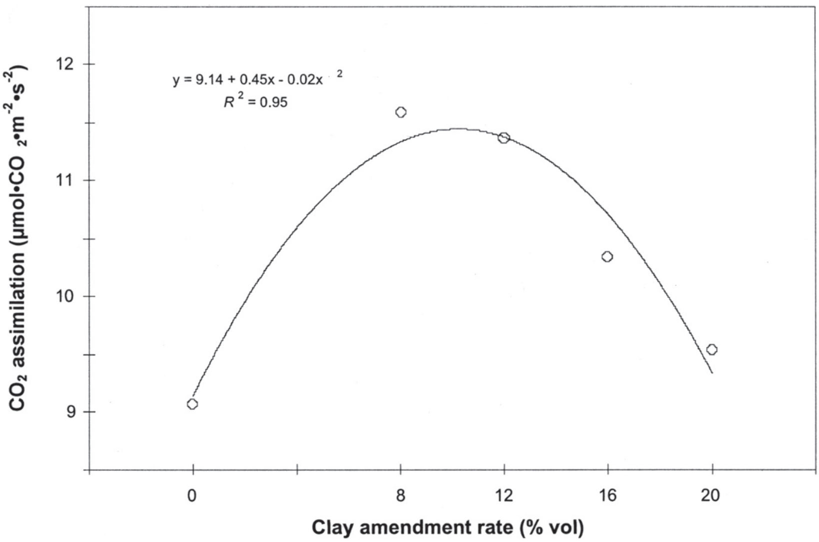


Figure 2. Effect of clay amendment rate on net photosynthesis of ‘Skogholm’ cotoneaster. Measurements were taken on August 26, 2003, ≈ 24 hr after irrigation was applied.



Timing of Overhead Irrigation Affects Growth and Substrate Temperature of Container-grown Plants

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Index Words: *Cotoneaster dammeri*, Leaching Fraction

Significance to Industry: Overhead irrigation timing had a significant effect on plant growth and container temperature. Plants that were irrigated both during the afternoon (12:00 pm, 3:00 pm, and 6:00 pm) and all day (6:00 am, 12:00 pm, and 6:00 pm) significantly outperformed plants irrigated during predawn hours (3:00, 5:00, and 7:00 am). Growers should avoid letting the container substrate dry out by late afternoon. Our data suggests that growers may want to investigate irrigating at times other than early morning.

Nature of Work: Pine bark based container substrates, common in the southeastern United States, have low moisture retention properties; therefore, daily irrigation during the growing season is required to maximize plant growth. Current "best management practices" state that overhead irrigation should occur during the early morning hours (before 1000 HR) (Yeager et al., 1997). A recent survey of Alabama nurseries stated that most nurseries (> 60%) are following this recommendation (Fain et al., 2000). Recent research, however, has demonstrated that microirrigation applied during other times of the day may increase plant growth.

Microirrigation applied at 1200, 1500, and 1800 HR produced 63% greater total plant dry weight of *Cotoneaster dammeri* 'Skogholm' ('Skogholm' cotoneaster) compared to cotoneaster irrigated at 0300, 0500, and 0700 HR (Warren and Bilderback, 2002). Reduced substrate temperature from 1800 to 2200 HR and increased rates of photosynthesis accounted for the increase in growth. Beeson (1992) working with four woody ornamentals also reported increased growth when microirrigation was applied during the day in contrast to predawn (0600 HR). He attributed the increased growth to lower daily accumulated water stress. Similarly, microirrigation with either two cycles applied at 0500 and 1300 HR or three cycles applied at 0500, 1100, and 1500 HR increased growth of red maple (*Acer rubrum* L.), winged elm (*Ulmus alata* Michx.), live oak (*Quercus virginiana* Mill) and crepe myrtle (*Lagerstroemia indica* L.) compared to a single cycle (Beeson and Haydu, 1995). Ruter (1998) also reported that microirrigation applied with 3 cycles at 0800, 1200, and 1600 HR or 4 cycles at 0800, 1100, 1300, and 1600 HR increased shoot dry weight of 'Okame' Cherry (*Prunus x incamp* 'Okame') by 40% compared to a single cycle at 0800 HR. Thus, irrigating during the day may increase growth by reducing heat load and minimizing water stress in the latter part of the day. Growers frequently ask if these results are applicable to overhead irrigation. A single study has examined the effect of timing of overhead irrigation on plant growth, Keever and Cobb (1985) reported that overhead irrigation during the day (1300 HR or split application at 1000 and 1500 HR) reduced substrate and canopy temperature that they proposed enhanced top and root growth of *Rhododendron* x 'Hershey's Red' compared to irrigation at 2000 HR. Therefore, our objective was to evaluate the effects of timing of overhead irrigation on growth of 'Skogholm' cotoneaster and substrate temperature.

The study was a randomized complete block design with 4 replications with three containers in each plot. Rooted cuttings of *Cotoneaster dammeri* 'Skogholm' were potted into one gallon containers in an 8 pine bark : 1 sand (by vol) substrate amended with 1.2 kg/m^3 (2 lbs/yd^3) dolomitic limestone on May 17, 2003. Each plant was fertilized at potting with 5.0 g N (0.18 oz) from 17-5-10 (5-6 month with minors, Pursell Technology, Sylacauga, AL). Containers were watered as needed during the predawn hours until treatments were initiated May 30, 2003.

Leaching fraction (LF) is defined as the volume leached from a container divided by the total amount applied to that container. The daily total volume of irrigation to maintain a 0.2 LF within each treatment was divided into three equal parts and applied at the following times: 0300, 0500, and 0700 HR (predawn); 1200, 1500, and 1800 HR (afternoon); or 0600, 1200, and 1800 HR (all day). Leaching fraction was monitored weekly. Irrigation was applied overhead [961P, 120 liters/hr (32 gal/hr), Agridor Ltd., Rosh Ha Ayin, Israel].

Substrate temperatures were measured in two containers in every replication (total of 8 thermocouples/treatment) for the entire study. One copper-constantan thermocouple was positioned in the substrate halfway down the container profile 1 in from the container wall on the southern exposure in each container. Thermocouples were connected to a Hobo datalogger (Onset Computer Corp., Pocasset, MA). Temperature data were recorded every 5 min and averaged over each 60-min interval. Maximum, minimum, and average temperature along with time of maximum, and time of minimum were recorded every 60 min.

After 117 days, tops (aerial tissue) were removed (total of 12 containers / treatment). Roots were placed over a screen and washed with a high pressure water stream to remove substrate. Tops and roots were dried at 65C (150F) for 5 days and weighed. Data were subjected to analysis of variance procedures. Treatment means were separated by Fishers protected LSD, P = 0.05. The following variables were determined: total plant dry weight = top dry weight + root dry weight; water utilization efficiency (WUE) = irrigation volume retained in substrate ÷ total plant dry weight (milliliters of water required to produce 1 g plant dry mass); and root : top ratio = root dry weight ÷ top dry weight.

Results and Discussion: A total of 40.5 L, 50.5 L, and 37.5 L (10.7 gal, 13.2 gal, and 9.9 gal) of irrigation water was applied to predawn, afternoon, and all day, respectively resulting in LFs of 0.25, 0.19, and 0.22, for predawn, afternoon, and all day, respectively. Plants irrigated all day and PM had significantly greater top dry weight compared to predawn irrigation (Table 1). Top dry weight was ≈ 31% heavier when irrigated with afternoon and all day compared to predawn. When irrigated with microirrigation top dry weight of 'Skogholm' cotoneaster was 71% heavier when irrigated with afternoon compared to predawn. Root dry weight was unaffected by irrigation timing. All day irrigation timing had higher WUE requiring 134 ml per g of plant dry mass (10.3 pints/oz) compared to 175 ml per g of plant dry mass (14.0 pints/oz) when irrigated predawn (Table 1). This is an increase of 23%. Water use efficiency of predawn and afternoon were similar. This may be a consequence of irrigation water lost to evaporation when irrigating during the afternoon. Data herein suggests that if daily irrigation is restricted to early morning hours, growth will be significantly reduced compared to plants grown with irrigation applied during the day.

Time of daily maximum temperature for containers irrigated predawn, afternoon, and all day were similar (1630 HR). Data from Aug. 26, 27, and 28 are presented in Fig. 1. Daily maximum temperature ranged from 46 to 48C, 44 to 46C, and 39 to 41C (115 to 118F, 111 to 115F, and 102 to 106F) for predawn, all day, and afternoon irrigation, respectively. Containers irrigated with afternoon had significantly lower temperatures from 1100 to 2400 HR compared to predawn for most days. This difference in temperature in combination with available water could have a significant impact on photosynthesis and subsequent plant growth (Ruter and Ingram, 1990).

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Table 1. Effect of overhead irrigation timing on top, root, and total plant dry weight, root : top ratio, and water utilization efficiency (WUE).

Irrigation timing[z]	Top (g)	Root (g)	Total (g)	Root : Top[y]	WUE[x] (ml/g)
Predawn	146 c[w]	27 a	173 b	0.17 a	175 a
All day	186 a	33 a	219 a	0.18 a	134 b
Afternoon	197 a	34 a	231 a	0.17 a	177 a

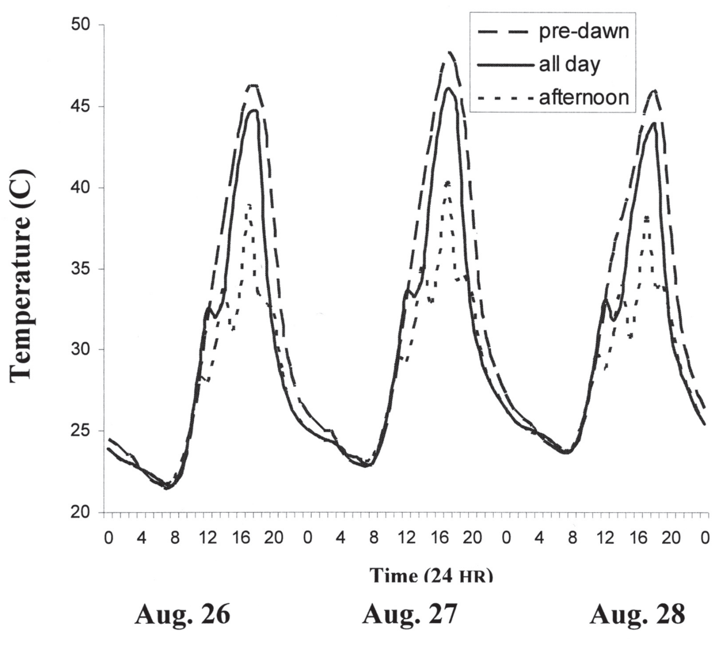
[z]Predawn = irrigation at 0300, 0500, and 0700 HR; All day = 0600, 1200, and 1800 HR; Afternoon = 1200, 1500, and 1800 HR.

[y]Root : top ratio = root dry weight ÷ top dry weight.

[x]WUE = millliters water ÷ g total dry mass.

[w]Means within columns followed by the same letter are not significantly different as determined by Fisher's protected LSD, P = 0.05.

Fig. 1. Effect of irrigation timing on substrate temperature. Predawn = irrigation at 0300, 0500, and 0700 HR; All day = 0600, 1200, and 1800 HR; Afternoon = 1200, 1500, and 1800 HR.



Influence of Shoot Pruning on Nutrient Uptake in Thyrallis (*Galphimia glauca* Cav.)

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Index Words: Plant Nutrition, Hydroponics, Hedging, Shearing, *Thryallis glauca* Cav., 'Rain-of-Gold'

Significance to Industry: Intentional (e.g., pruning) or non-intentional (e.g., defoliation due to pest damage) manipulation of the plant canopy can alter nutrient uptake. Environmental concerns of reduced nutrient uptake due to pruning include a greater potential for P and other nutrient leaching/runoff. Economically, significant amounts of nutrients (production inputs) can be removed in the pruned biomass. Yeager and Ingram (1986), found that in *Ligustrum sinense* Lour. 'Variegatum', 11% of applied N and 3% of applied P and K were lost in pruned stems and leaves.

Nature of Work: Thyrallis is an ornamental evergreen shrub suitable for landscapes in USDA hardiness zones 9B through 11. Thyrallis is a moderately-vigorous plant that forms a dense mass of stems (Gilman, 1999). These growth characteristics often require that Thryallis be pruned in the nursery and landscape to maintain a compact and full canopy. Pruning influences plant growth and physiology in several ways, including: altering endogenous hormone levels, affecting root and shoot growth, removing carbon and nutrient reserves, reducing photosynthates, and altering nutrient uptake (Peter and Lehman, 2000; Caradus and Snaydon, 1986; Yeager and Ingram, 1986). The consequence of altering nutrient uptake is an increased potential for nutrient leaching/runoff. In the nursery setting, nutrient leaching from the container relates to a loss of production inputs (i.e., an economic concern), and the possibility of contaminating water resources with nutrients (i.e., an environmental concern). Therefore, the objective of this pilot study was to assess the effects of pruning on nutrient uptake in Thryallis.

Materials and Methods: Thryallis in a peat:aged pine bark:sand (1:1:0.2) media in 3 gal (11.4 L) containers were acquired from a local nursery. Plants were removed from containers and roots washed clean of substrate under a stream of tap water. Plants were then transferred to a hydroponic system in greenhouse maintained at venting/heating temperatures of 85/74 °F (29.4/23.3 °C). Opaque hydroponic containers [total volume 2.5 L (0.66 gal)] were filled with 2.0 L (0.53 gal) of a modified Hoaglands solution (Solution no. 2) (Hoagland and Arnon, 1938). Nitrogen (and all other nutrients proportionally) were increased weekly in 50 ppm (ppm = $mg.L^{-1}$) increments to a final concentration of 200 ppm N (4 weeks after transfer to hydroponics). Plants were maintained at 200 ppm N for two weeks before initiating the pruning treatment. The pruning treatment consisted of removing 10 cm (3.9 inches) of each shoot (from the shoot apex). Controls consisted of plants not pruned and hydroponic containers with nutrient solution but without plants so that nutrient solution loss due to evaporation could be estimated. The study was setup as a completely randomized design with 6 replications per treatment. Data collected daily during the study included solution volume, pH, EC, and temperature, and from a 10 mL sample, the concentration of calcium (Ca), magnesium (Mg), phosphorous (P), potassium (K), iron (Fe), and manganese (Mn) by ICP (IRIS 1000 HR Duo, ThermoElectron, Franklin, MA.) after filtration (gravity filtered; Whatman no. 541, Whatman Paper Lmt., Maidstone, Kent, England). Daily maintenance on the study included adjusting solution pH to 6.0 ± 0.1 with HCl or NaOH, and adding DI (deionized) water to containers to bring solution volume to 2 L. The 10 mL sample used to monitor nutrient depletion by ICP was taken after solution volume was adjusted to 2 L. Once per week, nutrient solutions were changed, and root and shoot (stems and leaves) plant fresh weight was non-destructively determined by measuring total plant fresh weight, and plant fresh weight with roots submerged in DI water, yielding shoot fresh weight. The difference between total and shoot (roots submerged) fresh weight, yields root fresh weight. Nutrient uptake data presented here are for the 14 day period following the initiation of the pruning treatment. Data were analyzed to determine the main effects of shoot pruning using an ANOVA. Calculations performed with the General Linear Model (GLM) of SAS (SAS Inst., Cary, NC.).

Results and Discussion: On average, 49% (19 g/plant) of plant shoot fresh weight was removed by pruning, altering the shoot (stems and leaves): root ratio from 1.1:1.0 to 0.5:1.0, in the non-pruned and pruned treatments, respectively (data not shown). Of the nutrients determined, uptake decreased for Ca (57%), K (40%), P (35%), Mg (23%), and Fe (19%) in response to pruning (Table 1). Manganese, however, in response to pruning, was exported (active process) or exuded (passive process) from roots as more of the nutrient was detected in the nutrient solution than was supplied (Table 1). A similar observation was made by Peter and Lehmann (2000) where Mn leaching through the rootzone of field-grown acacia [*Acacia saligna* (Labill.) H.L. Wendl.] was significantly greater in pruned than non-pruned trees. They also found that Mn (and P) content of leaves sampled 4 months after pruning was significantly lower in trees that were pruned compared to non-pruned trees (Peter and Lehmann, 2000). In hydroponically-grown white clover, within 24 hours of shoot pruning, P uptake compared to the non-pruned controls, decreased by 77% (Caradus and Snaydon, 1986). In summary, this pilot study has shown that pruning does alter nutrient uptake in Thryallis. In future studies, the long-term effects of pruning on growth and foliar nutrient content in Thryallis and other woody ornamentals will be determined.

Acknowledgement: We thank Martin R. Kinnamon, Andy Hamm, and Ryan Hamm, U.S. Horticultural Research Laboratory for technical assistance.

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Table 1. Nutrient uptake by thryallis plants pruned or non-pruned six weeks after transfer to hydroponics.

	Nutrient uptake ($\mu g.gFW.d^{-1}$)[z]					
Treatment	Ca	Mg	K	P	Fe	Mn
Non-Pruned	39.85	35.52	49.46	30.95	0.37	0.16
Pruned	17.31	27.30	29.86	20.22	0.30	-0.14[y]
Significance[x]	***	***	**	***	***	*

[z]Nutrient depletion: micro-grams per gram fresh weight per day.

[y]A negative value indicates that more of the element was detected in the nutrient solution than was supplied (i.e., nutrient export/efflux).

[x]Significance at $P < 0.05$ (*), 0.01 (**), or 0.001 (***) by ANOVA, n = 6.

Importance of Substrate Nutritional Testing Following Potting

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Index Words: Electrical conductivity, *Juniperus horizontalis* Moench 'Blue Rug', *Juniperus chinensis* L. var. *sargentii* A. Henry

Significance to Industry: Our evaluations indicate the importance of monitoring substrate electrical conductivity (EC) after filling containers to ensure that excessive EC levels do not exist at planting. The high EC levels in this evaluation, resulting from water soluble superphosphate and potassium sulfate, decreased rapidly inferring that nutrients leached from the containers. These results support Best Management Practices for container plant production that require substrates be amended with fertilizers that are not readily leached.

Nature of Work: Substrates used for container plant production are typically amended with various micro- and macronutrients. The amounts of amendments may vary, but most amendments are intended to provide adequate nutrition for an extended period of time depending on environmental conditions. Because environmental conditions affecting fertilizer availability and leaching vary, it is important to monitor the release or availability of nutrients by monitoring substrate EC.

The following study was conducted at May Nursery, Inc. in Havana Florida because nursery personnel had reported that some species of newly potted plants failed to thrive or grow roots and shoots according to expectations. Our objective was to determine if soluble fertilizers used as substrate amendments contributed to this undesirable plant response.

The substrate used for this investigation was composed by volume of 93 % fresh pine bark, 2 % coarse sand and 5 % Canadian peat. Micronutrients were provided by Pip II (Graco Fertilizer Company, Cairo, Georgia) at 7.4 lb/cubic yard, iron sulfate at 1.6 lb/cubic yard, copper sulfate at 0.002 lb/cubic yard, potassium sulfate at 0.7 lb/cubic yard, single superphosphate at 3.7 lb/cubic yard, dolomitic limestone at 17.9 lb/cubic yard and urea formaldehyde at 3.7 lb/cubic yard (UF, Blue chip, Nor-am Chemical Company, Wilmington, Delaware), and Polyon NPK+™ 18-6-8 (9 month, Pursell Technologies, Inc., Sylacauga, Alabama) at 5 lb/cubic yard. A 10-4-6-solution fertilizer (≈ 100 ppm N) was applied in the irrigation water 3 times per week during the growing season.

Experiment 1. On September 12, 2003, five # 3 containers were randomly selected for pour-through leachate collection (Yeager et al., 1983) from several hundred containers that had just been filled and placed touching each other on a black plastic surface in the nursery. Pour-through leachates were collected weekly for 4 weeks and leachate (EC) determined. Juniper liners were planted after the first leachate collection. Plants were irrigated as needed (average of 0.67 inch/hour) with overhead impact sprinklers. The irrigation water EC was 0.9 mmhos/cm.

Experiment 2. Five additional #3 containers with the same substrate but without plants were placed on a greenhouse bench at University of Florida, Gainesville and irrigated daily with 0.3 inches applied overhead by Spectrum 360™ Jet (Antelco Corp., South Australia). Irrigation water had an EC of 0.3 mmhos/cm. Pour-through leachates were collected every 7 to 10 days and EC determined.

Experiment 3. On November 5, 2003 several hundred #1 containers were filled with substrate like that used in the first experiment or filled with substrate without the superphosphate and potassium sulfate amendments. All containers were placed touching each other in the nursery production area on a black plastic surface. On November 14, pour-through leachates were collected randomly from ten containers without superphosphate and potassium sulfate amendments and EC determined. Leachate EC was subsequently determined every 7-10 days for 3 additional times. *Juniperus hortizontalis* 'Blue Rug' and *Juniperus chinensis* Green Sargent liners were planted in #l containers (with and without superphosphate and potassium sulfate amendments) after the first leachates were collected. The ten containers without superphosphate and without potassium sulfate amendment that were designated for leachate collection were located randomly among the 'Blue Rug' junipers. On April 27 and July 19, 2004, leachate EC was determined for five 'Blue Rug' junipers without the super phosphate and potassium sulfate amendments as well as five 'Blue Rug' juniper plants that were randomly selected from adjacent plants growing in substrate amended with superphosphate and potassium sulfate. In March 2004, junipers were pruned according to standard nursery practices. Containers were spaced 12 x 14 inches in March 2004 (Green Sargent) and in June 2004 ('Blue Rug'). Plant height, widest width, and perpendicular width of 'Blue Rug' junipers were recorded March 19 and for both species on April 27 and July 19, 2004.

Experiment 4. Five additional #1 containers filled with substrate without superphosphate and potassium sulfate amendments and without plants were placed on a greenhouse bench at University of Florida, Gainesville and irrigated as described for *Experiment 2*. Pour-through leachates were collected seven times at approximately 7-day intervals.

Results and Discussion: Pour-through leachate EC for #3 containers in *Experiment 1* ranged from greater than 5 mmhos/cm (surpassed scale on meter) immediately after filling containers and placing in field to 1.8 mmhos/cm, 4 weeks after containers were placed in field. The high initial EC indicates excessive salts that may have damaged plant roots and caused the reduction in root growth observed in previous plantings.

Data from the greenhouse study (*Experiment 2*) indicated that leachate EC decreased rapidly from 8 mmhos/cm at planting to 2 mmhos/cm after 10 days (Figure 1). The rapid decrease indicates that a very water-soluble amendment was contributing to the high initial EC. Yeager and Barrett (1984) had shown that single superphosphate was very water soluble and about 55% of the phosphorus leached in one week when used as an amendment in substrates with 50-66 % pine bark. Yeager and Ingram (1985) determined that potassium leached rapidly from sand substrate amended with water-soluble potassium sulfate.

Pour through leachate EC for the #1 containers without superphosphate and potassium sulfate ranged from 0.8 mmhos/cm 9 days after containers were filled to 0.4 mmhos/cm approximately one month later (*Experiment 3*). These values are 4 to 6 fold less than observed for the first experiment with water-soluble amendments. Similar results (Figure 2) were obtained in the greenhouse (*Experiment 4*) with pour through leachate EC ranging from 0.9 to 0.5 mmhos/cm. This range of EC values is desirable for optimal plant growth (Ingram et al., 1990). These results indicate that removal of the water-soluble superphosphate and potassium sulfate amendments resulted in desirable EC ranges in the container substrate following planting. Yeager and Wright (1982) had previously reported elevated EC during the first 2 weeks after a pine bark substrate was amended with superphosphate. Substrate EC for ‘Blue Rug’ juniper grown 5 and 8 months (April 27 and July 19, 2004, respectively) without superphospate and potassium sulfate amendments averaged 1.2 and 0.5 mmhos/cm, respectively, and with the amendments averaged 1.4 and 0.6 mmhos/cm, respectively.

On March 19, 2004, heights and widths of ‘Blue Rug’ juniper grown in #1 containers with the superphosphate and potassium sulfate amendments were slightly larger than plants grown without the amendments; however, on April 27 and July 19, 2004 heights and widths were not different (Table 1). A similar response was observed for Green Sargent juniper (Table 1). These data concur with previous findings that superphosphate amendment is not necessary if controlled-release fertilizer supplies sufficient phosphorus (Yeager and Wright, 1981 and Yeager et al., 1985). However, the trend for larger size plants in amended substrates should not be overlooked and deserves further investigation. It is possible that an impurity in superphosphate supplied a constituent for growth that may have been lacking or not in sufficient quantities in other added fertilizers.

In conclusion, EC levels resulting from superphosphate and potassium sulfate amendments indicated potentially damaging salt concentrations in container substrate during the first 10 days after filling containers. It is likely that excessive leaching occurred because EC decreased rapidly. The findings that juniper growth was not greatly affected by superphosphate and potassium sulfate amendments supports Best Management Practices for container plant production that requires substrates be amended with fertilizers that are not readily leached.

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Table 1. Juniper liners planted November 2003 at May Nursery, Inc. in #1 containers filled with 93 % fresh pine bark, 2 % coarse sand and 5 % Canadian peat substrate (by volume) amended with potassium (K) sulfate at 0.7 lb/cubic yard, single superphosphate (P) at 3.7 lb/cubic yard, dolomitic limestone at 17.9 lb/cubic yard, urea formaldehyde at 3.7 lb/cubic yard, Polyon NPK+™ 18-6-8 (9 month) at 5 lb/cubic yard, and additional micronutrients or plants were grown without the P and K amendments.

	'Blue Rug' Juniper		Green Sargent Juniper	
Amendment	**Average height (in)**	**Average width (in)**	**Average height (in)**	**Average width (in)**
March 2004				
With P and K	5.0 a	8.2 a	-	-
Without P and K	4.2 b	6.5 b	-	-
April 2004				
With P and K	5.2 a	12.9 a	7.5 a	10.3 a
Without P and K	4.6 a	10.8 a	6.4 a	9.8 a
July 2004				
With P and K	4.6 a	19.9 a	7.9 a	23.9 a
Without P and K	4.3 a	16.0 a	7.5 a	21.9 a

Averages within columns and within dates followed by the same letter are not significantly different by Duncan's multiple range tests $P \leq 0.05$.

Figure 1. Pour through leachate EC for a 93 % fresh pine bark, 2 % coarse sand and 5 % Canadian peat substrate (by volume) amended with potassium sulfate at 0.7 lb/cubic yard, single superphosphate at 3.7 lb/cubic yard, dolomitic limestone at 17.9 lb/cubic yard, urea formaldehyde at 3.7 lb/cubic yard, Polyon NPK+™18-6-8 (9 month) at 5 lb/cubic yard, and additional micronutrients. Substrate was in five #3 containers in a greenhouse and received 0.3 inches of irrigation daily. Irrigation water EC was 0.3 mmhos/cm.

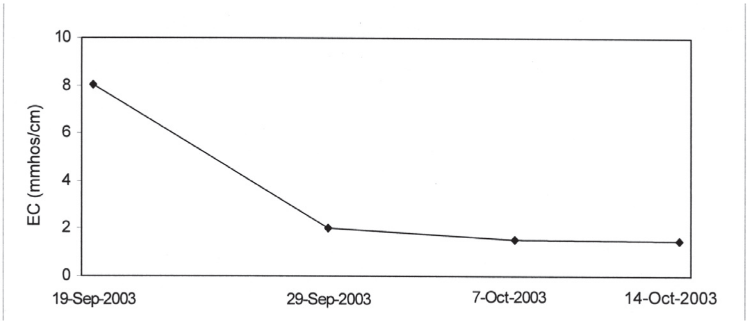
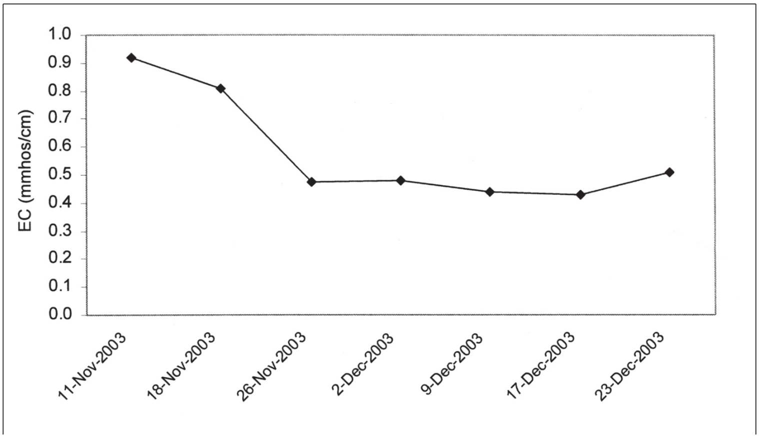


Figure 2. Pour through leachate EC for a 93 % fresh pine bark, 2 % coarse sand and 5 % Canadian peat substrate (by volume) amended with dolomitic limestone at 17.9 lb/cubic yard, urea formaldehyde at 3.7 lb/cubic yard, Polyon NPK+™ 18-6-8 (9 month) at 5 lb/cubic yard, and additional micronutrients. Substrate was in five #1 containers in a greenhouse and received 0.3 inches of irrigation daily. Irrigation water EC was 0.3 mmhos/cm.



A Leaf Interveinal Chlorosis-necrosis Disorder in Crape Myrtle

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Index Words: Fertilization, Mineral Nutrition

Significance to Industry: Growers of crape myrtles (*Lagerstroemia* spp.) as well as horticulturists throughout the southeastern US have noticed and informally discussed about a foliage (leaf) disorder that is characterized by a sudden and acute interveinal chlorosis, followed by necrosis of in flushes of growth that occur in the early to mid-summer but not in the initial spring flush. Our preliminary research confirms that this disorder mainly affects container-grown cultivars of *L. fauriei* and the interspecific hybrids *L. indica* X *L. fauriei*. An evaluation of leaf (foliage) nutrient profiles in 13 crape myrtle cultivars revealed that leaf zinc (Zn) nitrogen concentrations below 90-100 ppm were strongly associated with this disorder and suggest a Zn deficiency condition in the affected cultivars. Furthermore, the tissue analyses also revealed rather large concentrations of manganese (200 to 600 ppm Mn) that were differentially observed across the evaluated *Lagerstroemia* species, but their contribution to the disorder is unclear.

Nature of Work: Crape myrtles (*Lagerstroemia* spp.) are a favorite landscape plant and staple nursery crop for most of the southeastern US (1, 2). While cultivars of the common crape myrtle (*L. indica*) have been the most widely grown and used, the relatively recent introduction of interspecific hybrids of *L. indica* and the Japanese *L. fauriei* (1, 4), has brought significant improvements to cold hardiness, bark & foliage characteristics plus resistance to powdery mildew and certain insects (1, 2, 3, 4, 6).

In recent years growers and horticulturists have been anecdotally reporting and commenting about an apparent and sort of transient physiological disorder in crape myrtles that has not yet affected the sales and popularity of this species. This foliage (leaf) disorder is characterized by a sudden and acute interveinal chlorosis that is followed by necrosis. Leaf size can be reduced moderately to severely, but some leaves may retain their normal size (compared to symptomless leaves of the same age). In the necrosis stage the disorder may resemble damage caused by an insect like a leafminer, with interveinal perforations (holes) observed in the middle of the necrotic tissue. This disorder is expressed in the flushes of growth subsequent to the initial spring flush (early to mid-summer) and sort of fades or dissipates as the season progresses and masked by the growth of new symptom-less foliage. Interestingly, the chlorotic tissue may recover its normal green color later in the season. This disorder has been primarily observed in container-grown crape myrtles, and mostly in the widely popular *L. indica* X *L. fauriei* hybrids. Conversations with growers, researchers and extension specialist from several states confirm these observations and have identified 'Tuskegee', Muskogee', 'Miami' and 'Natchez' as some of the hybrid cultivars most vividly expressing the symptoms of this disorder.

While establishing an experiment to evaluate the salinity tolerance of crape myrtle cultivars we observed the differential expression of this disorder and decided to document it along with the collection and analyses of leaf tissue to explore whether a nutrient disorder (deficiency or toxicity) may be involved in its development.

Rooted liners of 13 crape myrtle cultivars representing *L. indica*, *L. fauriei*, *L. indica* X *L. fauriei* hybrids and L. speciosa (Table 1), were transplanted, on late May into 4-gallon containers filled with a peat: pine bark: sand (2:1:1 v/v) medium amended with dolomitic limestone (5.0 lbs/yd^3), Micromax (1.0 lbs/yd^3) and the wetting agent Aquagro (1.0 lbs/yd^3). Following transplant the pots were topdressed with 10.4 lbs/yd^3 of the controlled-release fertilizer Osmocote 18-6-12 (The Scotts Co.) The plants were placed in gravel beds lined with weed barrier fabric. A total of 30 plants per each cultivar were arranged in a completely randomized block design. The plants were micro-irrigated with tap water using Roberts spitters (one per plant). Applied water volumes were based on evapotranspiration measurements done (gravimetrically) in control plants (2-3 times a week), with enough water to produce a target leaching fraction of 25%. The plants were grown from late May to October and the chlorosis-necrosis disorder symptoms reached a maximum expression during the fist weeks of July, when the number affected plants from each cultivar were tabulated at this time. The plants were destructively harvested October 10-14 and the whole leaf tissues of eight randomly chosen plants were subjected to full nutrient analyses at the Agricultural Analytical Services Laboratory of Pennsylvania State University.

Results and Discussion: The chlorosis-necrosis disorder was observed in most plants of the hybrid crape myrtle cultivars (grand average of 97.5%) as well as in the Japanese *L. fauriei* cultivars (grand average of 94.4%), whereas only a few plants of the *L. indica* cultivars ‘Dallas Red’ (6.7%) and ‘Country Red’ (13.3%) showed some mild symptoms and none in the other cultivars (Table 1). These observations confirm the anecdotal reports from growers and horticulturists and suggest a strong genetic linkage to the *L. fauriei* species and its progeny, in a similar fashion to the strong differential resistance of these cultivars to powdery mildew (6) and the *Altica* flea beetle (3).

While the nutrient analyses data was taken from all the whole plant leaf tissue (not just the affected leaves) about 12 weeks after the disorder symptoms were fully expressed and tabulated, we thought that the nutrient concentrations and profiles of these cultivars may yield clues as to which, if any, nutrients could be involved. As expected, there were significant differences among cultivars in the concentration of all nutrients (Table 1), although most of them fell within the ranges reported in the literature for the genus *Lagerstroemia* (7). Across species the most remarkable macronutrients concentration differences were the extraordinarily high calcium (Ca) concentrations in the hybrid ‘Tuscarora’ and the significantly lowest Ca concentrations for all the Japanese (*L. fauriei*) cultivars.

Given the symptoms of the chlorosis-necrosis disorder, we hypothesized that a nutrient disorder or more specifically a metallic (Fe, Mn, Cu, Zn) micronutrient deficiency may be involved. While there were statistical differences for leaf iron (Fe) and boron (B) concentrations among all the cultivars (Table 1), these were fairly well clustered within the reported normal ranges (9) and did not show any trend or pattern that could be associated with the disorder. Across species, manganese (Mn) concentrations were significantly differentiated, with *L. indica* having the highest average concentrations (505 ppm), *L. fauriei* averaging the lowest (199 ppm), and *L. indica* X *L. fauriei* and L. speciosa having intermediate concentrations (382 and 322 ppm, respectively). These concentrations not only exceeded the reported Mn deficiency levels of 10-20 ppm (8), but approached and/or exceeded the toxicity ranges reported for some plant species (5). On the other hand, an extensive survey of leaf nutrient concentrations in ornamental crops (9) shows *Lagerstroemia* cultivars having a Mn concentration range of 105-828 ppm. While it has been reported that high levels of Mn can produce deficiencies of other elements like iron (Fe), with typical chlorosis symptoms (7), further research attention is needed to ascertain whether Mn is involved in the chlorosis-necrosis disorder in crape myrtles.

Similar to Mn, leaf zinc (Zn) concentrations were differentially expressed across the *Lagerstroemia* species, with *L. indica* having an average concentration of 105 ppm compared to the 71 ppm averaged for the rest of the species (Table 1). While the critical concentrations of 15-20 ppm associated with Zn deficiency (8) were exceed in this study, closer examination of the data reveals that 'Country Red' and 'Dallas Red', the only *L. indica* expressing (albeit moderately) the chlorosis-necrosis disorder, had Zn concentrations similar to all the disorder-affected *L. fauriei* and *L. indica* X *L. fauriei* cultivars. Based on our raw data, the chlorosis-necrosis disorder was associated almost exclusively with plants having leaf Zn concentrations below 90-100 ppm. Further research is needed to confirm that a critical leaf Zn concentration of <90-100 ppm is associated with the chlorosis-necrosis disorder.

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Table 1. Occurrence of chlorosis-necrosis disorder in 13 crape myrtle cultivars and their leaf tissue nutrient concentrations.

Species & Cultivar	Disorder[y]	N[z]	P	K	Ca	Mg	Fe	B	Mn	Zn
		(% DW)					(ppm)			
L. indica										
Carolina Beauty	0	2.94 a	0.36 a	2.18 ab	1.83 bcd	0.42 de	109 a	73 b	596 ab	162 a
Country Red	13.3	2.37 bc	0.29 abc	1.76 cdef	1.79 bcde	0.54 abc	86 ab	75 b	432 bcd	59 d
Dallas Red	6.7	2.45 bc	0.29 abc	1.94 bcd	1.64 cde	0.58 ab	93 ab	68 bc	469 bcd	68 cd
Dynamite	0	2.47 bc	0.28 abc	2.27 a	1.76 bcde	0.37 e	85 ab	112 a	380 cde	113 b
Red Rocket	0	2.53 bc	0.31 ab	1.53 fg	1.93 bc	0.55 abc	82 ab	69 bc	646 a	124 b
Species average	***4.0***	***2.55***	***0.31***	***1.93***	***1.79***	***0.49***	***91***	***79***	***505***	***105***
L. indica X fauriei										
Basham's Party Pink	100	2.47 bc	0.20 c	1.83 cde	1.83 bcd	0.48 bcde	87 ab	40 e	295 def	60 d
Biloxi	93.3	2.69 ab	0.30 ab	1.53 fg	1.76 bcde	0.55 abc	97 ab	62 bcd	325 def	64 cd
Natchez	96.7	2.45 bc	0.26 bc	1.47 fg	1.99 b	0.61 a	92 ab	42 de	401 cde	76 cd
Tuscarora	100	2.96 a	0.34 ab	1.92 bcde	2.75 a	0.42 de	108 a	60 bcde	507 abc	76 c
Species average	***97.5***	***2.64***	***0.27***	***1.69***	***2.08***	***0.51***	***96***	***51***	***382***	***69***
L. fauriei										
Fantasy	93.3	2.43 bc	0.25 bc	1.70 defg	1.30 f	0.50 abcd	79 b	50 cde	168 f	49 d
Kiowa	90.0	3.00 a	0.29 abc	1.88 cde	1.28 f	0.37 e	81 ab	46 de	193 f	95 bc
Townhouse	100	2.95 a	0.31 ab	1.65 efg	1.45 ef	0.47 cde	80 b	45 de	235 ef	75 cd
Species average	***94.4***	***2.80***	***0.28***	***1.74***	***1.34***	***0.45***	***80***	***47***	***199***	***73***
L. speciosa	0	2.25 c	0.31 ab	2.03 abc	1.52 def	0.57 abc	41 c	38 e	322 def	74 cd

[z] Nutrient concentration values are averages of 8 plants.

[y] Percentage of plants (30 per cultivar) showing the disorder symptoms.

Evaluating the Effectiveness of a Bio-soil Enhancer on Container Plant Production

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Index Words: Beneficial soil microorganisms, Fertilization, Leaf nutrient concentration, Growth, Quality

Significance to Industry: The results from this study highlight the importance of evaluating or testing the effective nutrient (fertilizer), chemical and biological activity of any product claiming bio-fertilizer, bio-stimulant or bio-enhancing properties before proceeding to use it in large scale. As with any new pesticide or herbicide, the effects (or lack thereof) of any new product need to be tested or evaluated in small scale using representative or indicator species (i.e. those with which the grower is more familiar) and compared to adequate controls.

Nature of Work: Live organisms from all five kingdoms, animalia (animals, worms, insects), plantae (plants, algae), fungi (molds, yeasts, rusts), protista (protozoa, slime molds) and monera (bacteria, actinomycetes) constitute a small portion of the seemingly inert mass of mineral or field soils (3, 5). This biological activity is, however, as important as the physical and chemical characteristics of soils, and can greatly influence the growth and development of plants. The mostly organic growing media and mixes used to grow modern container plants also contain biological activity, albeit often it can be very small due to physical (heat, flame) or chemical pasteurization to eradicate pathogenic or disease-causing organisms (1, 2). While the primary benefit of soil microorganisms is to decompose organic matter (5, 6), they also interact with soils and plants by improving soil aggregation, degrading, mineralizing and immobilizing materials, enhancing nutrient levels thru nutrient cycling and organic matter decomposition and forming symbiotic relationships with plants (3, 6). In recent years there has been a proliferation of commercial nursery & landscape products labeled as (bio)stimulants and enhancers of soil biological activity that not only list the above roles of soil beneficial microorganisms, but also claim others like remove toxins, enhance water infiltration-drainage, reduce soil compaction-erosion, increase seed germination, promote flowering, increase nutrient uptake, augment root and plant metabolic activity, etc.

The present study evaluated the effects of N-TEXX 15-5-5 Bio Soil Enhancer (CXI Industries, Coppell, TX) on the growth, quality and nutritional status of selected ornamental plants growing under standard container nursery conditions. This product consists of a blend of a commercial inorganic complete fertilizer (Chem-X 31-10-10; SDT Industries Inc., Winnsboro, LA) plus a cocktail of the following microorganisms: *Bacillus* sp., *Pseudomonas* sp., *Arthrobacter* sp., *Rhodococcus* sp., *Chlorobium* sp., *Cyanbacteria* sp. and *Actinimycetes* sp.

Liners (growing in 1-gallon pots) of *Rudbeckia* 'Goldstrum', *Coreopsis* 'Early Sunrise', *Nandina domestica* 'Compacta', *Loropetalum chinense* var. *rubrum* 'Burgundy' and *Lagerstroemia* X 'Natchez' and 'Tuscarora' were transplanted, on May 9, 2003, to 5-gallon pots filled with a pine bark growing medium amended with dolomitic limestone (3.0 lbs/yd^3). Following transplant the pots were topdressed with the CRF Osmocote Pro 19-5-9 plus minors with Poly-S (12-14 month formulation) at 11 lbs/yd^3. The plants were placed in gravel beds lined with weed barrier fabric. Within each bed (one per species), there were 6 replications (plants) per each treatment, completely randomized. The plants were irrigated, with individual Roberts spitters, 2-3 times a week with enough water to produce a target leaching fraction of 30%. The following treatments were applied, as described from June 19 to October 22, 2003.

T1. Control. Water in same volume as used to apply rest of treatments.

T2. Soil N-TEXX 15-5-5 BioSoil Enhancer at label rate 1 gallon/5 acres, equivalent to 33.66 mg of N per m2; applied (label instructions) every 2 and 4 weeks to perennials and other species, respectively.

T3. Foliar N-TEXX 15-5-5. Same as treatment 2 (T2), but applied to foliage (with handheld sprayer, making sure run-off from foliage landed on growing medium surface).

T4. Chem-X 31-10-10 (base fertilizer used to manufacture N-TEXX 15-5-5 Bio Soil Enhancer) at rate equivalent to 33.66 mg of N per m2; frequency of application as in T2.

T5. Cocktail of microorganisms used to manufacture N-TEXX 15-5-5 Soil Bio-enhancer. Applied in tap water at same rate and frequency as T2.

T6. Carl Pool 30-10-10 High N Special (water soluble fertilizer). Fertilizer with macronutrient composition similar to N-TEXX 15-5-5 and Chem-X 31-10-10. Applied at rate equivalent to 33.66 mg of N per m2 and with same frequency as T2.

On October 20-24 the plants were evaluated for growth (height, width) and quality (chlorophyll concentration), and destructively harvested, dried and weighed. Leaf tissues were subjected to full nutrient analyses at the Agricultural Analytical Services Laboratory of Pennsylvania State University.

Results and Discussion: No significant differences in final plant dry weights were observed among treatments or plant species (Table 1). Conversely, the growth data (height, width, growth index) collected at the end of the experiment showed some significant differences among treatments for *Nandina, Coreopsis* and the crape myrtles, but not for *Loropetalum* and *Rudbeckia* plants. For *Nandina* only the treatment with the microorganism cocktail had the largest width and growth index compared to the other treatments. A similar response to the microorganism cocktail was observed in the *Coreopsis* plants, but only for plant height and this response was matched by the Carl Pool fertilizer treatment. While the soil and foliar applied N-TEXX 15-5-5 treatments produced some significantly higher heights, widths and growth indices in the crape myrtle plants, these were not significantly different from the water control. Our periodic and subjective observations on the overall plant aesthetics and foliage quality of the plants over the course of the experimental period did not reveal any major or distinctive differences among the treatments. These observations were confirmed for the most part by quantitative measurements of chlorophyll readings (Table 1), which showed minor treatment differences only in *Coreopsis* plants. Within each species tested, full tissue analyses did not show any statistical differences in leaf nutrient concentrations (data not shown) of treated plants with respect to the water control and all nutrient concentrations were within the normal ranges reported in the literature (4).

While N-TEXX 15-5-5 Bio-Soil Enhancer is manufactured to be both a fertilizer and a soil microorganism inoculant, we focused this study mainly on its nutritional (fertilizer) effects and found them to be insignificant or non-existing in an intensively managed cropping system like a nursery crop. At its recommended application rates the potential nutrient contribution of this product is miniscule compared to the nutrient release from a conventional controlled-release fertilizer or a liquid feeding program.

In a separate study with Coastal bermudagrass growing in PVC columns with four different soil types and in which N-TEXX 15-5-5 Bio-Soil Enhancer was applied at 1X and 428X the recommended rate we observed that it did not contribute to any significant biological activity (expressed as total bacterial colony forming units or Pseudomonas populations) to the soils as compared to a control treatment that included only a matching rate of N-P-K fertilizer (data not shown). A microbiological evaluation of an undiluted sample of N-TEXX 15-5-5 Bio-Soil Enhancer (direct from the bottle) and from the concentrated microorganism cocktail used in its manufacture (employed in Treatment 5) showed a minimal concentration of microorganisms (483 and 159,000 CFU of total bacteria per mL, respectively) as compared to the native populations that would be normally found in most soils (3, 5). This observation leads to consider the shelf-life or the longevity/viability of the biological activity of this product in storage. Furthermore, we wonder about the osmotic effects of a relatively concentrated fertilizer solution on a biologically active cocktail as it is found in the stock (concentrated) N-TEXX 15-5-5 bottles.

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Table 1. Growth parameters and leaf chlorophyll content of selected ornamental crops in response to the Bio Soil Enhancer N-TEXX 15-5-5 and other treatments.

TREATMENTS	Dry Wt. (g)	Height (cm)	Width (cm)	G-Index[x] (cm^3)	Chlorophyll (SPAD)[y]
	Lorpetalum				
Control (water)	178	97	96	97	44
N-TEXX soil	184	101	99	100	43
N-TEXX foliar	151	97	95	96	43
Chem-X (31-10-10)	159	97	95	95	42
Microorganism cocktail	144	99	98	99	43
Carl Pool (31-10-10)	144	97	98	97	44
Significance[z]	***ns***	***ns***	***ns***	***ns***	***ns***
	Rudbeckia				
Control (water)	144	50	50	50	57
N-TEXX soil	95	49	50	49	58
N-TEXX foliar	115	54	47	49	58
Chem-X (31-10-10)	84	49	47	48	58
Microorganism cocktail	115	50	48	48	58
Carl Pool (31-10-10)	91	48	49	49	57
Significance[z]	***ns***	***ns***	***ns***	***ns***	***ns***
	Nandina				
Control (water)	71	66	51 *b*	56 *b*	42
N-TEXX soil	71	69	54 *b*	59 *b*	42
N-TEXX foliar	53	70	54 *b*	59 *b*	41
Chem-X (31-10-10)	84	72	55 *b*	60 *b*	43
Microorganism cocktail	75	76	59 *a*	65 *a*	42
Carl Pool (31-10-10)	68	70	54 *b*	59 *b*	43
Significance[z]	***ns***	***ns***	**	**	***ns***
	Coreopsis				
Control (water)	159	41 *b*	54	50 *ab*	59 *b*
N-TEXX soil	144	44 *b*	48	47 *b*	61 *a*
N-TEXX foliar	121	45 *b*	46	46 *b*	60 *ab*
Chem-X (31-10-10)	136	46 *b*	47	47 *b*	57 *b*
Microorganism cocktail	98	52 *a*	45	48 *b*	58 *b*
Carl Pool (31-10-10)	117	55 *a*	52	53 *a*	60 *ab*
Significance[z]	***ns***	***	***ns***	*	*
	Crape Myrtle				
Control (water)	190	117 *a*	57 *b*	77 *ab*	59
N-TEXX soil	175	114 *ab*	61 *a*	78 *a*	58
N-TEXX foliar	214	114 *ab*	55 *b*	75 *bc*	59
Chem-X (31-10-10)	196	109 *bc*	55 *b*	73 *c*	58
Microorganism cocktail	144	106 *c*	55 *b*	72 *c*	58
Carl Pool (31-10-10)	163	104 *c*	58 *ab*	74 *bc*	60
Significance[z]	***ns***	***	*	**	***ns***

Growth Index= (Width 1 + Width2 [perpendicular to W1] + Height)/3

[y] Chlorophyll index (SPAD units)

[z] ns, *, **, ***= not significant and significant at 0.05, 0.01 and 0.001, respectively. Means in the same column and species followed by the same letter are not significantly different according to Duncan's MRT (α= 0.05).

Evaluating the Salinity Tolerance of Crape Myrtles (*Lagerstroemia* spp.)

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Index Words: Irrigation, Salinity, Water quality

Significance to Industry: The results from this preliminary study indicate that while growth of crape myrtles in general is affected by increasing levels of salinity in the irrigation water, the genetic background of the cultivar may be influencing its qualitative response (its overall aesthetic value) and tolerance to this stress. The common crape myrtle, *L. indica*, may be more susceptible to salt damage (expressed in poor foliage quality due to worse salt burn symptoms and lower chlorophyll readings) than the interspecific hybrids *L. indica* X *L. fauriei*.

Nature of Work: The woody ornamental *Lagerstroemia*, native to SE Asia, has been a favorite landscape plant and a staple nursery crop for the southern US since the late 1700's (2, 6, 7). Cultivars of the common crape myrtle (*L. indica*) have been the most widely used, favored for their colorful summer flowering and wide assortment of inflorescence colors and plant sizes (7). The relatively recent introduction of interspecific hybrids of *L. indica* and the Japanese *L. fauriei* (2, 6, 7) have significantly enhanced its versatility by enhancing its cold hardiness and resistance to powdery mildew and certain species of beetles (2, 3, 4, 7, 8). Crape myrtle has been recently named the official shrub for Texas (3), a state in which water quantity and quality are a pervasive issue for its nursery and landscape industries. While the literature suggests that crape myrtles are a salt sensitive species (1, 5), the only formal salinity study that included this genus did it only with a single *L. indica* cultivar (5). Therefore the present study was conducted to obtain some preliminary information regarding the tolerance of representative crape myrtles cultivars to increasing levels of salinity.

Rooted liners of the crape myrtle cultivars 'Pink Lace', 'Natchez' and 'Basham's Party Pink' ('BPP') were transplanted on June 7 into 4-gallon containers filled with a peat: pine bark: sand (2:1:1 v/v) medium amended with dolomitic limestone (5.0 lbs/yd^3), Micromax (1.0 lbs/yd^3) and the wetting agent Aquagro (1.0 lbs/yd^3). Following transplant the pots were topdressed with 8.5 lbs/yd^3 of the controlled-release fertilizer Woodace 20-4-11 (Vigoro Industries).

The plants were placed in gravel beds lined with weed barrier fabric. There were a total of 6 replications (plants) per each treatment (cultivar X salt level) arranged in a completely randomized block design. The plants were irrigated for 15 weeks with tap water containing 0, 3, 6 12 and 24 mM NaCl. Each container was provided with an individual Roberts spitter and the solutions delivered from 100-liter tanks fitted with submersible pumps connected to standard 1⁄2 inch polyethylene tubing. Applied water volumes were based on evapotranspiration measurements done (gravimetrically) in control plants (2-3 times a week), with enough water applied to produce a target leaching fraction of 25%. The salinity treatments were applied from June 29 to October 10.

On October 10-15 the plants were evaluated for growth (height, width) and quality (leaf chlorophyll concentration, salt burn ratings), and destructively harvested, dried and weighed. Leaf tissues were subjected to full nutrient analyses at the Soil Testing and Plant Analysis Laboratory of Louisiana State University.

Results and Discussion: Cultivar selection and salinity significantly affected plant growth and quality. The hybrid vigor of 'Natchez' and 'BPP' was readily visible and measured over that of 'Pink Lace', which incidentally was the *L. indica* parent used in the breeding of 'Natchez' (2, 7). Regardless of salinity level, 'Natchez' plants had higher leaf area, total and shoot (top) dry weights and growth indices, whereas 'Pink Lace' had the lowest. 'BPP' had the highest average root dry weights across salt treatments (data not shown).

In order to compare the effect of increasing salinity in the three cultivars without involving their actual and inherent differences in vigor and dry weights, these data were expressed on relative terms. This was accomplished by assigning a relative value of 100 to the salt treatment (concentration) having the highest mean value of each measured growth variable within a cultivar and then calculating the corresponding relative value for the rest of the salt treatments (concentrations) within that cultivar. Salt stress significantly decreased plant growth and quality in the three cultivars, but the rate at which these parameters were reduced with increases in salinity differed among the cultivars (Fig. 1A, B, C). It is interesting to note that while the 'Pink Lace' plants were the smallest (having the lowest absolute dry weights), their relative rate of growth reduction with increasing salinity was lower than for 'Natchez' and 'BPP' plants. The vigorous shoot (top) growth of 'Natchez' resulted in the generation of the largest average shoot to root ratio (S/R) across salinity levels, almost twice as large as that found in 'Pink Lace' (Fig. 1D), which was also the only cultivar showing decreases in S/R with increasing salt stress.

Reductions in overall plant quality, assessed by chlorophyll readings (Fig. 1E) and subjective foliage salt burn ratings (Fig. 1F) occurred at a steeper rate in 'Pink Lace' plants than in the hybrids, with 'BPP' plants being the most aesthetically pleasing across all salinity treatments.

Leaf concentrations of Na and Cl increased with salt stress in all cultivars, but significantly lower concentrations were found in 'BPP' plants. The leaf Na and Cl concentrations of 'Pink Lace' plants had stronger correlations with the recorded salt burn symptoms as compared to the other cultivars (Fig. 2). These correlations revealed critical leaf Na and Cl concentrations of 2,300 ppm and 2.0%, respectively, above which salt burn symptoms are likely to be expressed in these crape myrtle cultivars.

The apparent salinity tolerance of the interspecific *Lagerstroemia* hybrids compared to the sensitivity of *L. indica* 'Pink Lace' is currently being evaluated in a similar large scale study that includes a representative number of cultivars and hybrids from these and other *Lagerstroemia* species.

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Figure 1. Relative dry weight components (A,B, C), shoot:root ratio (D), leaf chlorophyll (E) and salt burn ratings (F) of three crape myrtle cultivars irrigated with increasing levels of NaCl salinity.

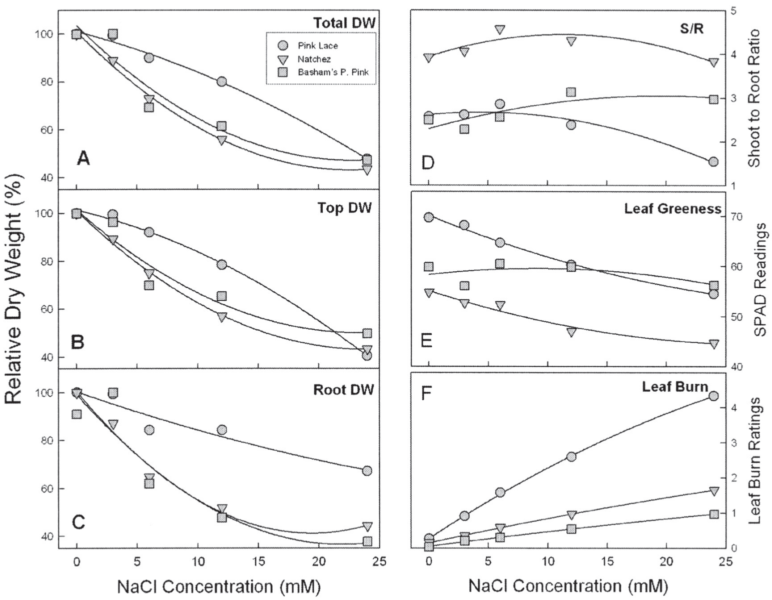
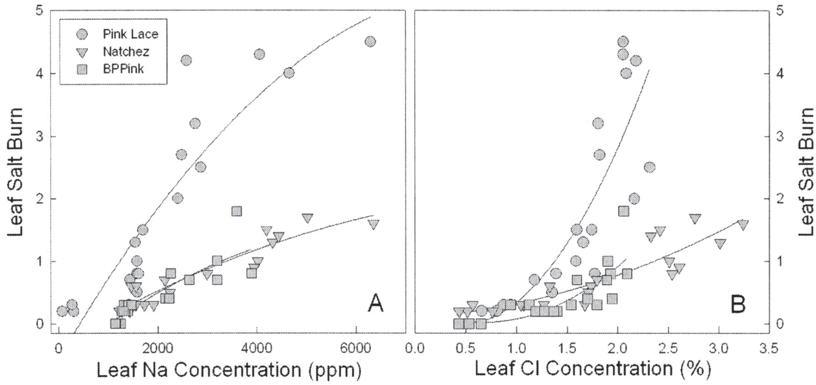


Figure 2. Foliage salt burn ratings in three crape myrtle cultivars as a function of sodium (A) and chloride (B) concentrations found in their leaves after 15 weeks of irrigation with increasing NaCl salinity.



Physical Property Measurements in Container Substrates: A Field Quantification Strategy

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Index Words: Physical properties, Substrate, Container, Air space, Pore space, Bulk density

Significance to Industry: Although conducting "home remedy" analysis of physical property results is not expected to be as precise as laboratory analysis, weighing drained containers and measuring drained pore space volume at grower sites can provide evidence related to differences in batches of potting substrates with excessive moisture retention or excessive aeration characteristics. Determining drained pore space (air space), using the simple procedure outlined here can provide useful insight into how to manage irrigation of crops having drainage or aeration problems and possibly into diagnosis of how to make changes to avoid future problems.

Nature of Work: Plant nurseries in the southeastern United States need a container substrate that does not waterlog after frequent rains over a period of several days. Under such conditions a substrate must provide excellent drainage and aeration capacity to avoid plant disease and death associated with fungal pathogens and/or excessive moisture. For nearly half a century the medium of choice in many areas has been screened pine bark.

Depending on the crop, container size, grower practices, and irrigation resources, growers may add sand or gravel screenings to the bark to improve water retention and to provide sufficient weight to the container to reduce blow-over. Growers receive bark inventory from bark processors. Processors may provide a bark and sand mix or growers may blend components themselves.

Variation in bark supplies occurs in relation to how it has been handled at the bark supplier's location. Some bark supply companies turn and moisten inventory piles during an aging process; other bark supplies may be considered fresh inventory with little aging before processing and shipping.

The moisture content of pine bark at the time of processing also affects particle size. Dry pine bark moves rapidly through a hammer mill and will have fewer fine particles compared to moist bark that tends to clump together and stay in the grinder longer creating more fines during processing (unpublished data). Consequently, when the bark is received from the processor, the range in particle size may vary from one delivery to the next. Since particle size directly affects the substrate's aeration and water retention (3), bark age and quality may dictate changes in a nursery's irrigation regime.

Experienced growers develop a sense of how a bark mix will perform and how they need to handle it in order to insure good crop response. Even experienced growers, however, can misjudge the “feel” of the bark or overestimate the capacity of employees to judge how to handle the bark. If growers have the space and time to submit bark samples for laboratory analysis, they may have better data on which to base irrigation decisions. But routine laboratory analysis has not been sufficiently convenient.

Growers could benefit from a field strategy for comparing one delivery of bark to a previous delivery in order to make quick decisions about how to manage irrigation. However, procedures for field methods to compare potting materials have been complicated, confusing, difficult to perform, and highly variable in results. It is our objective to develop procedures and identify specific measurements that would be useful for comparing potting components and potting mixes on site at nurseries.

In this demonstration substrate from three bark piles at two nurseries were compared: two were 100% pine bark (nursery bark 1 and nursery bark 2) and one was a 90:10 mix of bark and sand (nursery bark:sand). These were then compared to standards determined in laboratory analysis (1). For ten replications of each substrate, one gallon trade containers were filled over the top then scraped to remove excess level with the top. Each container was tapped three times to settle. Containers were irrigated thoroughly and allowed to drain for thirty minutes. Containers were weighed for calculation of an average wet drained weight.

In a second demonstration, replicated ten times for each of the three nursery media, drained pore space was determined by lining containers with a plastic bag. Containers were filled with media and tapped to settle as above. Water was slowly poured over the media allowing water to infiltrate into pore spaces. Water was applied until it just covered the surface of the media. Saturated containers were placed in buckets or trays and holes punched through all the container drain holes into the plastic bag. Water drained from the containers was measured. Since each ml of water equals one cc, then the volume of water drained from the saturated container equals the volume of air space in the media.

The data from these field demonstrations were compared with ten replicates each of the same media analyzed by the NCSU Porometer procedure at the NCSU Horticultural Substrates lab (2). Data were analyzed using Analysis of Variance and Duncan’s Multiple Range Test and are significant at $P = 0.05$.

Results and Discussion: Field methods can not be as precise as laboratory analysis, and they were not. Field data differed significantly from laboratory data in most cases (data not shown). It was not the objective, however, to provide data sufficient for research purposes. Our objective was to develop procedures and identify specific measurements that can be useful on site at nurseries using materials likely to be available. Since current laboratory data have little practicable application for field use by nurseries, we view these measurements as a beginning point for developing numbers that nursery operators can use. To that end, the numbers in Table 1 are provided only to give a point of comparison with averages of hundreds of samples, developed in the Horticultural Substrates Lab (1). Nurseries must be aware that the substrates they use are seldom average. For their purposes, numbers that they develop on site may prove more useful for comparing a new bark supply with a previous supply.

The procedure for weight of drained containers can also be used to compare potting practices among potting crew members. If newly potted containers have more than 10% difference in weight, the results suggest that potting practices need to be examined to determine if filling and planting practices are uniform among potting crew members.

Table 1. A comparison of air space percentage in 3 substrate supplies at two nurseries with laboratory analyses (1) for fresh and aged bark and bark sand mixes.

Substrate	Nursery bark 1	Nursery bark 2	Nursery bark:sand	fresh bark, Lab	aged bark, Lab	fresh bark + sand, Lab	aged bark + sand, Lab
Air Space	34%	32%	26%	42%	31%	31%	27%

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Efficacy of Conventional and Alternative Methods of Weed Control

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Index Words: Corn Gluten, Container Production, Ornamentals, Herbicide

Significance to Industry: Organic weed methods which prevented weed growth by coverage of the substrate are acceptable for production of saleable quality plant material.

Nature of Work: Nursery production of landscape plants in Florida relies heavily on the use of synthetic chemicals – rooting hormones, pesticides, fertilizers, etc. This reliance on non-indigenous materials is costly as well as unsustainable. Practices leading towards sustainable production of nursery/landscape plants could foster the development of new specialty organic nurseries, thus creating a new market niche for small farms, as well as promoting sustainability of existing conventional nurseries. Weed control in container-grown ornamental crops is one of the most important and costly cultural concerns (Gilliam, et al., 1990; Hodges, et al., 2001). Weeds compete with crop plants for space, water, light and nutrients. Weeds may also harbor harmful insects, disease organisms and invertebrate pests.

Since their invention, synthetic herbicides have been used to eradicate weeds in both horticultural and traditional agricultural systems. Using herbicides not only increases plant growth but also reduces the labor need to remove weeds. However the increased use of synthetic chemicals has come under intense scrutiny due to potential environmental and health problems. Weed control in horticultural systems is more of a problem than in traditional agriculture due to the need to eliminate the weeds completely rather than merely manage them.

In this study we compared three organic weed control methods: 1) Bio-Weed (98% corn gluten, 2% soybean oil) (Bioscape, Inc., Petaluma, CA), applied at a rate of 10g/pot (20 lbs/1000 ft^2); 2) Bio-Weed + 1⁄2 inch pine bark mulch, and 3) Geodisc (copper-impregnated fabric) (Texel, Inc., Saint-Elzear-de-Beauce, Quebec, Canada) with a commonly used synthetic herbicide, Pendulum 2G (BASF), applied at a rate of 1.1 g/pot (2.3 lbs/1000 ft^2) to evaluate their efficacy under a typical North Florida production system. Three crops (Blue Daze - *Evolvulus glomerata*, Mexican Heather - *Cuphea hyssopifolia* and Crape Myrtle - *Lagerstroemia* (*indica x fauriei*) ‘Apalachee’) were used in the study. In August 2003, plants were potted into 1-gal black plastic containers with one of four soil-fertilizer combinations: 1) standard nursery mix (pine bark:sphagnum peat moss: sand, 60:30:10 v:v:v) + Osmocote 15-9-12 (N-P_2O5-K_2O) (Scotts Horticulture) at a rate of 13.3 g/pot (8lbs/yd^3); 2) standard nursery mix + Nitrell 5-3-4

(N-P_2O5-K_2O) (Fertrell Co., Bainbridge, PA), an organic fertilizer blended from bonemeal, rock phosphate, oyster meal, kelpmeal, greensand, natural sulfate of potash/magnesia, vegetable protein meals, meat and bonemeal, natural nitrate of soda and fishmeal at a rate of 40 g/pot (24 lbs/yd^3; 3) standard mix with 30% mushroom compost + Nitrell 5-3-4 at a rate of 40 g/pot; and 4) standard mix with 10% worm castings + Nitrell 5-3-4 at a rate of 40 g/pot. The soil-fertilizer combinations were selected based on results of previous research (Duke et al., 2003). The plants were grown for 13 weeks on ground beds situated in full sun and were irrigated with overhead irrigation. Pots containing flowering and fruiting plants of bittercress (*Cardamine* sp.) and artillery fern (*Pilea microphylla*) were spaced in the experimental plot so that each experimental pot was adjacent to a pot containing weeds. Upon harvest, the following parameters were recorded: plant height, plant width, number of weeds per pot, and the percent surface area in each pot covered by weeds.

Results and Discussion: Treatment with the copper-impregnated Geodisc resulted in the best weed control for all three crops. When weeds were present in the Geodisc treatment, they were located around the periphery of the disc. The synthetic herbicide and the Bio-Weed (corn gluten) alone gave the poorest control, while the Bio-Weed + bark mulch performed intermediately (Figure 1).

There were small differences observed in growth (height, width or a calculated growth index (H + W/2)) among weed control treatments (data not shown). The synthetic herbicide treatment generally had the least change in growth and the Bio-Weed treatment showed the greatest change in growth. The Bio-Weed is composed of 98% corn gluten and has a nutrient analysis of 9-0-0. The additional nitrogen could account for the increased growth.

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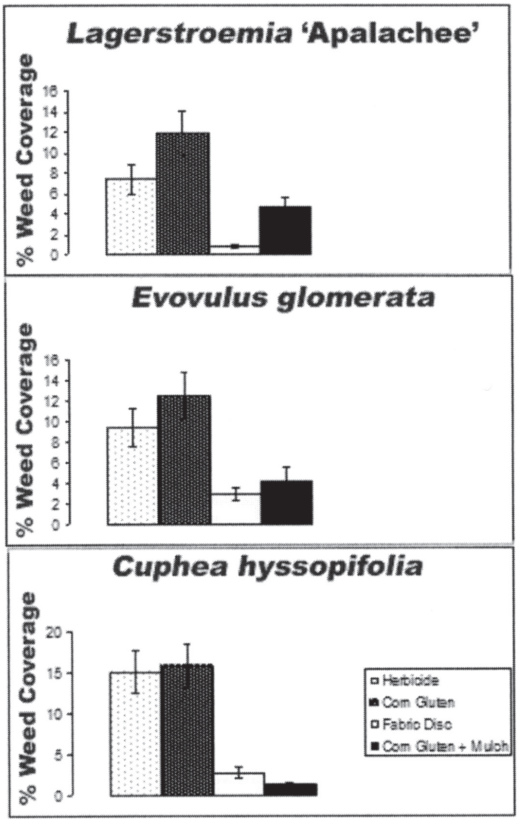
Figure 1. Percentage weed coverage in containers treated with Pendulum 2G (synthetic herbicide), Bio-Weed (corn gluten), Geodisc, or Bio-Weed + pine bark mulch. Error bars indicate Standard Error of the Mean (SEM).



Irrigation and Fertilizer Placement Affects the Production of Container-grown *Quercus shumardii*

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Index Words: Spurge, *Chamaesyce prostrata*, Rout, Weed control, Dibble, Topdress

Significance to Industry: Nursery growers rely primarily on multiple applications of preemergent herbicides to gain control over weeds in containers. The evaluation of alternative cultural practices that might reduce the reliance on or increase the efficacy of herbicides is of great benefit to the industry. This work further supports previous research which indicated topdressed fertilizer applications result in increased weed populations compared to dibbled applications.

Nature of Work: Weed control in container production is achieved primarily through use of preemergence herbicides, along with hand-weeding; however, most programs are not 100% effective. Therefore, growers are continually evaluating new strategies to improve weed control in their nurseries. Past research has show that fertilizer placement affects weed control (1,2). Research by this author has shown that increasing irrigation frequency decreases herbicide efficacy, which is most likely due to the increased moisture level at the substrate surface (3). The objective of this research was to determine the effect of fertilizer placement and irrigation method (specifically the introduction of irrigation water below the substrate surface) on plant and weed growth in production of *Quercus shumardii*.

On April 24, 2003, three gallon liners were potted into #15 containers (EG6900, Nursery Supplies Inc.) using an 8:1 (v:v) pinebark:sand medium amended with 3.0 $kg \cdot m^{-3}$ (5 lb/yd^3) of dolomitic limestone and 0.9 $kg \cdot m^{-3}$ (1.5 lb/yd^3) of Micromax (The Scotts Co.) micronutrients. Treatment design was a 3 x 2 x 2 factorial with two fertilizer placements, three irrigation methods, and two herbicide rates. Polyon (Purcell Technologies Inc.) 17N-2.9P-9.8K (17-7-12) was dibbled (placed 10.2 cm (4 in) below the surface of the container media at potting) or top-dressed at a rate of 280 g (7.4 oz) per container. Irrigation was applied using one of three methods: 1) a spray stake (Bowsmith, Inc. model JS-52) attached to an 11.4 liter (3 gal) per hour pressure compensating drip emitter (Plastro model 3245-0012); 2) a surface pressure compensating drip ring delivering water at a rate of 8.9 liters (2.34 gal) per hour (Netafim USA, Fresno, CA): and 3) the same drip ring placed 10.2 cm (4 in) below the container substrate surface. Rout® (oxyfluorfen + oryzalin, The Scotts Co.) was applied at 0 or 112 kg/ha (0 and 100 lbs/A). Herbicide applications were made with a hand held shaker and application was immediately followed by approximately 1.3 cm (0.5 in) of water applied evenly to the surface with a hand held water breaker.

Irrigation there after was applied as needed with each treatment receiving equal amounts of water.

Twenty prostrate spurge seeds (*Chamaesyce prostrata*) were applied to each container at 0 at 1 and 60 days after treatment (DAT). Data collected were weed number and percent weed coverage at 30, 45, 60, 75, 90 and 105 DAT, weed dry weight at 105 days DAT, tree height and caliper at 0, 30, 60, 90, 120 and 150 DAT, and root ratings at 165 DAT. The experimental design was a randomized complete block with 6 single plant replicates.

Results and Discussion: At 75 DAT containers with no herbicide and topdressed fertilizer had a percent weed coverage of 46% compared to 18% for dibbled containers with no herbicide. Weed top dry weight was also greater for topdressed containers compared to dibbled (Table 1). None of the treatments in the study had any effect on height increase (data not shown). Caliper increase was effected by an irrigation x fertilizer interaction (Table 2). Trees irrigated with drip rings at the surface had a 28% greater caliper increase among the dibbled fertilizer treated containers. Trees irrigated with the drip ring placed below the surface and fertilizer topdressed had the smallest caliper increase. Irrigation method had no effect on weed control in this study (data not shown), however a repeat fall application showed a significantly greater weed control with the drip ring below surface compared to the spray stake. This work further supports previous research which indicated topdressed fertilizer applications result in increased weed populations compared to dibbled applications. Further work needs to be conducted to determine the effects of irrigation placement on weed control and herbicide efficacy.

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Table 1. Effects of fertilizer placement on sapurge (Chamaesyce prostrata) control.

Fertilizer placement	Weed control	
	Percent coverage[z]	Top dry weight (g)[y]
	75 DAT[x]	75 DAT
Topdressed	45.8 a[w]	40.1 a
Dibbled	17.8 b	7.1 b

[z]Percent of container surface covered with weeds.

[y]Weed top dry weight in grams.

[x]Days after treatment.

[w]Means with different letters (within columns) are significantly different, seperated by Bonferroni t test (α = 0.05).

Table 2. Effects of a irrigation placement x fertilizer placement on caliper of *Quercus shumardii*.

Fertilizer placement	Irrigation method		
	Spray stake	Drip ring surface	Drip ring subsurface
		Tree caliper (cm)[z]	
Topdressed	1.86 a[y] A[x]	1.81 a A	1.25 b B
Dibbled	1.65 b A	2.11 a A	1.82 ab A

[z]Tree caliper increase in centimeters taken at 15.24 cm (6 in) above container surface.

[y]Means with different letters (within rows) are significantly different, seperated by Bonferroni t test (α = 0.05).

[x]Means with different letters (within columns) are significantly different, seperated by Bonferroni t test (α = 0.05).

Effect of Fertilizer Brand, Rate, Application Technique, and June Reapplication on Growth of *Amelanchier* x 'Autumn Brilliance'

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Index Words: Fertilization, Profit, Serviceberry, Environment

Significance to Industry: Precise fertilization practices can help producers maximize plant growth without wasting fertilizer or labor. While these data reflect just one study, growers may be able to fine-tune their fertilizer regime and create optimal fertilizer systems by experimenting with the following points: Growers using an 8-9 month controlled-release fertilizer may not realize any growth benefits to a summer reapplication. Growers using Polyon® may wish to incorporate to maximize caliper; growers using Osmocote Plus® may wish to top apply in order to maximize caliper. Growers may wish to fertilize with the high rate of Osmocote Plus® in order to achieve maximum caliper. Growers using Osmocote Plus® may wish to top apply in order to increase branching.

Nature of Work: Optimum fertilization practices are a critical component to profitable nursery crop production. Under-fertilization can reduce growth, lower quality, and cause unmarketable plants (2). Over-fertilization is wasteful and can cause plant damage (1). In addition, excess fertilizer can contaminate surface and ground water (3). Developing optimal fertilization regimes will allow growers to maximize growth in the most cost-efficient manner.

The objective of this research was to examine the effect of fertilizer brand, fertilizer rate, method of application, and summer reapplication on the height, caliper, and number of branches of *Amelanchier* x 'Autumn Brilliance'. On March 20, 2003, uniform A. 'Autumn Brilliance' whips were potted into trade 7 gallon, EG 2800 (24.6 L) containers (Nursery Supplies, Inc., McMinnville, OR) with a 5/8" locally available, aged, bark-based substrate and fertilizer treatments were applied. Polyon® (a polyurethane coated fertilizer) 18-4-8 with minors, 8-9 month release and Osmocote Plus® (an alkyd resin coated fertilizer) N&S 15-9-12, 8-9 month release were the fertilizers tested. Fertilizer treatments in March were the high and medium labeled rate and top-applying or incorporating each of the two fertilizers. Fertilizer applications were based on the labeled topdress rate. On June 6, 2003 summer reapplications were made. One-half of the of medium rate and one-half of the high rate of Polyon® 19-4-8 with minors, 5-6 month release and Osmocote Plus® 15-9-12, 5-6 month release were topdressed to the containers with corresponding March applications of medium and high rate applications of Polyon® of Osmocote Plus®. On June 6, 2003 the central leaders were pruned to 7 feet and lateral branches were pruned to 12 inches. The experiment was located on a gravel pad in Kirksey, Ky.

Electrical conductivity (EC) and pH were measured monthly with HI 9811 Portable pH/EC/TDS meter (Hanna Instruments, Inc., Woonsocket, RI) on leachate collected using the Virginia Tech Extraction Method (VTEM) (3). Caliper, height, and branch number were recorded on November 20, 2003. The experiment, a 2x2x2x2 factorial, was arranged in a randomized block design with 6 single plant replications. Data were subjected to statistical analysis using ANOVA and a mean separation with the PROC GLM procedure in SAS (SAS Institute, Cary, NC) at a p value of 0.05 or less.

Results and Discussion: Whether or not the trees received a summer reapplication (topdress) had no significant effect on the number of branches, caliper, or height (data not shown). No treatment had any impact on height (data not shown). This likely reflects the heading back pruning. The Osmocote Plus® treatments had significantly more branches than the control (Table 1). There was a rate by fertilizer brand interaction with regard to number of branches. There were significantly more branches with the high rate of Osmocote Plus® than the high rate of Polyon®. There was a method of application by fertilizer brand interaction. Method of application significantly affected the Osmocote Plus® treated trees with topdressing resulting in the greatest number of branches (11.9 Vs. 9.7 branches). Method of application had no effect on the number of branches for the Polyon® treated trees. There was a method of application by fertilizer rate interaction. Method of application had a significant effect on those trees treated with the high rate of fertilization. Topdressing resulted in more branches (10.6 Vs. 8.5) when plants were fertilized at the high rate. There were no significant differences observed for trees treated with the medium rate of fertilization. Trees treated with the high rate of Osmocote Plus® had significantly greater caliper than those treated with the high or medium rate of Polyon® or the control (Table 2). There was a fertilizer brand by method of application interaction for caliper. Incorporating the fertilizer significantly increased the caliper for the Polyon® treated trees, 1.7 cm compared to 1.5 cm for the topdressed, while topdressing significantly increased the caliper for the Osmocote Plus® treated trees, 1.8 inches compared to 1.6 inches for the incorporated treatment. All treatments led to EC levels that were high (> 0.5 mmhos/cm) at some point during the summer (4) (data not shown). These excess nutrients, when leached in rainfall and/or irrigation can endanger water quality.

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Acknowledgements: The authors thank Jamie Potts, Dava Hayden, and Todd Powell.

Table 1. Matrix of significance: number of branches on A. 'Autumn Brilliance'.

	Osmocote Plus® High (12.1)[z]	Osmocote Plus® Medium (9.7)	Polyon® High (7.1)	Polyon® Medium (8.8)	Control (6.0)
Osmocote Plus® High (12.1)	NA	*	*	*	*
Osmocote Plus® Medium (9.7)	*	NA	*	NS	*
Polyon® High (7.1)	*	*	NA	NS	NS
Polyon® Medium (8.8)	*	NS	NS	NA	NS
Control (6.0)	*	*	NS	NS	NA

*Indicates significant differences between compared means at 0.05 probability level.

[z]Branch means in parenthesis correspond with treatment listed in same cell.

Table 2. Caliper of A. 'Autumn Brilliance'.

Fertilizer brand	**Rate**	**Caliper (cm)**
Osmocote Plus®	High	1.79az
Osmocote Plus®	Medium	1.65ab
Polyon®	High	1.63b
Polyon®	Medium	1.59b
Control		1.38c

[z]Means with the same letter were not significantly different P<0.05 by LSD.

Effect of Fertilizer Rate on Growth of Seven Tree Species in Pot-in-Pot Production

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Index Words: growth response, height, leaf area, chlorophyll

Significance to Industry: Fertilizing with higher rates of fertilizer affected height, leaf color, and leaf size for some taxa tested, but had no influence on caliper for any of the taxa tested. While plants are not sized and graded based on leaf size or color, these differences would be readily apparent, particularly when the same taxa from multiple sources are displayed or stored in close proximity.

Nature of Work: Growers strive to maximize growth each season by optimizing fertilization practices and other inputs. Higher than recommended rates of fertilizer can contribute to nutrient leaching (5). Over-application can also reduce plant growth, cause damage (2), and be expensive. Under-application of fertilizer results in reduced growth and/or nutrient deficiencies, leading to plant stress and possible marketing problems. Good leaf color and new growth were important aspects of plant quality as measured by retail consumers (3).

The objective of this research was to determine the effects of fertilizing at two rates of Harrell's Inc. 18-5-10, 5-6 month release fertilizer on 7 taxa. The taxa tested were *Acer campestre, Acer x freemanii* Autumn Blaze®, Betula Renaissance Reflection™, *Malus* 'Spring Snow', *Prunus* 'Mt. St. Helens', *Quercus muhlenbergii*, and *Zelkova serrata*. Bareroot liners were potted into trade 15 gallon 6900 Econo-Grip™ (Nursery Supplies, Inc., McMinnville, OR) pots in Professional Grow Mix (Barky Beaver, Moss, TN) on May 13, 2002. Fertilizer was applied on May 15, 2002 and again on April 1, 2003. Two rates were used: the labeled medium rate, 100 grams (1x), and double the medium rate, 200 grams (2x). Plants were grown in a pot-in-pot system with cyclic irrigation. The experimental design was a randomized complete block design with 3 replications of each treatment.

On June 6, 2003 a SPAD 502 (Minolta Camera Co., Japan) chlorophyll meter was used to measure chlorophyll levels. Caliper readings were taken on June 11, 2003 and again on December 2, 2003. Leaf area was measured on June 13, 2003 on a LI-3100 (LI-COR Inc., Lincoln, NE). Height was recorded on December 2, 2004. Data were subjected to statistical analysis using ANOVA and mean separation with the PROC GLM procedure (SAS Institute, Cary, NC) at a p value of 0.05 or less.

Results and Discussion: There was an interaction between plant and replication on chlorophyll level. *B.* Renaissance Reflection™, *Q. muhlenbergii*,

A. Autumn Blaze®, *M.* 'Spring Snow', and *Z. serrata* had significantly higher levels of chlorophyll in the leaves from trees growing with the 2x rate of fertilizer than those growing with the 1x rate of fertilizer (Table 1). Due to plant mortality there were not enough plants to calculate an effect of rate on chlorophyll level for A. campestre and P. 'Mt. St. Helens'. There was no difference due to fertilizer rate on caliper development whether caliper was measured in June or December (data not shown). There were no significant interactions therefore error terms were pooled. The 2x fertilizer rate resulted in significantly taller trees for A. Autumn Blaze®, B. Renaissance Reflection™, and *Z. serrata*. Although the mean of the 2x rate leaf area was lower than the 1x rate for *Z. serrata* and M. 'Spring Snow' (Table 1), there was no statistically significant rate by taxa interaction. Across all taxa, trees fertilized at the 2x rate averaged significantly more leaf area than those trees fertilized at the 1x rate, 488.7 Vs. 354.3 cm^2, respectively.

Following a guideline of 3.0 grams of actual nitrogen per gallon container size (3.7 L) (1), a trade #15 (50.6 L) should receive approximately 41.0 grams of nitrogen. The 1x (medium) rate of 100 grams provided 18 grams of nitrogen. The high labeled rate of 120 grams would provide 21.6 grams of nitrogen. Both appear to be insufficient on some taxa. Sibley et al. (4) found that A. Autumn Blaze® had a June SPAD-502 average of 37 while the average 2x A. Autumn Blaze® value in this study was 28; this difference could be attributed to other factors other than fertilization.

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Table 1. Chlorophyll level, leaf area, and height of 7 taxa subjected to two fertilizer rates.

Taxa	Fertilizer Rate	Chlorophyll Level[z]	Leaf Area (cm^2)	Height (inches)
Acer x freemanii Autumn Blaze®	1x	24*	556	103*
Acer x freemanii Autumn Blaze®	2x	28*	804	122*
Acer campestre	1x	29	141	96
Acer campestre	2x	NE[y]	306	90
Betula papyrifera Renaissance Reflection™	1x	28*	619	104*
Betula papyrifera Renaissance Reflection™	2x	31*	831	130*
Malus 'Spring Snow'	1x	45*	211	62
Malus 'Spring Snow'	2x	50*	206	60
Prunus 'Mt. St. Helens'	1x	NE[y]	173	79
Prunus 'Mt. St. Helens'	2x	NE[y]	214	91
Quercus muhlenbergii	1x	33*	397	84
Quercus muhlenbergii	2x	40*	804	81
Zelkova serrata	1x	11*	384	59*
Zelkova serrata	2x	46*	256	95*

*Significant difference between the 1x and 2x rate of fertilizer for the individual taxa at the P= 0.05 level, each column assessed individually.

[z]Chlorophyll levels are unitless values.

[Y]Non-estimable data.

[X] 1x treatment was the medium rate (100 grams), the 2x rate was double the medium rate (200 grams).

Comparison of Canna (*Canna* 'King Humbert') and Willow (*Salix integra* 'Hakuro Nishiki') for Nitrogen and Phosphorus Uptake and Accumulation

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Key Words: Phytoremediation, Nutrient contaminants, Constructed wetlands, Nursery runoff, Nitrogen, Phosphorus, Water quality

Significance to Industry: The woody and herbaceous taxa used in this study thrived and absorbed N and P in a gravel-based screening experiment. They performed well at nutrient rates equivalent to the concentrations of N and P found in runoff, which suggests that some of these plants may be useful in a constructed wetland remediation system. Bilderback et al. (1993) reported on an aquatic plant production system designed to utilize the nutrients from catfish production ponds to produce salable plants. The plants in this study could also be commercially produced with nursery runoff without supplemental fertilization. The production area occupied by these plants would have the dual function of remediating nutrient pollutants and providing a saleable product.

Nature of Work: Commercial nurseries use large amounts of water and nutrients to produce container-grown plants. Excess water contaminated with N and P can impact the quality of surface water and groundwater. Earlier work by the authors found that constructed wetlands at a commercial nursery were highly efficient at removing N. However, phosphate (PO_4) removal was highly variable with uptake often coinciding with periods of active plant growth and heavy nursery use and net loss occurring during other periods. Landscape plants that remediate nutrients, especially P, would be very useful in constructed wetlands or production systems for commercial nurseries and greenhouses.

Porous gravel-based constructed wetlands have been of interest to Clemson University researchers as a way of remediating pesticide contaminated runoff from nurseries and golf courses (Wilson et al., 1999). Gravel-based systems were used successfully for treating sewage sludges (Lewis et al., 1982; Cooper and Boon, 1987). However, a drawback to these gravel-based systems is their longevity as they have a relatively short life span (10 to 15 yr) before replacement due to clogging and surface-ponding (Lewis et al., 1982; Cooper and Boon, 1987). To design a constructed wetland system to remediate both N and P contaminants for horticultural business, golf courses, and residential areas, we needed a suite of aesthetically attractive plant varieties that would thrive under anaerobic conditions and remediate levels of N and P found in runoff. To this end, we developed a screening test of commercially available landscape plants for their phytoremediation potential and their ability to thrive in a non-aerated pea gravel-based test system. Pea gravel was chosen as a medium because it has high hydraulic conductivity and low cation exchange capacity. While we examined a total of 19 species and cultivars in 18 genera during the study, only one woody and one herbaceous species are reported in this paper.

Liners of canna (*Canna* 'Yellow King Humbert') and willow (*Salix integra* 'Hakuro Nishiki') were washed free of planting medium, and transplanted to 6.5 inch azalea pots in pea gravel. Potted plants were placed in 1 gallon aquatic pots with rims even and watered with approximately 1.4 quarts (1350 mL) of 10% Hoagland's solution until water was visible through the gravel. After an acclimation period of 2 to 4 weeks, plants were washed with deionized water, and placed in a randomized complete block design with 6 replicates and five treatment levels of concentrations of Hoagland's solution. Experiments were replicated twice for each species. These treatment levels (concentrations given are nominal values) corresponded to a 0.1% solution (0.93 ppm NO_3; 0.095 ppm PO_4); 1% (9.3 ppm NO_3; 0.95 ppm PO_4); 5% (46.5 ppm NO_3; 4.75 ppm PO_4); 10% (93 ppm NO_3; 9.5 ppm PO_4); and 20% solution (186 ppm NO_3; 19 ppm PO_4). These concentrations fall within the range of nutrients used for nursery irrigation, those found in nursery runoff, and those found in constructed wetland discharge (high to low concentrations, respectively). Plants were watered as required every two days for 8 weeks for the herbaceous species and 13 weeks for the woody species. Total water usage, final fresh weight of shoots and roots, final dry weight of shoot and roots, and nitrogen and phosphorus content of shoot and root dry matter were measured. Data were analyzed using SAS (SAS Institute, Cary, NC) GLM procedure for the experimental model and LSD t-test for differences among treatment groups.

Results and Discussion: The willow Hakuro Nishiki is a better scavenger of nitrogen into shoots compared to yellow King Humbert canna although the canna can accumulate higher levels of nitrogen in its above ground shoots (see Figures 1-4). However, canna is the superior nitrogen scavenger for root tissues even though total uptake by the two species is similar. For phosphorus, yellow King Humbert canna is much better at P removal for both shoots and roots, both for scavenging phosphorus and for total uptake per gram of dry weight. There were significant differences in total biomass produced by the two species even though the willow grew for an additional five weeks. Yellow King Humbert canna averaged >50% more total dry weight than willow, primarily in root and below ground biomass. This suggests that yellow King Humbert canna would be the better candidate for a nutrient remediation wetland because it produces greater quantities of biomass and is the superior phosphorus scavenger.

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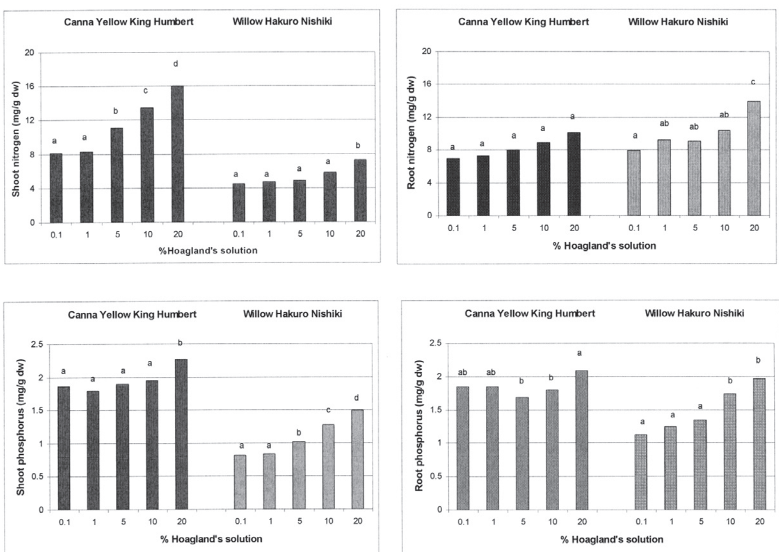
Figures 1-4. Comparison of shoot and root uptake of nitrogen and phosphorus (mg/kg dry weight) from 5 treatment levels of Hoagland's solution. Letters indicate significant differences among nutrient treatment levels within a species plant part at *P* < 0.05.



Effects of Vermicompost Amended Pine Bark on Basil Production

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Index Words: Worm Castings, *Ocimum basilicum L.*, Pine Bark

Significance to Industry: Vermicompost incorporated into pine bark substrates has potential to increase plant growth and nutrient levels. Amending pine bark substrates with vermicompost could also result in significant water savings at nurseries.

Nature of Work: A study was conducted at the NC State University Horticultural Sciences greenhouse to determine if vermicompost (VC) is a viable amendment for pine bark substrates to increase plant growth and/or water use efficiency (WUE). Vermicomposting is a proven approach for managing organic wastes by using earthworms to transform waste products (livestock, vegetative, and industrial wastes) into a stable by-product (vermicompost or worm castings). Many anecdotal reports have been put forth by farmers, gardeners, and horticulturalists as to the beneficial effects of VC.

Research conducted to evaluate the effects of VC added to container substrate has yielded mixed results. The waste product consumed by the worms has been shown to have a significant effect on plant response (1, 2). Increased growth of tomato and marigold plants was observed when amending a peat-based substrate with VC obtained from hog waste (3, 4). In addition to affecting plant growth, increasing rates of VC increased the container capacity (CC) or water holding capacity of a peat-based substrate (3). Very little research has been published using VC as a pine bark amendment to grow nursery crops. A "screening" study found inconsistent growth response results of a variety of different woody plants grown with substrate amended with vermicompost from difference sources. The inconsistencies were believed to be due to the variability among the different sources of vermicompost (5). No research has been published that quantify WUE when vermicompost is added to substrates.

The scope of this project included an evaluation of VC rates and whether the type of fertilizer used affects the response of the VC. The objective of our study was to determine the effect of VC on fertility, pH, plant growth, and WUE in a pine bark substrate. The study was a 4 x 5 factorial in a randomized complete block design with six single plant replications. The substrate was pine bark screened to 1/2 in (12.7 mm) and all treatments were blended volumetrically. The main factors were four VC rates (0%, 5%, 10%, and 20% by vol.) and five fertilizers (none, 8-5-5, 10-2-8, 19-5-9, and 19-5-13). VC was produced using hog waste as the food stock (Vermicycle Organics, Charlotte, NC). The fertilizers were selected to provide different nitrogen sources, which included two organic-based fertilizers 8-5-5 (organic N – meat meal) and 10-2-8 (organic N – meat and feather meal) (Nature Safe, Cold Spring, KY); two inorganic or controlled release fertilizers (CFR) 19-5-9 (urea) and 19-5-13 (nitrate and ammonium) (Harrell's, Sylacauga, AL); and a no fertilizer treatment. Fertilizer was applied at a rate of 5 g N/gallon (1.1 g N/L), and dolomitic lime was applied at a rate of 2 lbs/yd^3 (1.8 Kg/m^3) to the 0% VC treatment. No lime was added to the remaining treatments.

Basil (*Ocimum basilicum* L.) was selected as an indicator species. Seeds (Johnny's Selected Seeds, Winslow, ME) were sown in 96-cell flats on Sept. 24, 2003 in Fafard 4P Mix Professional Formula (Agawam, MA). No additional fertilizer was added. Two weeks after sowing, seedlings were transplanted into the four worm casting amended substrates in 4-inch (10-cm) containers [43 in^3 (710cm^3)] and topdressed with the fertilizer. Potted plants were placed in a greenhouse [average day/night temperatures 75°F (24°C)/ 65°F (18°C)], hand watered, and weighed to determine container capacity (CC). Irrigation was managed by weighing the pots daily and irrigating when each container lost 50 to 60% available water (AW) (available water determined in the NCSU Hort Substrate Lab; procedures described by Tyler et al.,1993). Upon loss of 50 to 60% AW, plastic saucers were placed beneath the plants, and irrigation was hand applied according to the following calculation based on gravimetric measures to achieve a 0.2 leaching fraction:

$$V = [(LF \times ET) / (1-LF)] + ET$$

V = Irrigation volume;

LF = Leaching fraction (volume leached / volume applied); and

ET = Evapotranspiration (mass at cc – mass before irrigation).

Thirty minutes after irrigation water was applied, the leachate in the saucers was reapplied to the container surface (to ensure adequate substrate wetting). After another 30 minutes, the 0.2 leaching fraction was verified, and the leachate was discarded.

Substrate solution was collected weekly on three replications via the pourthrough technique to measure pH and electrical conductivity (EC). Plants were grown for five weeks. On Nov. 12, 2003 plants were harvested and separated into roots, stems, and leaves. Leaf area was obtained on three replications. Plants were dried at 149°F (65°C) for 5 days prior to obtaining dry weights. Water use efficiency (WUE) was calculated for each plant by the following equation: WUE = total irrigation water applied during the 5-week study (ml) / total plant dry mass (g). All data were subjected to analysis of variance and treatments means were separated by Fishers protected LSD, $P = 0.05$ (SAS Institute, Cary, NC). There was no fertilizer x worm castings interaction.

Results and Discussion: The no fertilizer treatments produced very small, unsalable plants, as indicated by the total dry weight (Table 1). We concluded that VC alone did not provide adequate fertility to grow a containerized basil crop, or that the VC did not served as a complete fertilizer source. As a result, the no fertilizer treatment was removed and the data were reanalyzed as a 4 x 4 factorial.

Basil growing in the 20% VC rate showed a significantly greater growth response than basil grown in the 0%, 5%, and 10% VC rates, with 19% greater dry weight than 0% and 10% VC and 65% greater dry weight than 5% VC (Table 2). These results are consistent with other reports that VC increases plant growth. However, the mechanism has not been determined. Possible variables associated with the VC that may be responsible for increased growth include fertility, pH adjustment, substrate physical properties, microbial activity, and/or organic matter components.

The 20% VC rate significantly increased WUE compared to 5% VC, with 43% less water use per gram of dry tissue (Table 2). Although no statistical difference was indicated, the 20% VC used 13% less water per gram of tissue than the 0% or 10% VC.

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Table 1. Effect of fertilizer on total plant dry weight of basil

Fertilizer	Total Dry Weight[z] (g)
8-5-5	2.80 ± 0.06[y]b[w]
10-2-8	2.69 ± 0.06 b
19-5-9	4.13 ± 0.05 a
19-5-13	4.38 ± 0.05 a
None	0.37 ± 0.05 c

[z]Total plant dry weight = leave + stem + root.

[y]Standard Error.

[w]Means within columns followed by the same letter are not significantly different as determined by Fisher's protected LSD, $P = 0.05$.

Table 2. Effect of vermicompost rate on total plant dry weight and water use efficiency.

Rate of Vermicompost (% by volume)	Total dry weight[z] (g)	Water Use Efficiency (WUE)[y] (ml/g)
0	3.66 ± 0.20[w]a[v]	796 ± 53 b
5	2.62 ± 0.29 c	1208 ± 119 a
10	3.65 ± 0.26 a	788 ± 43 b
20	4.33 ± 0.32 b	694 ± 46 b

[z]Total plant dry weight = leave + stem + root.

[y]WUE = millliters water ÷ g total dry mass.

[w] Standard Error.

[v]Means within columns followed by the same letter are not significantly different as determined by Fisher's protected LSD, P = 0.05.

Costs of Establishing and Operating Container Nurseries Differentiated by Size of Firm, Zone 7

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Index Words: Economics, Costs, Container Production, Size and Scale, Budgets

Significance to Industry: To make more informed decisions as to whether to enter, leave or expand container production, nursery producers require production, marketing and financial information. Complete cost models for production of container-grown nursery crops representing five categories of container-grown production schemes and two sizes of nurseries were developed, as appropriate for climatic zone 7. Information was derived so as to provide a basis for decision-making for those evaluating the profitability of establishing a new container nursery, expanding a greenhouse operation to include container production or expanding an existing container nursery, or shifting from field production to container production.

USDA reports floriculture and nursery crop production is experiencing a decline in the number of growers and average sales per acre of production area. USDA also cites the addition of more open-field and container production area to existing farm acreage, while keeping greenhouse and covered acreage unchanged. Despite the advantages offered by year-round greenhouse production, greenhouses are expensive to build and operate, particularly with respect to higher fuel and energy costs for heating and cooling. In addition, as overall demand for ornamental crops has weakened, growers have increasingly resorted to container and open-field production, apparently in a quest for larger market share.

Nature of Work: Container production of nursery crops allows greater flexibility in production and marketing, and at least in some cases container production is less expensive than field production. Consequently, escalating competition and narrowing profit margins make it imperative that nursery growers systematically determine production costs, including fixed, variable, and overhead costs.

Several Southern Cooperative Series Bulletins dating from the 1980s were published by members of the S-103 research technical committee (currently known as S-290). Procedures and data developed by these earlier comprehensive studies have proved useful as a template and as complementary to this analysis. In this economic analysis, two model firms were synthesized using the economic engineering conceptual framework wherein the best management practices were included in each model. The complete model included developing appropriate production cycles for representative species of five plant categories, identifying the resources (land, buildings and structures, machinery and equipment, labor and capital) necessary to accomplish the production, and developing fixed and variable cost budgets to determine the annualized cost per salable plant for each of the five plant groups.

A model facility was developed for both a small (20-acre) and large (40-acre) nursery with 10- and 20-acre growing areas, respectfully. The five plant groups for whom production cycles were modeled for a representative species included azaleas, narrow-leaf evergreens (*Juniperus*), broadleaf evergreens (*Ilex*), deciduous shrubs (crapemyrtle), and deciduous ornamental trees (*Acer rubrum*). The marketing assumptions were that approximately 1⁄3 of the azaleas, 1⁄4 of the evergreens, and 1⁄2 of the deciduous shrubs and trees are sold during the fall after each crop reaches marketable size. The remaining plants in each plant group were sold the following spring. The costs of holding plants were estimated and included in the budgets for each plant group and each size of nursery.

Results and Discussion: Fixed costs for all plant categories accounted for a greater proportion of total costs in the smaller, 20-acre nursery than the larger, 40-acre nursery, averaging 68-percent in the small nursery and 30-percent in the large container production nursery. This is attributed to more efficient use of buildings and structures, and machinery and equipment in the larger facility. As for the representative species selected for the five groups of container grown nursery plants, cost differences were caused primarily by container-spacing requirements (azaleas, hollies, junipers, and crapemyrtles were produced in standard 1-gallon nursery pots, while the red maples were produced in 3-gallon containers), over-wintering costs, and labor requirements (hours). Calculations were based on 2003 inputs prices and data obtained from wholesale nurseries and nursery suppliers, primarily in Georgia.

The estimated capital requirements for the 20-acre container nursery totaled $881,670 – land and improvements, $211,568; buildings and structures, $300,000; and machinery and equipment, $370,102. The number of salable plants in the production cycle was 432,634, for an average capital investment per salable plant of $2.04. Total annual fixed costs for the 20-acre container nursery were estimated to be $279,198 – land and improvements, $21,677; buildings and structures, $42,000; machinery and equipment, $80,894; general overhead, $129,029; and interest on general overhead, insurance and taxes, $5,598 – for an average total annual fixed cost of $0.65 per salable plant. The estimated capital requirements for the 40-acre container nursery added to $1,557,990, of which $423,120 was for land and improvements, $483,875 for buildings and structures, and $650,995 for machinery and equipment, including irrigation. The average total capital investment per salable plant in the large nursery was $1.80, based upon 865,265 salable plants in the production cycle. Total annual fixed costs for the 40-acre container nursery were estimated to be $442,063 -- $50,121 for land and improvements, $67,743 for buildings and structures, $142,290 for machinery and equipment, $174,236 for general overhead, including owner-manager costs, and $7,673 for interest on overhead, insurance and taxes – for an average total annual fixed cost of $0.51 per salable plant.

Total production costs per salable plant by representative species in the 20-acre nursery with 10-acres of container production were $1.65 for 1-gallon junipers (98,011 salable plants) and hollies (103,455 salable plants), $1.71 for 1-gallon crapemyrtles (94,744 salable plants), $2.03 for 1-gallon azaleas (98,010 salable plants), and $11.20 for 3-gallon red maples (19,602 salable plants), or an average total cost per saleable plant for the 20-acre container nursery of $2.01. For the larger, 40-acre container nursery with 20 acres in container production, comparable figures were $1.45 for 1-gallon junipers (196,020 salable plants) and hollies (206,910 salable plants), $1.54 for 1-gallon crapemyrtles (189,486 salable plants), $1.93 for 1-gallon azaleas (196,020 salable plants), and $10.05 for 3-gallon red maples (39,204 salable plants). The average total cost per salable plant from the larger nursery was $1.72.

Conclusions: Due to the increasing interest in container production, the economic requirements for land, equipment and labor, the enterprise budgets for five representative container production schemes, and fixed and variable cost budgets for two different sized model nurseries were developed. For the larger, 40-acre container production nursery, the production costs were slightly less due to more efficient use of machinery, equipment, buildings, greenhouse structures, and similar overall inputs used over the entire nursery. Cost differences among crops varied mainly due to production time and production procedure differences.

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Container Nursery Liability Waiver for Nitrates in Ground Water

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Index Words: Proactive, Container plant production

Significance to Industry: Nursery operators had the opportunity to participate in a process to develop a voluntary incentive-based regulation that was a consensus of nursery and regulatory personnel regarding the best fertilization and irrigation cultural practice information available for producing plants in containers. Nursery operators who voluntarily implemented these practices received a waiver of liability from the recovery costs associated with the cleanup of ground water contaminated with nitrate nitrogen if each of the following activities had taken place: 1) a notice of intent was filed with Florida Department of Agriculture and Consumer Services to implement accepted practices, 2) practices based on consensus of the industry were used and guidelines followed, and 3) fertilization and irrigation records were maintained.

Nature of Work: Recognizing that ground water can have nitrate concentrations above the 10-ppm drinking water standard, the Florida Legislature in 1994 passed legislation referred to as the Nitrogen Best Management Practices Program. This was a significant event for all of Florida agriculture in that it facilitated a proactive approach for agricultural industries to ensure they were not contaminating ground water. The legislation provided for the development of Best Management Practices (BMP) that specifically related to nitrates in ground water. Best Management Practices, as addressed in the legislation, are proactive production practices that are proven by research to be beneficial in minimizing or preventing groundwater contamination from nitrate nitrogen. Additionally, the legislation provided for interim measures. Interim measures are management practices that users and regulatory personnel believe will result in minimal to no groundwater contamination from nitrates but are not yet supported by research. This legislation provided for a waiver of the cost of remediation of drinking water wells if contamination from nitrates had occurred after voluntary adoption and implementation of BMPs and/or interim measures. The Florida Nursery, Growers and Landscape Association (FNGLA) and Tampa Bay Wholesale Growers, LAA capitalized on this opportunity and facilitated the process for development of the Interim Measure for Florida Producers of Container-Grown Plants (http://www.floridaagwaterpolicy.com).

Results and Discussion: The Interim Measure focuses on fertilization and irrigation. Three possible management strategies are considered with regard to fertilization and a nursery operator implements the strategies applicable to his/her nursery to participate in the Interim Measure program.

First, electrical conductivity or concentration of nitrate nitrogen in the substrate must be monitored at least once a month. Substrate electrical conductivity is an indicator of fertilizer salts in the container. Consequently, for the monitoring requirement of the Interim Measure, electrical conductivity maybe monitored in lieu of nitrate nitrogen. However, it is advisable to periodically monitor nitrate nitrogen and other essential nutrients to ensure adequate concentrations are maintained in the container substrate. Sufficiency ranges and an explanation of sampling methods, including how many plants to sample, are given in the *Implementation Guide for Container-grown Plant Interim Measure*, which is available at http://edis.ifas.ufl.edu. The second consideration is whether nitrogen is applied in overhead irrigation water. If so, the runoff water must be retained and reused unless container spacing allows for an exemption. Another option is to convert overhead sprinkler irrigation to microirrigation or low volume delivery systems (see the Interim Measure text for details http://www.floridaagwaterpolicy.com). Third, bulk substrate that contains nitrogen fertilizer should have an impermeable barrier above and below the substrate during storage. A plastic sheet will suffice for an impermeable barrier. The barrier over the bulk substrate may be omitted if runoff water is collected and reused.

The other important focus of the Interim Measure is irrigation. Strategies for consideration with regard to irrigation are mentioned below. A nursery operator implements the strategies applicable to his/her nursery to participate in the Interim Measure program. Overhead sprinklers and microirrigation systems should be checked to ensure water is delivered uniformly. Non-uniform delivery will result in too much water in some areas (causing excessive leaching of nutrients from container) and insufficient water in other areas. Uniformity should be checked once a year close to the pump and far away from the pump for each irrigation system that is infrastructurally or uniquely different. Guidelines for determining uniformity are given in the *Implementation Guide for Container-grown Plant Interim Measure*, which is available at http://edis.ifas.ufl.edu. Test results for substrate electrical conductivity or nitrate nitrogen, and irrigation uniformity should be recorded and records saved in case they are needed to verify participation in the Interim Measure program. Participation by following the Interim Measure practices is voluntary and should be of minimal burden; however, records must be kept. Examples of record keeping formats, presented as forms for nursery operators to modify or use as presented, are available with the Interim Measure at http://www.floridaagwaterpolicy.com. Any format for the records may be used as long as the information is recorded and retained indefinitely.

To participate in the Interim Measure program and to receive a waiver of state-imposed liability for ground water contaminated with nitrate nitrogen, container nurseries and greenhouses must do the following.

1. Complete the Notice of Intent form and send to Florida Department of Agriculture Office of Agricultural Water Policy, 1203 Governors Square Blvd. Suite 200 Tallahassee, FL 32301.
2. Implement pertinent fertilization and irrigation practices, which are outlined in the Interim *Measure for Florida Producers of Container-grown Plants*.
3. Maintain records as suggested in the Interim Measure. A copy of the Interim Measure and example record forms may be printed from http://www.floridaagwaterpolicy.com.

In conclusion, the nursery industry in Florida provided input to the process for development of a voluntary, incentive-based regulation to address groundwater quality concerns. This process, which relied on industry and regulatory personnel consensus, was different than the traditional process for developing regulations. Additionally, the experience and confidence gained from the process was important because the nursery industry reached a consensus and committed to make changes when a crisis did not exist. It brought to the forefront an urgency of proactiveness and a sense of how one's small involvement can contribute to something that was unachievable alone. This experience will be invaluable as the industry embraces future urban challenges.

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Monitoring Phosphorus and Nitrate Nitrogen in Above Ground Porous Container

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Index Words: Suction Lysimeter, *Quercus virginiana* Mill., Live Oak

Significance to Industry: Nitrate nitrogen and phosphorus concentrations in substrate of above ground soft-sided porous container (≈ 30 gallon) with controlled-release fertilizer and in adjacent native soil were monitored for 5 months using suction lysimeters. Phosphorus concentrations were higher in container substrate than in native soil throughout the monitoring period. Nitrate nitrogen concentrations were higher in container substrate than in adjacent native soil for the first 6 weeks of monitoring. For three of the four monitoring dates during the first 6 weeks, nitrate nitrogen concentrations in the container substrate were above 15 ppm, the lower limit for production. Nitrate nitrogen concentrations in the native soil on these same dates were below 10 ppm, the maximum allowable concentration in drinking water. Thereafter, nitrate concentrations in the container substrate decreased and were similar to concentrations in native soil, ranging from 2.8-3.2 ppm for the last 4 weeks.

Nature of Work: A new production method involves placing a large soft-sided porous container (≈ 30 gallon) on the native soil surface and filling with substrate commonly used for a similar-sized rigid plastic container. Substrate nutrition of large plastic, rigid containers is commonly monitored using suction lysimeters (Wright et al., 2001). The purpose of this investigation was to monitor the substrate nutrition of a soft-sided porous container and obtain preliminary data regarding the movement of water-soluble phosphorus and nitrate nitrogen from porous container to adjacent native soil. Nineteen seedling live oak trees (*Quercus virginiana*, container size #3) were planted May 5, 2003 with a commercially prepared 6 pine bark: 4 Florida peat: 1 sand substrate (by volume) in soft-sided porous non-woven polypropylene containers called "The Smart Pot" (Root Control, Inc., Oklahoma City, Oklahoma). Each soft-sided porous container was 24 inches in diameter and ≈16 inches high with the bottom made from 10-ounce/square yard non-woven polypropylene. The substrate was amended with dolomitic limestone (pH 5.5 – 6.0). Florikan® Blend 15-4-9 controlled-release fertilizer (Florikan, Sarasota, Florida) was applied during potting by distributing 1 pound of fertilizer around the roots of the transplant as the porous container was filled with substrate. Trees were placed 5 feet apart in a guy-wire supported row at Sun City Tree Farm, Ruskin, Florida and were watered as needed via Chapin spray stakes type P [(0.6 quarts/minute≈12 psi) Chapin Watermatics, Inc.,Watertown, New York]. Harrell's 17-8-8 (≈0.5 lb/container, Harrell's, Inc., Lakeland, Florida) was surface-applied on July 15, 2003.

Two suction lysimeters (2 x 24 inches, 7.3 psi porous tip, Soilmoisture, Equipment Corp., Santa Barbara, California) were installed on August 21, 2003. One lysimeter was placed 2 inches away from the north sidewall of the fourth porous container within the row and inserted to the bottom of substrate. A second lysimeter was positioned adjacent to the first, but 2 inches outside the porous container and was placed 6 inches deep in Myakka fine sand, which is native to the area. Solution samples were removed from lysimeters (Wright et al., 2001) approximately every 2 weeks until January 21, 2004. Water-soluble phosphorus and nitrate nitrogen concentrations of samples were determined by standard analyses at University of Florida Analytical Research Laboratory. Caliper (6 inches above substrate) and height of six trees averaged 0.5 inch and 6 feet, respectively, on May 5, 2003 and 1 inch and 9.8 feet, respectively, on January 9, 2004.

Results and Discussion: Phosphorus concentrations were higher in the container substrate than in the native soil (Figure 1). However, phosphorus concentrations in the container were below the desirable concentration of 5 ppm (Yeager et al., 1997) necessary for optimal growth. A similar trend was observed for nitrate nitrogen (Figure 2), particularly during the first 6 weeks of monitoring (until October 10, 2003) when nitrate nitrogen concentrations in container were higher than in native soil. During the first 6 weeks except for September 23, nitrate nitrogen concentrations in container were higher than 15 ppm, which is the lower limit for desirable growth (Yeager et al., 1997), yet nitrate concentrations of the native soil were less than 10 ppm (drinking water standard). Nitrate nitrogen concentrations in the container and native soil were 13 and 11 ppm, respectively, on September 23.

During the first 8 weeks of monitoring, it appeared that nitrate nitrogen concentrations in the porous container had an impact on nitrate nitrogen concentrations in the native soil adjacent to porous container. As nitrate nitrogen concentration in the porous container decreased on the September 23 and October 22 monitoring dates, a concomitant increase in nitrate nitrogen in native soil was observed. Native soil nitrate nitrogen concentrations for all sampling dates averaged 2.8 ppm, except on September 23 and October 22 when higher concentrations were observed. After November 6, nitrate nitrogen concentrations in the container substrate were similar to concentrations in adjacent native soil, ranging from 2.8 to 3.2 ppm.

Based on this evaluation, nursery operators can expect nutrition of above ground soft-sided porous container to impact nutrition of adjacent native soil. Lysimeters provided a quick and simple means of repetitively monitoring nutrition of the soft-sided porous container and monitoring nutrients in the native soil.

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Figure 1. Phosphorus concentrations in Myakka fine sand native soil and adjacent soft-sided porous non-woven polypropylene container with 6 pine bark: 4 Florida peat: 1 sand substrate (by volume) amended with 1 pound Florikan® Blend 15-4-9 controlled-release fertilizer at time of planting (May 5, 2003) live oaks. Two months later, Harrell's 17-8-8 (≈0.5 lb/container) was surface-applied.

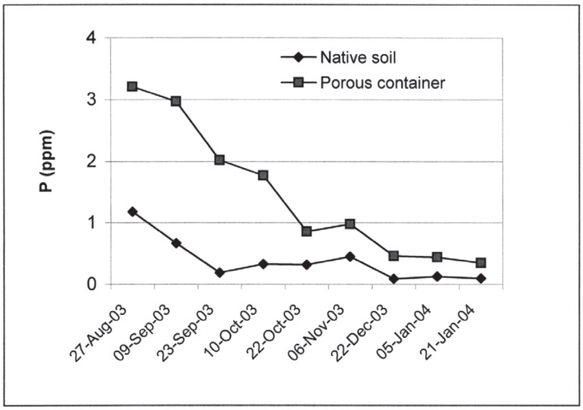

Figure 2. Nitrate nitrogen concentrations in Myakka fine sand native soil and adjacent soft-sided porous non-woven polypropylene container with 6 pine bark: 4 Florida peat: 1 sand substrate (by volume) amended with 1 pound Florikan® Blend 15-4-9 controlled-release fertilizer at time of planting (May 5, 2003) live oaks. Two months later, Harrell's 17-8-8 (≈0.5 lb/container) was surface-applied.