

Container-Grown Plant Production

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'Amelia Rose' Azalea Branching Habit Affected by PGR Applications

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Index Words: plant growth regulator, branching agent, cyclanilide, gibberellic acid, 6-benzyladenine, woody ornamentals

Significance to Industry: One desired characteristic of ornamental plants for nursery production is a good branching habit. Many woody ornamental species do not branch adequately when grown from small liner plants in the nursery. These plants have to be pruned frequently in order to produce a compact and well branched product. Plant growth regulators may improve branching of woody ornamentals and reduce production cost with fewer pruning events and shorter production cycles.

Nature of Work: 'Amelia Rose' is an azalea cultivar with appealing flowers but undesirable branching habit (Fig. 1). It was recommended by growers for this study because plants are marketable only when they have flowers. Cyclanilide (CYC) has been reported to increase lateral branching of apple and sweet cherry (1). 6-benzyladenine (6BA) was reported to induce bud growth and branching of spruce and Ilex seedlings at a low rate (2, 3). Gibberellic acid (GA) in combination with 6BA increased shoot numbers of apple trees but effect of GA application was unclear (4). The objectives of this study were to (i) determine the effects of cyclanilide, Fascination (6BA+GA₄₊₇), MaxCel (6BA), and NovaGib (GA₄₊₇) on branching and growth of 'Amelia Rose' azalea; and (ii) determine the timing and application frequency of cyclanilide for its use on this cultivar.

'Amelia Rose' plants were provided by Jenkins Farm & Nursery (Amite, LA). Plants were potted into # 1 pots on 21 March, 2006 and 14 February, 2007 in Experiment 1 and 2, respectively. Potting medium was MetroMix 700 amended with Osmocote 14-14-14 (14N-6.2P-11.6K) at 1 lb N/yd³. Plants were grown under an outdoor shade structure covered with black shade cloth to provide 35% light reduction. In Experiment 1, a total of 100 plants with uniform growth in terms of number of branches and plant height, were divided into two groups: pruned or left un-pruned, respectively, before PGR treatments. Fascination (Valent Inc.), MaxCel (Valent Inc.), and NovaGib (Fine Americas) were applied as foliar spray at 100 ppm, and CYC was applied at 112 ppm as a single spray or two applications at a two-week interval. Distilled water was applied as control. Plants in the un-pruned group were treated on 4 April, when new shoot growth was visible. Plants in the pruned group were pruned on 30 March, 2006 when majority bloom ended and treated with PGRs on 14 April, 2006 when new growth was visible. Each treatment

had 10 replications (pots) in a completely randomized design. Ninety plants with uniform growth were selected and potted for Experiment 2 with 10 plants for each treatment. Fifty plants were pruned on 7 April, 2007 then treated with CYC at 112 ppm at different timing and treatment frequency (Table 2). Ten plants were treated with CYC on 30 March then pruned on 7 April. Thirty plants served as un-pruned controls (Table 2). In both experiments, plants were evaluated for numbers of new shoots, plant height and branch diameter during ten weeks after treatments (WAT). New shoots were defined as new leaf bud break followed by elongation from any position of a plant. Plant height was measured from the rim of pot to the tallest point of all the inflorescences of a plant with open flowers. Branch diameter was calculated as the average diameters of all primary branches measured by a dial caliper. Phytotoxicity was rated on a scale from 0 to 10 (where 0 being no injury, 1 to 2 represent minor or transient injuries, 3 to 5 represent moderate injuries, 6 to 9 represent severe injuries, and 10 being total plant death) two days after treatments. Overall plant quality was rated on a scale of 1 to 10 (where 1 represents plant death, 1 to 5 represent plants to be discarded, 6 to 8 represent sale at a discounted price, and 9 and 10 being premium quality) were rated weekly after treatments. Data were analyzed with analysis of variance (ANOVA) by using SAS General Linear Models. Differences between treatment means were compared by Fisher's LSD.

Results: In Experiment 1, PGR treatments did not increase number of new shoots of the un-pruned group (Table 1). In the pruned group, CYC at 112 ppm treated once one week after pruning or twice at one and three weeks after pruning resulted in increased numbers of new shoots compared to other treatments. Plant height was not affected by PGR treatments regardless of pruning practices. Branch diameter in CYC treatments was smaller than other treatments, which may be caused by the growth of more number of new shoot. However, this reduced diameter did not affect plant overall ratings (data not shown).

In Experiment 2, CYC did not promote branching when applied to un-pruned plants even when plants were in active growth at the time of treatment (Table 2). When applied 2 weeks after pruning where new growth was visible but foliage had not expanded yet (Fig. 2), CYC significantly increased number of new shoots per branch to 10.7 compared to un-pruned untreated and pruned untreated plants (3 and 7.5, respectively). Plants treated with a single application two weeks after pruning had similar numbers of new shoots per branch as the two applications at weeks 2 and 4 (Table 2). Plants treated one week before pruning (with active new growth) then pruned also had higher numbers of new shoots per branch. However, CYC did not increase new shoot number when plants were treated 4 weeks after pruning when new growth had expanded young leaves.

In summary, 'Amelia Rose' responded to CYC treatments with an application window from a week before to two weeks after pruning. Plant may not respond to treatment at a later stage i.e. 4 weeks after pruning when new foliage had expanded. Increased new shoots with effective treatment emerged along the branch. More than one new shoots were observed emerging from a single leaf node.

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Table 1. Plant height, average branch diameter, and numbers of new shoots per branch of 'Amelia Rose' azalea treated with foliar application of plant growth regulators at 8 WAT in Experiment 1.

PGR Treatment	Pruned			Un-pruned		
	Plant Height (cm)	Branch Diameter (cm)	No. of New shoots/Branch	Plant Height (cm)	Branch Diameter (cm)	No. of New shoots/Branch
CYC - single appl.	54.5 a ^z	0.93 ab	7.8 a	34.3 a	1.09 b	3.2 a
CYC - 2 appl.	58.2 a	0.82 b	7.3 a	36.1 a	1.02 b	2.7 a
Fascination	52.9 a	1.05 a	4.9 b	37.0 a	1.14 ab	2.8 a
MaxCel	57.4 a	1.01 a	5.3 b	34.6 a	1.08 b	3.0 a
NovaGib	51.6 a	1.0 a	5.7 b	34.1 a	1.09 b	2.6 a
Control	52.5 a	1.01 a	5.0 b	35.4 a	1.23 a	3.0 a
LSD _{0.05}	7.49	0.14	1.6	3.89	0.13	0.82

^zMeans followed by different letters within columns are significantly different at $P = 0.05$ according to Fisher's LSD.

Table 2. Numbers of new shoots per branch in ‘Amelia Rose’ azalea treated with cyclanilide at 112 ppm applied at various dates and frequency. Week 0 was when plants were pruned.

Treatment	Number of New Shoots per Branch ^Y
Non-pruned untreated control	2.7 c ^Z
Non-pruned control, CYC at week 2	3.0 c
Non-pruned control, CYC at weeks 2 and 4	3.0 c
Pruned (week 0), untreated control	7.5 b
CYC at 1 week before pruning, Pruned (week) 0	9.7 a
Pruned (week 0), CYC at week 2 (visible new growth)	10.7 a
Pruned (week 0), CYC at weeks 2 and 4	9.5 a
Pruned (week 0), CYC at week 4 (new leaves expanded)	7.1 b
Pruned (week 0), CYC at weeks 4 and 6	7.8 b

^ZMeans followed by different letters within columns are significantly different at $P = 0.05$ according to Fisher’s LSD.

^YData shown were collected at 8 weeks after pruning if not treated with CYC, or the first CYC treatment applied in a treatment regime if treated with CYC.

Figure 1: Un-pruned and PGR untreated azalea cultivar ‘Amelia Rose’ showing acceptable flowers (A) but undesirable branching habit (B).

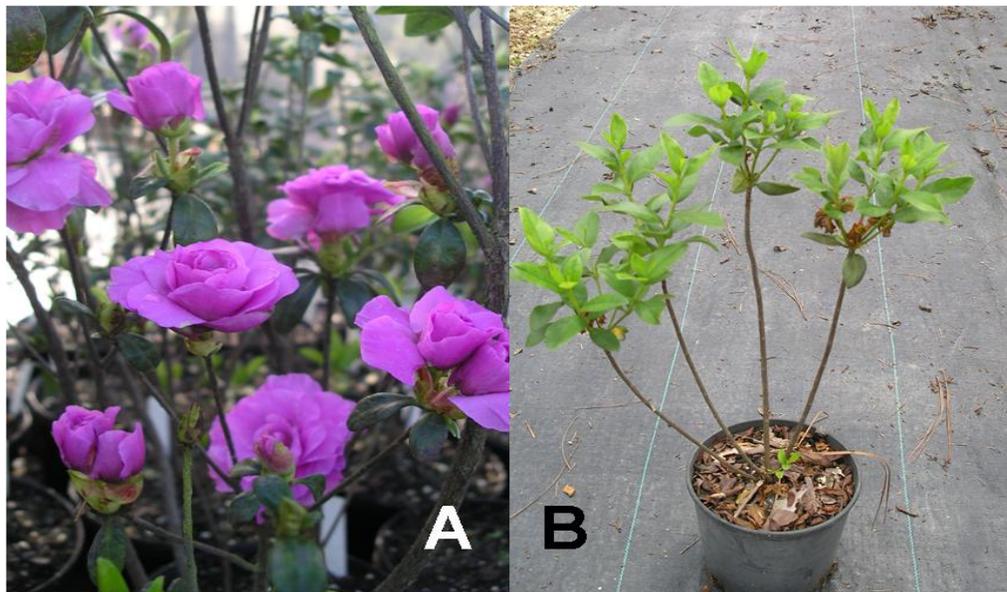


Figure 2: Pruned, PGR untreated control plants in Experiment 2 showing stages of new growth at 2, 4, and 6 weeks after pruning.



Evaluation of Composted Poultry, Whole Tree, and Clean Chip Residual as Components of Media for Container Grown Nursery Woody Ornamentals

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Index Words: Composted poultry litter, alternative substrate, woody ornamentals

Significance to Industry: This study evaluated composted poultry litter as an amendment in pine bark, whole tree, and clean chip residual substrates for use in container production of five woody ornamental species. Results indicate that woody ornamentals can be grown in whole tree, and clean chip residual substrates 6:1 (v:v) basis with composted poultry litter. Use of composted poultry litter in whole tree and clean chip residual substrates could provide an alternative to traditional pine bark and peat based combinations in container production while providing poultry producers an environmentally sound means of waste disposal.

Nature of Work: Pinebark (PB) and pine bark plus peat (P) are the predominant substrate components for container production in the southeastern United States (1). The growing concerns over the future availability of pine bark, high shipping costs associated with peat and the argument that it is a relatively non-renewable resource, has lead researchers to explore alternatives to these two commonly used substrate components (1,2,3).

Whole Tree (WT) consists of entire pine trees (*Pinus taeda* L.) which are harvested from pine plantations at the thinning stage and chipped whole and later ground into smaller sizes based upon crop specification (1). WT is made up of wood, bark, limbs, needles, cones, and used fresh after grinding. Studies by Fain suggest that WT can be used sustainably in production of short term horticultural crops (2).

Mobile field equipment is now being used in pine tree harvesting operations which process trees into 'clean chips' for pulp mills leaving behind a product composed of approximately 50% wood, 40% bark, and 10% needles (1). This material, referred to as 'clean chip residual' (CCR) is either sold as boiler fuel or spread across the harvesting area. CCR accounts for about 25% of the total biomass harvested and with the millions of acres in the southeast in forestry production, CCR has the potential to provide an economical media alternative for the nursery industry (1).

One of the largest problems in modern agricultural operations is the large amount of waste generated by intense animal production in concentrated areas. These wastes which pose environmental concerns were once thought to have little economic value but

now it is known that the nutrients found in animal manure can provide an economical alternative to costly inorganic fertilizers and soil amendments. Fertilizer prices rise with the cost of natural gas which is the primary raw material used to produce ammonia (5). National composite fertilizer prices increased 113% between 2000 and 2007 due to increases in nitrogen costs. During this seven-year period the price of ammonia, the main source of nitrogen in fertilizer production, increased 130% and the price of urea, the primary solid nitrogen fertilizer used in the US, rose 127% (5). As fertilizer prices continue to rise, growers are looking for cost-saving alternatives. Poultry litter is particularly valuable; it has higher concentrations of nutrients than other animal wastes, it is relatively dry, and is totally collectable (4).

Due to environmental concerns over animal waste management practices and strict federal and state regulations put in place in recent years, poultry producers are looking for new economical ways to safely dispose of this waste. Adding composted poultry litter to pine bark, whole tree, or clean chip residual substrate could provide the nursery industry with a valuable alternative substrate and a low cost nutrient supplement while providing poultry producers an economically and environmentally sound alternative means of waste disposal.

Treatments were nine substrate blends of pine bark (PB), whole tree (WT), clean chip residual (CCR), peat (P), and composted poultry litter (CPL) that included by volume: 6:1 WT:CPL, 6:1 CCR:CPL, 6:1 PB:CPL, 100:0 WT, 100:0 CCR, 100:0 PB, 6:1 WT:P, 6:1 CCR:P, and 6:1 PB:P. WT and CCR used in this study were processed to pass a ¼ inch (.64 cm) and 3/8 inch (.95 cm) screen, respectively. Poultry litter used in this experiment was obtained from Greenville, Al. and was composted in an in-vessel rotating drum digester (BMG Organics Inc.) for two weeks. Poultry litter was analyzed by Brookside Laboratories Inc. (New Knoxville, OH). Composted poultry litter analysis showed 2.5% nitrogen, 1.4% phosphorous, and 2.3% potassium on a wet weight (as is) basis. Each substrate blend was incorporated with Harrell's 15-6-12 8 to 9 month fertilizer plus micros at 18lb/yd³. Five species *Rhododendron* x 'Iveryana', *Buxus sempervirens* L., *Ilex crenata* Thunb. 'Compacta', *Loropetalum chinense* Oliv. 'Chang's Ruby', and *Ternstroemia gymnanthera* Thunb. were transplanted from cell pack liners into full gallon containers on 31 May 2007 and placed under over-head irrigation. Plants were arranged by species in a randomized complete block design with eight single plant replications. Pour-through extractions were conducted at 7, 15, 30, 60, 90, 120 and 180 days after transplanting (DAT). Foliar color ratings were taken at 60 and 120 DAT on a scale of 1 to 5 where 1 = severe chlorosis, 2 = moderate chlorosis, 3 = slight chlorosis, 4 = light green, and 5 = dark green. Growth indices [(height + width¹ + width²)/3], shrinkage measurements were taken at 120 DAT and 340 DAT. Root ratings were taken at 340 DAT on a scale of 1 to 5 with 1 = no visible roots, 2 = 25% of surface covered with roots, 3 = 50% root coverage, 4 = 75% coverage, and 5 = 100% coverage.

Results and Discussion: Substrate pH measurements varied throughout the study. Substrates containing CPL had the highest pH while substrates containing PB, P or combinations had the lowest pH. Electrical conductivity was the highest in substrates

containing CPL but all treatments were within acceptable ranges for the duration of the test. At 120 and 340 DAT the WT:CPL substrate exhibited more shrinkage than all other treatments, followed by the CCR:CPL combination. (Table 1). Growth indices of Buxus at 340 DAT indicated that the CCR:CPL 6:1 substrate grew the largest plants throughout the experiment (Table 1). CCR 100:0 grew the largest Ilex but growth was statistically similar to other treatments. No differences in growth indices of Ternstroemia were observed amongst any treatment. Rhododendron and Loropetalum growth indices were slightly higher in 100:0 CCR but also similar to other treatments (Table 1). Foliar color ratings were similar among all treatments and all species for the duration of the study (data not shown). No major differences were observed at 340 DAT in root ratings for Ilex or Ternstroemia, Buxus grew a stronger root system in 6:1 CCR:CPL than in any other treatment, and Loropetalum and Rhododendron grew slightly less roots in 6:1 WT:CPL than any other treatment (data not shown).

Similarities amongst substrates in this study amended with peat or composted poultry litter indicate that poultry litter could be an economically viable and sustainable substrate amendment for containerized plant production. Species used in this experiment showed little or no difference compared to control treatments, indicating that composted poultry litter could be a valuable and economical substrate component for container production while providing an environmentally friendly way of waste disposal.

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Table 1. Influence of substrate composition on growth indices² and substrate shrinkage at 120 and 340 days after transplanting.

Substrate	Growth Indices										Shrinkage ³	
	Holly		Boxwood		Loropetalum		Azalea		Cleyera		120 DAT	340 DAT
	120 DAT ¹	340 DAT	120 DAT	340 DAT	120 DAT	340 DAT	120 DAT	340 DAT	120 DAT	340 DAT	120 DAT	340 DAT
WT ⁴ :CPL ⁵ 6:1 ⁶	27.0 bcd [*]	32.8 b	15.3 b	25.2 b	34.4 e	39.5 c	20.5 d	29.1 c	20.0 a	31.3 a	5.7 a	7.35 a
CCR ⁷ :CPL 6:1	32.3 a	35.8 ab	20.6 a	30.2 a	45.8 bc	46.4 b	19.8 d	31.6 bc	24.7 a	35.6 a	4.9 b	6.5 b
PB ⁸ :CPL 6:1	31.1 ab	36.2 ab	17.4 b	23.7 bc	37.3 de	40.7 c	21.1 cd	29.6 c	25.3 a	32.3 a	3.1 e	3.6 e
WT 100:0	28.8 abcd	36.7 a	14.7 cb	21.7 cd	45.1 e	46.4 b	23.0 bcd	33.7 b	25.6 a	35.1 a	3.7 cd	4.5 cd
CCR 100:0	29.4 abc	37.4 a	14.8 cb	19.2 de	53.3 a	53.2 a	27.3 a	39.4 a	25.6 a	35.9 a	4.0 c	4.5 cd
PB 100:0	28.1 bcd	36.2 a	12.4 c	16.5 e	41.8 cd	43.2 bc	24.8 ab	33.4 b	24.8 a	33.5 a	3.4 de	4.1 de
WT:P ⁹ 6:1	26.0 cd	34.5 ab	15.1 bc	20.4 d	41.9 cd	42.6 bc	20.7 d	38.9 a	20.7 a	32.3 a	4.1 c	4.8 c
CCR:P 6:1	28.3 abcd	36.7 a	14.8 bc	19.5 de	51.2 ab	51.6 a	24.0 bc	37.9 a	24.6 a	32.4 a	3.7 cd	4.3 cd
PB:P 6:1	24.7 d	32.8 b	12.5 c	17.0 e	42.6 cd	44.1 bc	20.4 d	31.9 bc	24.2 a	41.0 a	3.7 cd	4.3 cd

¹Growth Indices = [(height + width1 + width2)/3]

²WT = Whole Tree.

³CPL = Composted Poultry Litter.

⁴Calculations based on volume.

⁵CCR = Clean Chip Residual

⁶PB = Pine bark

⁷DAT = Days after transplanting.

⁸Means separated using Duncan's multiple range test at P = 0.05

⁹P = Peat moss.

¹⁰Shrinkage = measurement in centimeters from the media surface to the top of the pot in *Buxus*.

Utilization of Spent Tea Grinds as a Substrate Component in Greenhouse Crop Production

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Significance to Industry: 'Dreams Mix' petunia and 'Harmony Mix' begonia were grown in substrates containing various amounts of spent tea grinds (STG). Results suggest that spent tea grinds, used in the proper proportions, can replace standard industry substrate components such as pine bark and sphagnum peat moss. By utilizing spent tea grinds as a substrate component, growers may be able to reduce the amount of pine bark and peat used.

Nature of Work: Pine bark (PB) and peat (P) are major substrate components used in nursery and greenhouse production. P is the most widely used substrate component for the production of greenhouse plants (1). The steadily increasing costs of PB and P are of major concern to growers. Future availability of PB for horticulture production is also predictably low (2). Increased transportation costs have led to higher P prices for growers (4). Rapidly rising fuel costs have surely escalated this problem. These factors have led to a search for alternative substrate components. Tea brewers are generally faced with disposal problems of their waste materials. These materials are most often dumped into landfills at the tea brewer's expense. Spent tea grinds (STG) is a term used to describe the organic waste product of the tea-brewing process. STG contains finely ground tea leaves that have a high water holding capacity, with peat-like qualities, offering the potential to replace P as a substrate component. STG was shown to be a viable substrate component in greenhouse production (3).

Materials and Methods: Begonia (*Begonia x semporflorens-cultorum* 'Harmony Mix') and petunias (*Petunia x hybrida* 'Dreams Mix'), from 288 cell plug trays, were planted into 8.89 cm (3.5 in.) diameter pots containing various substrate blends for each species. Four different substrates were 70:20:10 PB:STG:perlite, 45:45:10 PB:STG:perlite, 70:20:10 PB:P:perlite, and 45:45:10 PB:P:perlite. All substrates were pre-plant incorporated with 0.9 kg/m³ (1.5 lbs/yd³) Micromax™ (The Scotts Company, Marysville, Ohio), 1.19 kg/m³ (2 lbs/yd³) bifenthrin, and 3.0 kg/m³ (5lbs/yd³) dolomitic limestone. Bifenthrin was added to control possible fungus gnat (*Orphelia* spp.) populations. Two different rates of agricultural grade elemental sulfur were also pre-plant incorporated, yielding a total of eight treatments. Four treatments contained 2lbs/yd³ sulfur and four treatments contained 3lbs/yd³ sulfur. Elemental sulfur was added to the substrates to manipulate pH and to change the chemical dynamic of the substrate.

All plants were hand watered as needed. Beginning at 1 week after planting (WAP), all plants were irrigated with a 150 parts per million (ppm) fertilizer solution (20-10-20). From 3 WAP to 10 WAP, a 300 ppm (20-10-20) solution was used to water plants once daily. Plants were watered with mineral water (without fertilizer) every fourth day. At the end of the study, all foliage was removed and weighed to determine shoot fresh weight values. The samples were then oven-dried at 68 °C (154 °F) for 48 hours to determine shoot dry weight values. A visual rating scale was developed for overall plant quality. Each plant was assigned a numeric value between 1 and 5 based on the overall health and quality of the plant (1 = lowest quality; 5 = highest quality). Foliar chlorophyll content was estimated using a SPAD-502 Chlorophyll Meter (Konica Minolta Inc., Tokyo, Japan). An average of the chlorophyll content of three leaves of each plant was recorded. This study was a randomized complete block design (RCBD) conducted at the Paterson Greenhouse Complex in Auburn, AL. Each species was arranged as a separate experiment. For each species there were ten blocks containing eight plants each. Data was analyzed using Tukey's Studentized Range Test ($\alpha = 0.05$).

Results and Discussion: No statistical interactions between substrate and rate of incorporated elemental sulfur were identified for any collected data for either species. Petunias grown in treatments containing 70:20:10 PB:Peat:Perlite, 70:20:10 PB:STG:Perlite, and 45:45:10 PB:Peat:Perlite had the highest shoot dry weight values (Table 1). Petunias grown in treatments containing 45:45:10 PB:STG:Perlite exhibited the lowest shoot dry weight values. No significant shoot dry weight differences, due to incorporated elemental sulfur rate, were observed in petunias. Petunias grown in all substrates had statistically similar leaf greenness values (Table 1). No statistical differences in petunia leaf greenness existed based on rates of incorporated elemental sulfur.

Petunias grown in treatments containing 70:20:10 PB:Peat:Perlite and 70:20:10 PB:STG:Perlite exhibited the highest aesthetic quality (Table 1). Plants grown in treatments containing 45:45:10 PB:STG:Perlite had the lowest aesthetic quality ratings, but were statistically similar to plants grown in 45:45:10 PB:Peat:Perlite. Petunias grown in treatments containing 2 lbs/yd³ incorporated elemental sulfur had significantly higher quality ratings than plants grown in treatments containing 3lbs/yd³ incorporated elemental sulfur.

Begonias grown in treatments containing 70:20:10 PB:Peat:Perlite and 45:45:10 PB:Peat:Perlite exhibited the highest shoot dry weight values (Table 1). Statistical analysis showed that shoot dry weight values of begonias were independent of the rate of incorporated elemental sulfur.

Begonias grown in all substrates had statistically similar SPAD readings (Table 1). Incorporation rate of elemental sulfur was not significant.

Begonias grown in treatments containing 45:45:10 PB:Peat:Perlite had the highest aesthetic quality ratings (Table 1). Plants grown in treatments containing 70:20:10 PB:Peat:Perlite were statistically similar. Begonias grown in treatments containing 70:20:10 PB:STG:Perlite were statistically similar to plants grown in treatments containing 70:20:10 PB:Peat:Perlite. Begonias grown in treatments containing 45:45:10 PB:STG:Perlite had the lowest aesthetic quality ratings. Aesthetic quality of begonias was statistically independent of the rate of incorporated elemental sulfur.

Results suggest that marketable 'Harmony Mix' begonias and 'Dreams Mix' petunias can be grown in substrates containing PB:STG in proper proportions. Furthermore, incorporation of agricultural grade elemental sulfur at 2 lbs/yd³ was a sufficient rate to deter nutrient deficiency symptoms, observed in previous studies, in petunias.

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Table 1. Effects of substrate and incorporated sulfur on *Petunia x hybrida* 'Dreams Mix' and *Begonia x semporflorens-cultorum* 'Harmony Mix'.

Treatment	Petunia			Begonia		
	Shoot Dry Weight (g)	SPAD ^z	Quality Rating ^y	Shoot Dry Weight (g)	SPAD	Quality Rating
Substrate ^x						
70:20:10 PB:STG:Perlite	4.514a ^w	43.20a	3.65a	1.969b	44.32a	2.60bc
70:20:10 PB:Peat:Perlite	5.016a	43.43a	3.45a	2.384a	43.18a	3.10ab
45:45:10 PB:STG:Perlite	2.981b	43.48a	2.65b	1.899b	44.57a	2.30c
45:45:10 PB:Peat:Perlite	5.214a	41.66a	3.15ab	2.661a	45.37a	3.45a
Incorporated Elemental Sulfur ^v						
2 lbs/yd ³	4.489a	43.81a	3.45a	2.271a	44.74a	2.90a
3 lbs/yd ³	4.409a	42.04a	2.98b	2.185a	43.98a	2.83a
Significance ^u						
Substrate	***	NS	**	***	NS	***
Incorporated Elemental Sulfur	NS	NS	*	NS	NS	NS
Substrate x Incorporated Elemental Sulfur	NS	NS	NS	NS	NS	NS

^zRelative leaf greenness measured using a SPAD-502 Chlorophyll Meter (Konica Minolta Inc., Tokyo, Japan).

^yQuality Rating Scale was: 1 = lowest quality; 5 = highest quality.

^xSubstrates were: PB = pine bark; STG = spent tea grinds; Peat = peat moss; Perlite = horticultural grade perlite.

^wValues in column followed by different letters are significant according to Tukey's Studentized Range Test ($\alpha = 0.05$).

^vAgricultural Grade Elemental Sulfur (90% S).

^uSignificance denoted as: NS = not significant; * = significant at 0.05 level; ** = significant at 0.01 level; *** significant = at 0.001 level.

Plug and Container Production of Softhair Coneflower (*Rudbeckia mollis* Elliott)

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Significance to Industry: Nursery production of native wildflowers is limited because of the lack of technical information about cultural practices. For sofhair coneflower, which flowers in early summer, greenhouse-produced plugs were the best product to make available to the commercial or retail landscape industry. Two months were required to produce a commercially acceptable plug propagated by seed sown January, March or May. Plugs finished in 10.8-cm (4.25-inch) pots or #1 containers were too tall for shipping even when potting date was delayed to minimize inflorescence height.

Nature of Work: Nursery and landscape industries are continuously expanding the number of species they produce and utilize. Industry, community, and consumer interest in native wildflowers is increasing. Container propagated protocols for several native wildflower species have been developed (1,2,3,5). Unfortunately, limited commercial production of some Florida wildflowers restricts their availability and broader use. Softhair coneflower (*Rudbeckia mollis* Ell.) is a coastal plain native wildflower that occurs in dry sandy soils mainly from southern Alabama to southeastern South Carolina (4). While this tap-rooted wildflower has been classified as an annual, biennial, and perennial (4), we have observed it to be either annual or biennial in northern Florida (unpublished observations). Softhair coneflower has a light to mossy green, woolly appearance due to hairs on leaves and stems. A raceme up to 1 m (40 inches) tall arises from a basal rosette in very late spring to summer in the wild. The showy flowers are golden-yellow, up to 5.1 cm (2 inches) in diameter, and have a prominent brown to purplish black, cone-shaped center.

In this study, we evaluated the effect of seeding date on greenhouse plug production, and subsequently the effects of container size and fertilization rate on shipping date and final size of a finished plant. All seeds used in this study were a north Florida ecotype of sofhair coneflower harvested 4 June 2004 from containerized plants at the UF/IFAS, North Florida Research and Education Center in Quincy.

The first sowing date was 2 January 2007. Seeds were sown into two 25.4 x 50.8-cm (10 x 20-inch) flats with #1201 inserts filled with MetroMix 200 (MM200; Sun Gro Horticultural Products, Vancouver, B. C., Canada) and lightly covered with sifted MM200 using a #12 U.S.A. standard test sieve (Fisher Scientific Co. Pittsburgh, PA). The flats were placed in a greenhouse on thermostatically controlled propagation mats (Pro-Gro PGPM9A; Cassco, Montgomery, AL) at ~30° angle for drainage, with the temperature set at 21°C (70°F). Each morning, seedlings were overhead irrigated via a

mist system. Starting 11 January, seedlings were bottom-fertilized weekly with 100 ppm N of Miracle-Gro All Purpose Plant Food 15N-13.2P-12.4K (Scotts Miracle-Gro Products, Inc., Marysville, OH). On 2 February, seedlings were transplanted into #1204 inserts (one seedling/3.8 x 6.0 x 5.7 cm (1.5 x 2.38 x 2.25 inch) cell; 48 cells) filled with MM 200 in 25.4 x 50.8-cm (10 x 20-inch) flats and placed back on the propagation mats. On 1 March, shoots and roots of 10 plugs were harvested and dried at 63°C (145°F) for 3 days to determine dry mass. Other plugs were transplanted into 10.8-cm (4.25-inch) pots (0.64L; 0.17-gal) or #1 containers for finishing. The potting medium was a 60:20:20 mix (pine bark:sand:peat; Graco Fertilizer Company, Cairo, GA) incorporated with Osmocote 15N-4.0P-10.0K (12-14 month; Scotts Inc., Marysville, OH) at 2.5, 5.8, or 9.0 kg/m³ (4.2, 9.7 or 15.2 lb/yd³). The potted liners were measured (height and two widths) and then placed on a full sun production bed. There were five single container replications for each of the container size x fertilizer rate treatments.

The second sowing date was 1 March, with seedling fertilization starting 8 March. Seedlings were transplanted to cell packs on 29 March, as described above. On 7 April, Subdue Maxx™ at 30 ml/379L (1 oz/100 gal; Syngenta Crop Protection, Inc., Greensboro, NC), Cleary's 3336™F at .7L/379L (24 fl oz/100 gal; Cleary Chemical Corp., Dayton, NJ), and Heritage® at 15ml/379L (0.5 oz/100 gal; Syngenta) were applied because we suspected that one or more diseases were causing chlorosis and poor growth; *Fusarium*, *Pythium*, and *Rhizoctonia* had been isolated from softhair coneflower the previous year. On 1 May, seedlings were transplanted to 10.8-cm (4.25-inch) or #1 containers, or harvested for dry mass as previously described. The potted plants were measured and placed on the full sun bed.

The third sowing date was 30 April, with seedling fertilization starting 10 May. Seedlings were transplanted to cell packs as previously described on 31 May. On 29 June, seedlings were transplanted to 10.8-cm (4.25-inch) or #1 containers, or harvested for dry mass as previously described. The potted plants were measured and placed on the full sun bed.

The 90 plants (3 seeding dates x 2 container sizes x 3 fertilizer rates x 5 replications) were arranged in a completely randomized design. Overhead irrigation was 0.71 cm (0.28 inch) once per day until 23 April, and then 0.71 cm (0.28 inch) twice per day. Plants were hand weeded as needed. Plants were grown until the first flower of each plant showed color, the stage at which it would be shipped to retailers. Shipping date of each plant was recorded along with total plant height, widest width and the width perpendicular to the widest point. The commercially acceptable plant height for shipping was 18 inches or less (Sue Watkins, pers. comm.).

Results and Discussion: Well-rooted plugs (48/tray) of softhair coneflower were produced in 2 months under greenhouse conditions when seeds were sown near the beginning of January, March or May. The largest plugs were produced when sown 30 April (Table 1). Plugs from the March sowing date were the smallest because of disease. Plugs produced at any of the three sowing dates seemed suitable for transplanting directly into the landscape.

The only finished plants that were 18 inches or less were those in 10.8-cm (4.25-inch) pots at the lowest rate of fertilizer (2.5kg/m³ 4.2 lb/yd³) regardless of sowing/plug transplant date (Table 2); however, plants in 10.8-cm (4.25-inch) pots were too top heavy and easily blew over. Delaying the sowing date, which tended to reduce the time needed to produce a finished plant in 10.8-cm (4.25-inch) or #1 container, did not reduce plant height to a desirable size. Total plant height was a function of inflorescence height, which seemed to be directly related to container size. Use of growth regulators may be needed to produce salable sizes of softhair coneflower in 10.8-cm (4.25-inch) or #1 containers. Plants in #1 pots were larger than those in 10.8-cm (4.25-inch) pots at all dates.

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Table 1. Effect of sowing date on size of softhair coneflower plugs.

Sowing date	Height (in)	Avg width (in)	Growth index ^z (in)	Dry mass (oz) ^y
2 Jan	0.9 ± 0.1	2.8 ± 0.1	1.8 ± 0.1	0.001
1 Mar ^x	0.4 ± 0.0	1.8 ± 0.1	1.1 ± 0.1	<0.001
30 Apr	1.4 ± 0.1	4.0 ± 0.1	2.7 ± 0.1	0.003

^zGrowth index = (plant height + average width)/2.

^yAll standard errors ≤ 0.0003.

^xUnidentified disease likely contributed to reduced size.

Table 2. Effect of container size, fertilizer rate and potting date on shipping date, production time, flower and vegetative growth of softhair coneflower.

Potting date	Container size	Fertilizer rate (lb/yd ^{3z})	Shipping date ^y	No. days in production ^x	Flowering plant ht (in)
1 Mar	4.25-inch pot	4.2	14 Jul ± 4	135 ± 4	17 ± 2
		9.7	15 Jul ± 6	136 ± 6	19 ± 2
		15.3	19 Jul ± 7	140 ± 7	20 ± 2
	#1	4.2	27 Jun ± 1	118 ± 1	24 ± 5
		9.7	22 Jun ± 5	113 ± 5	35 ± 2
		15.3	19 Jun ± 2	110 ± 2	31 ± 1
1 May	4.25-inch pot	4.2	4 Aug ± 4	95 ± 4	18 ± 1
		9.7	4 Aug ± 3	95 ± 3	19 ± 1
		15.3	9 Aug ± 8	100 ± 8	21 ± 1
	#1	4.2	26 Jul ± 3	86 ± 3	31 ± 1
		9.7	18 Jul ± 2	78 ± 2	26 ± 2
		15.3	24 Jul ± 3	84 ± 3	26 ± 3
29 Jun	4.25-inch pot	4.2	23 Oct ± 21	116 ± 21	18 ± 4
		9.7	26 Sep ± 5	89 ± 5	23 ± 1
		15.3	2 Oct ± 4	95 ± 4	20 ± 1
	#1	4.2	1 Oct ± 5	94 ± 5	27 ± 1
		9.7	28 Sep ± 14	91 ± 14	28 ± 1
		15.3	7 Sep ± 2	70 ± 2	29 ± 2
Significance ^w					
Potting date			***	***	NS
Container size			NS	***	***
Fertilizer rate			NS	NS	NS
P x C			***	***	NS
P x F			***	***	NS
C x F			*	*	***
P x C x F			***	***	*

^z Fertilizer levels – Osmocote 15-9-12, 12-14 month southern formulation, incorporated.

^y Shipping date – Day of the year when color first observed (± std. err., days); converted to calendar date.

^x Number of days in production - Number of days from potting date to shipping date.

^w NS, *, **, ***; nonsignificant, or significant at P=0.05, 0.01, 0.001, respectively.

Resource Management Tool for Container Production

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Index words. Best management practices (BMP), decision support, irrigation scheduling, leaf area, model, nitrogen, nursery, runoff, simulation, *Viburnum odoratissimum*

Significance to the Industry. The management tool described in this paper allows the industry to objectively evaluate the effects that management practices can have on plant growth, water usage, and runoff. As such it provides a tool which can help make decisions regarding BMP implementation which are based upon local weather information and grower practices. Currently, the tool is limited to simulating production of a fast-growing shrub in a #1 container. Future research is aimed at expanding its usefulness to species with different growth characteristics and at validating its accuracy for simulating growth in larger containers.

Nature of Work. Decisions regarding the management of container crops are largely based upon grower knowledge and experience. Models which simulate crop growth can provide a scientifically-based tool for objectively evaluating the effects that critical management practices can have on crop production and resource utilization (1). For any given set of management inputs imposed by the grower, weather is the primary factor which affects crop production, nutrient and water requirements, and runoff. By running what-if experiments using historical weather data, a simulation tool can be used to select practices which would likely result in an acceptable product while maximizing the efficient use of resources such as water, fertilizer, space, and labor. This paper describes a model that has been developed to simulate the production of overhead-irrigated #1 sweet viburnum [*Viburnum odoratissimum* (L.) Ker-Gawl.] and gives an example of how this tool can be used to evaluate a best management practice (BMP) tailored to your nursery.

Crop simulation models are computer programs which use equations to describe plant growth. For our model, these equations are physically-based, meaning the equations in the model describe known physiological processes (e.g. transpiration, evaporation, photosynthesis, light interception, radiation use efficiency, etc). Our equations are based on a daily time period so that the rates of these physiological processes are integrated over a 24-hour day rather than by the hour or minute. A daily time frame has implications for real-time decision-making such as irrigation scheduling.

The heart of the model is the simulation of leaf area growth and development. Leaf area development (i.e. leaf appearance rate) determines the 'photosynthetic sink' or potential for biomass growth and is controlled primarily by temperature. The leaf canopy intercepts incoming solar radiation and therefore determines the 'photosynthetic source' available for new leaf area growth and biomass accumulation. Depending upon the weather and stage of growth, growth can either be sink-limited or source-limited. Leaf area also affects substrate temperature by intercepting solar radiation that would otherwise impinge upon container walls and substrate surfaces. Furthermore, leaf area affects the amount of overhead irrigation water that is captured by the container. Leaf area is directly related to the amount of evapotranspiration that occurs and biomass accumulation is directly related to the amount of nutrients required. Therefore, simulating leaf area growth and development plays an integral role in estimating water and nutrient requirements during production. If these resources are not available, equations are in place to provide negative feedback.

Runoff in the nursery is a result of both container drainage and un-intercepted irrigation and rain. Container substrate has a finite capacity to store water. If irrigation and rain exceed this capacity then drainage occurs. Plant spacing and leaf area affect the amounts of un-intercepted irrigation and rainfall that fall between the containers. The model estimates daily runoff based upon daily rain and irrigation inputs and loss through evapotranspiration. Nitrogen in runoff is a function of the pool of soluble N in the substrate. The pool of soluble substrate N is estimated using equations that predict N release from controlled-release fertilizer (CRF) and N removal from plant uptake and container drainage. By simulating runoff volume and N content, management practices can be selected which minimize these losses while maintaining acceptable growth.

The following inputs are needed to run the model:

- location (i.e. daily weather – min and max air temperatures, solar radiation and rain)
- transplant size, plant date, container size
- container spacing and move schedule
- harvest date or harvest size
- substrate volume, substrate water contents at container capacity and at wilting point
- irrigation schedule (fixed rate, ET-based, or input file), auto rain cutoff
- fertilizer grade, longevity rating and application rate, N conc. of irrigation water
- pruning schedule and degree of pruning

The following outputs are generated by the model:

- finish date or size, root and shoot biomass, leaf area, leaf area index, plant size
- irrigation amount, irrigation capture, substrate water content, water sufficiency
- evapotranspiration, drainage, runoff amount
- actual and optimum root and shoot N concentration
- N demand, N supply, N uptake, and N sufficiency
- N release from CRF, substrate N, drainage N, runoff N, irrigation N

Outputs include daily and season totals and can be expressed on a per-container basis for efficiency analyses or expressed on an area basis for runoff and nutrient management evaluations. Also, simple statistics (e.g. mean, median, max, min, standard deviation) can be generated to describe responses when the simulation is run using multiple years of weather data.

A web-based interface is being developed which allows the user to select critical management factors, run the simulation and view the output in graphical or tabular form. Currently, the tool has two basic versions – a grower-friendly version and a technical version. The technical version, which is in metric units, allows the user to change essentially any input in the model. The grower version, which is in English units, has fewer input options but is easier to use. With the grower version, the user has the option of comparing two or more levels of a factor keeping all other inputs the same. For example, there are comparison tools to evaluate different fertilizer rates, different irrigation schedules, and different plant dates. By running “what if” scenarios or comparisons, the grower achieves knowledge of the best practices to implement with minimal environmental impacts. For example, a 30-yr simulation comparing 1, 2, and 3 lb of N per cubic yard for a March planting in central Florida showed that by decreasing the fertilizer rate from 3 to 2 lb N per cubic yard N loss was reduced >50% (0.6 vs. 1.3 g N/container) without sacrificing growth (Fig. 1).

Crop simulation models help producers make decisions with little investment costs and enhance decisions where directed experimentation is lacking. Decisions from simulations are based on the best science available for the range of inputs encountered in production. Decision support systems that use models to evaluate input variables will be very important in the future as input costs escalate. With these tools, producers will be able to choose BMPs which maximize environmental benefits and minimize input costs.

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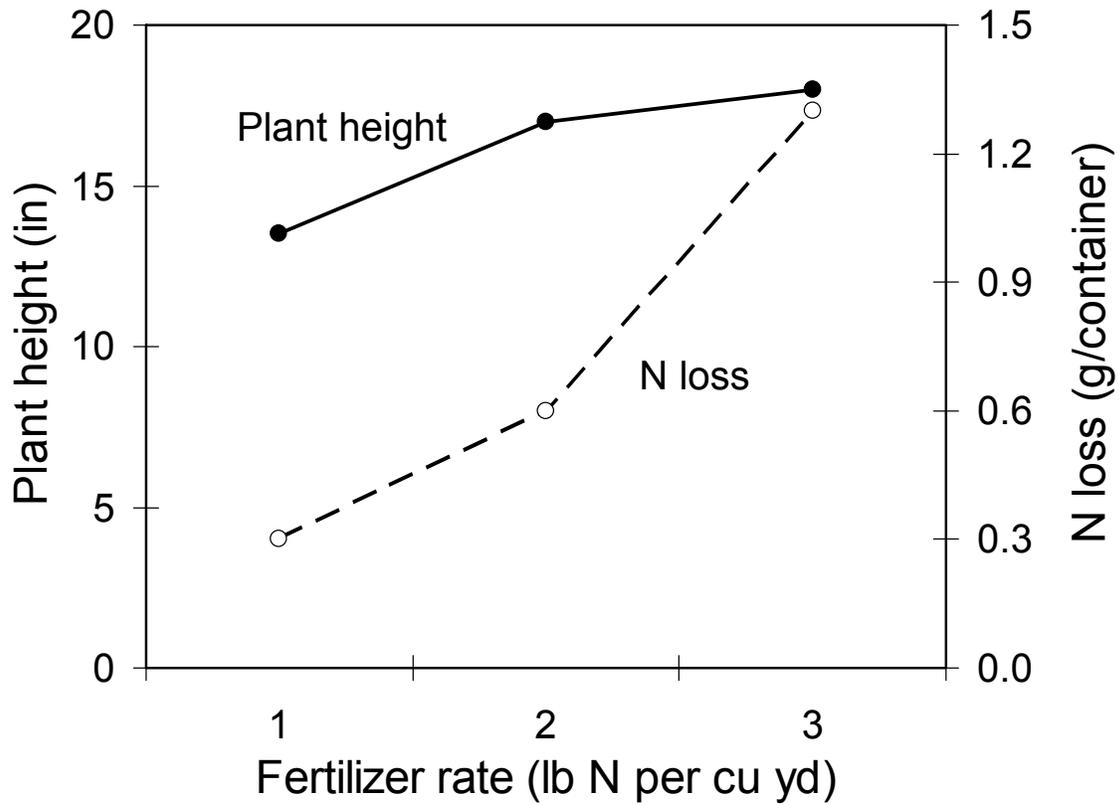


Fig. 1. Average growth and fertilizer N loss during the simulated production of #1 sweet viburnum fertilized with three different controlled-release fertilizer rates. Simulations were based on 30 years of historical weather for central Florida, a March 1 plant date, overhead irrigation rate of 0.5 inch/day, and a 20-week growing period.

Can vermicompost replace slow release fertilizer in greenhouse production of marigold?

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Significance to Industry: Growers looking for ways to extend a substrate or include natural/organic sources of fertilizer may be considering vermicompost (VC). Blends of up to 18% VC as a sole source of macronutrient fertilizer, were shown to produce marketable marigold plants, but ones that were slightly smaller and lighter in color than ones grown with a traditional slow-release fertilizer. Vermicompost-amended substrates produced similar quality marigold root systems to those fertilized with slow release fertilizer. The VC used in this work raised the substrate pH and electrical conductivity, factors growers will need to test for and understand if they choose to incorporate VC into their production methods. It may be that the VC used here would be better used as part of a fertilizer program rather than as a substrate, in and of itself. This work did not evaluate hormonal and disease suppressive properties that are sometimes attributed to VC.

Nature of Work: Today's cost and environmental concerns have the nursery and bedding plant industries working hard to reduce inputs costs and minimize the environmental impact of production. Growers can choose from a broad range of alternative substrate components made from composts and agricultural wastes to extend their basic substrate without compromising crop quality or extending days to finish. Among the many readily available products today are VCs, which are castings made from organic materials that have been digested and excreted by worms. Vermicomposts can vary in physical and chemical qualities, depending on what the worms are fed, and the handling and age of the VC.

Most research has shown VC to have positive influences on crops, including a few recent papers investigating VC use in bedding and pot plants. Arancon, et al (1) reported that petunias responded positively, but differently, to VC blends, depending on the feedstock used to produce the VC. In their peat-based system with supplemental liquid fertilizer, VC additions increased petunia germination, shoot dry weight, and flower number. Tomato growth responses to VC have also been shown to be mostly positive and to vary based on feedstock (3). Hidalgo, et al (4) concluded that VC made from cattle manure could be a suitable substrate amendment for marigold production. Among other things, they found that VC additions elevated substrate pH, increased flower number, and had variable effects on root growth and growth index, depending on what ingredients the VC was blended with and at what rate.

Some of the effects of VC have been attributed to hormonal and other non-nutritional factors. In experiments investigating the hormone-like properties of VC extracts, Arancon, et al (2) found that spraying strawberry or pepper plants with humic acids extracted from VCs increased the number of fruit produced. Spraying extracts of VC has been found to reduce disease incidence and alter fruit quality in tomato (5).

The objective of this study was to evaluate the influence of commercially available VC on substrate characteristics and growth of marigold in a peat-based substrate.

This study was conducted in Spring 2008 at the Mississippi State University Truck Crops Branch in Crystal Springs, MS. Vermicompost (Wormwise, Church Hill Worm Farm, Church Hill, Mississippi) was blended at 0 to 18% v:v with a custom made peat-based substrate (CUST), and compared with commercial growing substrate [(3B, Fafard 3B (Fafard Co., Agawam MA) and slow release fertilizer (SRF), Osmocote 14-6.2-11.6 without micronutrients (3-4 months) (Scotts-Sierra Company, Marysville, OH)]. Treatments evaluated are listed in Table 1. The CUST blend contains peat moss, vermiculite and perlite (75:10:15 by volume). Both CUST and 3B substrates were blended 0.89 kg/m³ (1.5 lb/yd³) Micromax (Scotts-Sierra). All treatments except 3B + SRF were blended with 3.0 kg/m³ (5 lb/yd³) dolomitic limestone. French marigold cv. Janie Deep Orange (*Tagetes patula* L.) seedlings were transplanted from standard 128 cell flats into 6 inch round plastic azalea pots (one plant/pot) on 24 March 2008.

All plants were placed on benches in a greenhouse at the station. Plants were arranged in a completely randomized design with each treatment unit (pot) replicated ten times for each substrate. Plants were hand watered as needed. At 1 and 34 days after treatment (DAT), electrical conductivity of the substrate was measured using a Field Scout Direct Soil EC Meter (Spectrum Technologies, Plainfield, IL) 30-60 minutes after saturating the substrate with tap water,. At the same time, substrate pH was measured directly with an IQ 150 pH meter (Spectrum Technologies). Plants were harvested 36 DAT. Prior to harvest, relative leaf chlorophyll content was determined using a SPAD-502 Chlorophyll Meter (Konica-Minolta, Inc., Tokyo, Japan). Single readings were taken from three recently matured leaves on each plant. The mean of the three readings was used for data analysis. Growth indices [(height + widest width of foliage + width at right angles to the widest width)/3] and number of open flowers were recorded. Plants were separated into shoots (stems + leaves) and flowers. Samples were dried at 60°C in a forced-air oven. Dry weight was recorded for each tissue type.

Results and Discussion: All plants in CUST were slightly shorter than those in 3B + CRF (Table 2). Vermicompost at 3% v:v significantly increased shoot height and growth index over the 0% VC control, but increasing the rate up to 18% v:v did not result in further height increases. Dry weights of all measured tissues were lower in the unfertilized control plants than in the other treatments. Dry weight of leaves + stems, and of the leaves + stems + flowers, increased with increasing rate of VC up to 18% v:v, but was significantly lower in all VC-treated plants than in plants grown with SRF (Table 2). Vermicompost treated plants had somewhat lower SPAD meter readings at 36 DAT (Table 3). The influence of VC rate on flower number was somewhat variable.

Substrate pH was lower in the CUST +SRF than in the 3B + SRF (Table 4). Addition of VC significantly increased substrate pH in the custom blend. Substrate pH increased over the course of the experiment in the VC treated pots, but remained nearly steady in the 3B and CUST blends with or without SRF (Table 4). CUST, with or without SRF, had a lower EC at 1 DAT than the Fafard 3B + SRF (Table 4), but had higher EC at 36 DAT. Increasing rates of VC resulted in increases in EC at 1DAT. By 36 DAT, all treatments, except the CUST + 0 and CUST + 18% VC treatments, had reduced EC levels.

The VC used in this study tended to elevate substrate pH and EC. Without additional fertilizer, the VC-amended substrate produced marigold plants with strong root systems and somewhat smaller shoots than were produced by fertilizing with SRF. Combining results from the SPAD meter readings, EC readings, growth indices, and flower numbers leads us to recommend that VC be evaluated in combination with other fertilizers in an effort to develop a production systems using VC that produce marigold plants of equal quality and size to those produced by substrates blended with SRF.

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Table 1. Substrate blends used in this study.

Treatment	Substrate
3B + SRF	Fafard 3B + slow release fertilizer ^z (SRF)
CUST + SRF	Peat-based blend (100%) ^y + SRF
CUST + 0% VC	Peat-based blend (100%) (No fertilizer)
CUST + 3% VC	Peat-based blend (97%) + Vermicompost (3% v/v)
CUST + 6% VC	Peat-based blend (94%) + Vermicompost (6%)
CUST + 9% VC	Peat-based blend (91%) + Vermicompost (9%)
CUST + 12% VC	Peat-based blend (88%) + Vermicompost (12%)
CUST + 15% VC	Peat-based blend (85%) + Vermicompost (15%)
CUST + 18% VC	Peat-based blend (82%) + Vermicompost (18%)

^zSlow Release Fertilizer was Osmocote 14-6.2-11.6, 3-6 mo. formulation, without micronutrients.

^yPeat-based blend was 75% sphagnum peat moss: 15% medium perlite: 10% fine vermiculite.

Table 2. Influence of substrate and rate of vermicompost amendment on marigold growth and dry weight accumulation in six-inch pots.

Treatment	Shoot Height (cm)	Growth Index ^z (cm)	Dry weight (g)		
			Leaves + Stems	Flowers	Leaves + Stems + Flowers
3B + SRF	19.4	24.8	5.52	1.68	7.20
CUST + SRF	17.4	23.6	5.68	1.77	7.45
CUST + 0% VC	14.3	13.5	1.08	0.05	1.58
CUST + 3% VC	16.6	19.0	2.79	1.63	4.42
CUST + 6% VC	17.0	19.6	3.05	1.42	4.47
CUST + 9% VC	16.6	19.7	3.07	1.61	4.68
CUST + 12% VC	16.7	21.7	3.58	1.36	4.94
CUST + 15% VC	16.7	20.9	3.70	1.38	5.08
CUST + 18% VC	16.6	22.0	4.23	1.52	5.75
LSD _{0.05}	1.82	1.79	0.57	0.39	0.76
p <	0.0004	<0.0001	<0.0001	<0.0001	<0.0001

^zGrowth Index: [(height + widest width of foliage + width at right angles to the widest width)/3].

Table 3. Influence of substrate and rate of vermicompost amendment on marigold SPAD color readings, and number of flowers and root quality ratings at harvest of marigolds in six-inch pots.

Treatment	SPAD reading	Number	
		of flowers	Root rating ^z
3B + SRF	48.1	7.4	4.2
CUST + SRF	54.0	8.0	4.0
CUST + 0% VC	46.8	4.9	2.9
CUST + 3% VC	39.1	6.8	4.0
CUST + 6% VC	39.3	7.6	3.9
CUST + 9% VC	41.3	8.1	4.0
CUST + 12% VC	44.8	6.9	4.1
CUST + 15% VC	42.3	6.7	4.2
CUST + 18 % VC	45.8	7.1	4.1
LSD _{0.05}	2.86	1.20	0.33
p <	<0.0001	<0.0001	<0.0001

^zRoot rating: 0= none visible on surface of root ball, 5 = best, largest and most vigorous.

Table 4. Influence of substrate and rate of vermicompost amendment on substrate pH and electrical conductivity in six-inch marigold pots.

Treatment ^z	pH		Electrical conductivity (mmho cm ⁻¹)	
	1 DAT	36 DAT	1 DAT	36 DAT
3B + SRF	6.28	6.18	0.73	0.14
CUST + SRF	5.24	5.05	0.55	0.30
CUST + 0% VC	5.41	5.72	0.57	0.64
CUST + 3% VC	5.78	6.29	0.68	0.25
CUST + 6 VC	6.17	6.59	0.83	0.44
CUST + 9% VC	6.21	6.63	0.74	0.40
CUST + 12 VC	6.44	6.73	0.96	0.39
CUST + 15% VC	6.48	6.93	0.92	0.41
CUST + 18 % VC	6.48	6.84	1.35	0.83
LSD _{0.05}	0.312	0.268	0.294	0.314
p <	<0.0001	<0.0001	<0.0001	<0.0022

**Gibberellin A₃ Treatment of Seeds, Container Volume,
Substrate pH, and Nitrogen Source and Rate
Influence Growth of Containerized Seabeach Amaranth (*Amaranthus pumilus*)**

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Index Words: Beach Restoration, Amaranthaceae, Recovery Plans, Threatened Species, Dune Species, Mineral Nutrition, Sexual Propagation

Significance to Industry: Results demonstrate that seedling transplants of seabeach amaranth (*Amaranthus pumilus* Raf.) can be produced successfully in containerized production with maximum top growth occurring with N supplied at 300 mg·L⁻¹ (ppm) from an acidic or basic fertilizer having a 4.5N-1P-1.9K or 6.8N-1P-5.6K ratio, respectively.

Nature of Work: Seabeach amaranth is a summer annual native to the beaches and barrier islands of the Atlantic Coast and once ranged from Massachusetts to South Carolina (6). However, by 1990, it no longer occurred in six of the nine states of its original range with the remaining populations occurring in New York, North Carolina, and South Carolina (6). Disappearance of the species from a large portion of its historic range and vulnerability of the plants to various threats, both natural and human, resulted in seabeach amaranth being listed in 1993 as “threatened” by the U.S. Fish and Wildlife Service (4). The threatened status of the plant resulted in development of a recovery plan by Weakley et al. (6).

Loss of seabeach amaranth from many areas where it was once endemic has raised concerns as it plays an important role in the initial stages of the development of sand dunes by trapping and binding sand on the beach (5, 6). The plant is also regarded by ecologists as an indicator species which allows one to access the vitality and vigor of a beach ecosystem. Thus, various state and federal agencies are interested in restoring seabeach amaranth to areas where it once grew. Beach restoration and sand renourishment projects have also created a demand for seedling transplants of the species that are unavailable. Therefore, to establish the plant in locations where it was once endemic and to meet the demand for transplants will require protocols for propagation and culture. One logical approach would involve production of seedlings that can be planted in suitable beach environments. If production protocols are developed for the species they may provide opportunities for growers to produce and sell plants to federal, state, and private agencies for recovery efforts.

Seeds of seabeach amaranth are relatively easy to germinate based on previous research (1, 2). Freshly harvested seeds of the species are physiologically dormant (have embryo dormancy) and require a period of stratification (moist-prechilling) to

break (release) dormancy (1, 2). Stratification of 84 to 120 days is necessary to remove physiological dormancy completely followed by germination at high temperatures [e.g., 8/16-hr thermoperiod of 30/20C (86/68F)] with light (e.g., a daily 16-hr photoperiod) to achieve maximum germination. A recent report by Norden et al. (3) noted the need for lengthy stratification to remove embryo dormancy can be eliminated by treatment of the seeds with the potassium (K) salt (K-salt) of gibberellin A₃ (K-GA₃). Treatment of the seeds for 24 hr with a solution of K-GA₃ at 1000 mg·L⁻¹ (ppm) will remove physiological dormancy without the need for stratification. Treatment of the seeds with K-GA₃ also reduces sensitivity of the seeds to light and appears to broaden the range of temperature at which germination will occur. Although Norden et al. (3) reported K-GA₃ treatment will remove physiological seed dormancy of seabeach amaranth, they did not observe subsequent growth of seedlings to determine if this treatment has any deleterious affects on seedling growth.

Although protocols for seed germination of seabeach amaranth have been published (1, 2, 3), little if any quantitative information has been published on culture. Therefore, the following research was conducted to develop protocols for containerized production of seabeach amaranth. To develop such protocols various factors were investigated including the influence of K-GA₃ treatment of seeds on subsequent seedling growth, container volume, substrate pH, and N source and rate.

Seeds of seabeach amaranth were stratified for 90 days at 4C (39F) or treated with a solution of K-GA₃ at 1000 ppm for 24 hr. After treatment, both groups of seeds were sown in containers of two differing volumes, 139 or 635 cm³ (8.5 or 38.7 in³), with a substrate of 1 peat : 1 pine bark (v/v) amended with one of two rates of pulverized dolomitic limestone [2.24 or 4.48 kg/m³ (3.78 or 7.55 lb/yd³)]. The containers were maintained in a greenhouse and after seedling emergence, seedlings were fertilized with a 20N-4.4P-8.2K(20N-10P₂O₅-20K₂O) acidic, water soluble fertilizer or a 15N-2.2P-12.3K(15N-5P₂O₅-15K₂O) basic, water soluble fertilizer. Each fertilizer was applied thrice weekly at N application rates (NARs) of 75, 150, 225, or 300 mg·L⁻¹. Eight weeks after initiation (sowing of seeds), the study was terminated and data recorded.

Results and Discussion: Regardless of fertilizer, acidic or basic, top dry weight and leaf area of seabeach amaranth increased linearly with increasing NAR, and maximum top dry weight, and leaf area occurred with N at 300 mg·L⁻¹, whereas root dry weight was unaffected by NAR. Both fertilizers increased electrical conductivity (EC) linearly with increasing NAR, and EC values of 1.15 to 1.18 dS·m⁻¹ should be adequate for maximum growth. Substrate pH decreased linearly with increasing NAR 21, 43, and 57 days after initiation. Top and root dry weights, and leaf area were greater for seedlings resulting from seeds treated with K-GA₃ compared to seedlings from stratified seeds. Seabeach amaranth grown in the large containers had top and root dry weights and leaf area 61%, 33%, and 57% larger, respectively, compared to plants grown in the smaller container volume.

Top N concentration increased linearly with increasing NAR, for acidic and basic fertilizers with concentrations of 58.4 and 50.4 mg·L⁻¹, respectively, at maximum top dry weight. Similarly, top nutrient content of N increased linearly with NAR, however, top N content was unaffected by either rate of limestone or type of fertilizer.

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**Comparison of Substrate Amendments for the Adjustment of Hydrangea
(*Hydrangea macrophylla* (THUNB.) SER 'Bailmer', Endless Summer®)
Flower Color**

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Index Words: Douglas-fir bark, aluminum sulfate, clay, peat, pH,

Significance to the Industry: Results demonstrated that pozzolan clay can be used as a soilless substrate amendment that results in enhanced blue sepal color in container produced hydrangeas. With the addition of clay to a Douglas-fir bark substrate, blue flowers occur at higher pH levels than with aluminum sulfate alone. Nursery growers who observe poor growth from low substrate pH or have difficulty achieving blue sepals could use a clay amendment to alleviate these issues.

Nature of Work: As hydrangeas gain popularity and new cultivars are developed, it is essential for growers to have the ability to produce quality containerized plants with the desired, marketable flower color. The availability of aluminum (Al) causes hydrangea sepal color to change between varying shades of pink and blue. Research by Takeda et al. (8) showed that Al causes blue flowers by interacting with anthocyanin and quinic ester pigments within the sepals. The amount of Al available in a soilless substrate is directly related to substrate Al content and pH. Commonly, Al is not available in adequate concentrations in soilless substrates. Altland and Buamscha (1) found that when adjusting the pH of Douglas-fir bark (DFB) with CaCO_3 , the DTPA extraction of (Al) went from 22.9 mg/L at a pH of 4.9 to an availability of 5.5 mg/L at a pH of 6.5. Therefore, it has been traditionally recommended for the greenhouse and nursery industry to grow pink flowering hydrangeas at a substrate pH of 6.5, and blue hydrangeas at a substrate pH of 5.5 (2). To achieve these low pH values while providing proper Al, aluminum sulfate (AlSO_4) drenches or amendments have been used as the industry standard to produce blue sepals in hydrangea production.

Various clay containing minerals have been used as soilless substrate components either to increase bulk density (3,5), or to improve water and nutrient holding capacities (6). Additional studies have been done using (aluminosilicates) clays as a substitute for aluminum sulfate replacement. Handreck (4) mixed a 10% kaolite clay amendment to a pine bark based substrate and was able to produce blue hydrangea sepals when the pH remained below 4.9. Using Al charged zeolite clay at rates from 10-40% in a peat and perlite mix, Opena and Williams (7) were able to produce blue hydrangea flowers in the pH range of 3.7-4.0.

To assess the ability of pozzolan clay [diatomaceous calcined clay containing 10% (by wt.) aluminosilicate] to produce blue hydrangea flowers at an elevated pH, an experiment was initiated on 1 June 2007 at the North Willamette Research and Extension Center, Aurora, OR. The experiment was a 3 x 3 factorial design (Al rate x substrate amendment) organized in a completely randomized design with nine

treatments each replicated 10 times. *Hydrangea macrophylla* (THUNB.) SER 'Bailmer' (PP15,298), Endless Summer® was potted into three bark based substrates with different amendments in trade #2 containers. Douglas-fir [*Pseudotsuga menziesii* (Mirb.)] bark of a fine and course textures (screened to 0.9 or 2.2 cm) was used as the primary component of all substrates (Marr Bros. Monmouth, OR.). The substrates were as follows: 9:1 (by vol.) DFB:pozzolan clay (Western Pozzolan Corp., Doyle, CA.), 7:3 (by vol.) DFB:sphagnum peat moss (Sun Gro Horticulture Canada Ltd., LAVAL, Quebec), and 3:2 (by vol.) coarse DFB:fine DFB. Three rates of AlSO_4 (GEO Specialty Chemicals, Baltimore, MD.) were added to the three substrates: the industry standard of $7.4 \text{ kg}\cdot\text{m}^{-3}$ (12.5 lb yd^{-3}); high rate, $\text{kg}\cdot\text{m}^{-3}$ (6.3 lb yd^{-3}); medium rate or no AlSO_4 . A requisite amount of dolomite lime was added to each of the treatments to equalize pH across treatments. Dolomitic lime (Chemical Lime Co., Fort Worth, TX) was incorporated at a rate of 4.8, 3.6, 2.4 $\text{kg}\cdot\text{m}^{-3}$ for the high, medium, and control AlSO_4 treatments, respectively. Micromax (The Scotts Company, Marysville, OH) was incorporated [$0.88 \text{ kg}\cdot\text{m}^{-3}$ (1.5 lb yd^{-3})] into the substrate for all treatments. Hydrangeas were topdressed with 60 g of 15N-9P-12K Osmocote Plus (5-6) mo. product (The Scotts Company, Marysville, OH) and were overhead irrigated following industry standards.

Growth index [(height + mean width)/2] and flower color were recorded 21 May 2008 when the plant was determined to be at a saleable stage. At this time substrate solution pH was measured via the pour-through nutrient extraction procedure (9). Flower color and customer appeal were evaluated independently by 8 individuals. Hydrangeas were rated 1 to 5; 5 being most blue and highest customer appeal, respectively. The rating results were arcsin transformed to ensure normal distribution. Data was analyzed by analysis of variance using the General Linear Models Procedure (SAS Institute, Cary, NC). Means were separated with Fisher's Protected Least Significant Difference, $P = 0.05$ when appropriate. Simple Effects were used to test significant interactions.

Results and Discussion: Substrate and AlSO_4 had a significant effect on ratings for sepal color and customer appeal (Table 1). Increasing aluminum sulfate and pozzolan clay amounts increased the blue color rating of hydrangea sepals. At each AlSO_4 concentration, the highest color ratings for all substrates occurred in combination with clay. The addition of the peat amendment did not significantly affect flower color compared to the unamended treatment. When the flowers were ranked for customer appeal, blue flowers were preferred (Table 1). As AlSO_4 rates increased, the flower color was rated as more blue and consequently appeal ratings also increased. The same effect was also seen when the AlSO_4 rate was 0, the addition of clay produced blue flowers which were rated higher for appeal than the flowers from the peat and none substrates. The clay amendment treatments had the highest color and appeal ratings, with the clay + high AlSO_4 rated highest overall.

Substrate and AlSO_4 had a significant effect on soilless substrate solution pH (Table 2). We hypothesize the differences in soilless substrate solution pH were due to discrepancies in the dolomite and aluminum sulfate rates. However, the variability of substrate pH, at 6.63 – 7.02, was not great and likely did not affect flower color or growth. The mean height ($55.0 \text{ cm} \pm 0.9 \text{ SE}$), mean width ($66.5 \text{ cm} \pm 0.7 \text{ SE}$) and mean growth index ($90.8 \text{ cm} \pm 0.6 \text{ SE}$) was not significantly different between treatments (data not shown).

The incorporation of pozzolan clay in addition to $AlSO_4$ in the substrate assists in blueing of hydrangea sepals even at high pH levels without negatively affecting growth. This will give growers more leeway in the production of blue hydrangeas, allowing for the desired flower color without the complications of maintaining a low pH.

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Table 1. Effect of substrate amendment and aluminum sulfate (AlSO₄) rate on flower color and customer appeal.

Substrate Amendment	AlSO ₄ (kg·m ⁻³)						Significance	
	0		3.7		7.4			
	color	appeal	color	appeal	color	appeal	color	appeal
Clay	3.7 ^v a ^z	3.7 ^w a	4.4a	3.7	4.7a	4.0	^{xxx}	ns
Peat	1.0b ⁴	1.0b	3.3b	2.8	3.9b	3.3	^{xx}	^{xx}
None	1.2b	1.3b	2.9b	2.7	4.2b	3.5	^{xx}	^{xx}
Significance	^{yy}	^{xx}	^{xx}	ns	^{xx}	ns		

^zMeans within a column and variable not followed by the same letter are significantly different as determined by Fishers Protected LSD $P = 0.05$.

^ySignificance for color and customer appeal within row

^xSignificance for color and customer appeal within column

^wCustomer appeal of the flower color rated on a scale from 1-5, 5 being most blue.

^vColor of the flower rated on a scale from 1-5, 5 being most blue

ns, ^{xx} Nonsignificant or significant at $P \leq 0.01$, respectively.

Table 2. Effect of substrate amendment and aluminum sulfate (AlSO₄) rate on pH at experiment completion on 22 May 2008.

Substrate Amendment	AlSO ₄ (kg·m ⁻³)			Significance
	0	3.7	7.4	
Clay	6.95	7.01 a ^z	6.86	ns ^y
Peat	6.89	6.63 b	7.02	^{xx}
None	6.72	6.81 b	6.84	ns
Significance	ns	^{xx}	ns	

^zMeans within a column and variable not followed by the same letter are significantly different as determined by Fishers Protected LSD $P = 0.05$.

^ySignificance within row

^xSignificance within column

ns, ^{xx} Nonsignificant or significant at $P \leq 0.01$, respectively.

Influence of Day/Night Temperatures on Containerized Production of Selected *Helleborus* sp.

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Index Words: *Helleborus foetidus*, *Helleborus xhybridus*, *Helleborus niger*, Perennials

Significance to Industry: *Helleborus foetidus*, *Helleborus xhybridus*, and *Helleborus niger* responded differently to day and night temperatures. Maximum total dry weight of *H. foetidus* occurred with days/nights of 18/14C (64/57F) whereas total plant dry weight of *H. niger* was maximized with days/nights of 14/10C (57/50F). At days of 22 or 26C (72 or 79F), there were quadratic responses in total dry weight with maximum growth of *H. xhybridus* at days of 22 or 26C (72 or 79F) with nights of 18 and 14C (64 or 57F), respectively.

Nature of Work: The genus *Helleborus* L. (hellebores) includes many exciting species and selections that offer extremely attractive winter to early spring flowers for shade gardens in the southeastern United States (1, 3). In the landscape, *Helleborus xhybridus* L. (Lenten rose) and *Helleborus foetidus* L. (stinking hellebore) are easy to cultivate having few disease and insect problems and tolerating a wide range of soils (1, 3). On the other hand, in the southeastern U.S., cultivation of *Helleborus niger* L. (Christmas rose) is difficult even under ideal landscape conditions.

Nursery production of hellebores can be very challenging. When grown in containerized production, hellebores suffer mineral nutrient deficiencies and slow growth rates. Hellebores also appear to be very sensitive to high temperature (Richard and Judith Tyler, Pine Knot Farms Perennials, Clarksville, VA, personal communication). Although some research has been reported on culture of hellebores (2), it appears no research has been reported on the influence of temperature. Therefore, the following research was conducted at the North Carolina State University Phytotron to study the influence of day/night temperatures on containerized culture of three species of hellebores.

On June 5, 2007, seedlings of *H. foetidus*, *H. xhybridus*, and *H. niger* were transplanted into square 1-L (1.1 qt) plastic containers filled with a substrate of 4 pine bark : 1 sand (v/v) amended with 1.8 kg•m⁻³ (3 lb/yd³) dolomitic lime. After transplanting, the plants were acclimated in a controlled-environment greenhouse at the Horticulture Field Laboratory, Raleigh, under natural photoperiod and irradiance with days/nights of 24/18C (75/64F). On June 12, 2007, seedlings were transferred to the Phytotron and temperature treatments were initiated the following day using four controlled-environment A-chambers and one B-chamber (4). Seedlings were arranged as a 3 x 5 x 5 factorial in a completely random design using four single-plant replications per temperature treatment per species. The two main factors were five day [(14, 18, 22, 26, and 30C) (57, 64, 72, 79, and 86F)] and five night temperatures [(10, 14, 18, 22, and 26C) (50, 57, 64, 72, and 79F)] provided to seedlings as 9/15-hr thermoperiods.

Temperatures were maintained within 0.25C (0.45F) of the set point. Plants were moved between chambers at 0730 and 1630 HR daily to maintain appropriate day/night temperatures. Plants exposed to the same day and night temperature were also moved daily to different areas of a chamber to simulate transient mechanical perturbations and to avoid possible gradient effects within chambers.

During the 9-hr portion of a thermoperiod, chamber irradiance was provided by a combination of cool-white fluorescent lamps and incandescent bulbs resulting in a *PPF* of 642 $\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$ (4). Incandescent bulbs providing a *PPF* of 44 $\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$ were used as a dark interruption between 2300 and 0200 HR daily. Plants were fertigated every other day with the standard Phytotron nutrient solution providing N, P, and K at 106, 10, and 111 $\text{mg}\cdot\text{L}^{-1}$ (ppm), respectively.

On September 14, 2007, 95 days after initiation, the experiment was terminated. Plants were separated into roots and shoots. Roots were washed to remove substrate. Roots and shoots then were dried at 70C (158F) for a minimum of 72 hr. Data were subjected to analysis of variance (ANOVA) procedures and regression analyses.

Results and Discussion: Analysis of variance revealed a significant species x day temperature x night temperature interaction. Therefore, data were reanalyzed and are presented by species. Additionally, the day temperature x night temperature interaction was significant for total dry weight of *H. xhybridus*. As such, day and night temperature main effects are only discussed for *H. foetidus* and *H. niger* and additional statistical analyses were conducted and treatment comparisons were made within each day temperature and within each night temperature for *H. xhybridus*.

Total dry weight of *H. foetidus* responded quadratically as day and night temperatures increased (Table 1). Maximum total dry weight of *H. foetidus* occurred with days/nights of 18/14C (64/57F). In contrast, total dry weight of *H. niger* decreased linearly with increasing day and night temperatures. Total dry weight of *H. niger* was maximized with days/nights of 14/10C (57/50F).

Total dry weight of *H. xhybridus* differed between each day and night temperature combination (data not presented). For all night temperatures except 14C (57F), plant dry weight decreased linearly as day temperature increased. At nights of 14C (57F) there was a quadratic response to total dry weight with maximum total plant dry at days of 18C (64F).

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Table 1. Effect of day temperature averaged over all night temperatures and the effect of night temperature averaged over all day temperatures on total dry weight of *Helleborus foetidus* and *Helleborus niger*.^z

Day temperature (C)	<i>H. foetidus</i> (g)	<i>H. niger</i> (g)
14	16.0 ^z	5.4
18	19.1	4.6
22	17.7	4.6
26	12.8	3.6
30	6.0	2.1
Linear	***	***
Quadratic	***	NS
Night temperature (C)	<i>H. foetidus</i> (g)	<i>H. niger</i> (g)
10	16.4	4.6
14	18.8	5.3
18	17.7	4.3
22	11.2	3.5
26	7.5	2.5
Linear	***	***
Quadratic	***	*

^zData are means of 20 observations.

NS, *, *** Nonsignificant or significant at $P \leq 0.05$ or $P \leq 0.001$, respectively.

Response of *Loropetalum Chinese var. rubrum* Cultivars Prone to Little-leaf Disorder to Substrate Applications of Copper

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Index words: Chinese fringe flower, Copper deficiency, Cuprous oxide, Cupric sulfate,

Significance to Industry: A study conducted in 2005 indicated that little-leaf disorder on *Loropetalum chinense var. rubrum* (R. Br.) Oliv. is caused by a deficiency of copper. Foliar applications of cupric sulfate to plants with severe deficiencies temporarily corrected the problem. This current research shows that increased rates of incorporated copper are required to prevent little-leaf disorder from occurring in container-grown *Loropetalum*.

Nature of Work: Chinese fringe-flower, *Loropetalum chinense var. rubrum*, was introduced into the United States in 1989 and they quickly became popular plants in the southeastern United States. Little-leaf disorder became a problem on container-grown plants in pine bark substrates during the late 90's. Symptoms are as follows: darkening of older growth, shortening of internodes, upward cupping of leaves, crinkling of new growth, particularly the distal part of the leaf, and a decrease in leaf size. In severe cases leaf necrosis occurs along with stem elongation, thus branches appear to be elongating without new leaves. Petioles become very short. Branchlets may also be reflexed or drooping (1,2). The cultivar 'Ruby' consistently has the problem, while it has also been noted on 'Chang's Ruby', 'Sizzling Pink' and 'Suzanne'. Plants in the ground do not generally express the problem, except on acidic, sandy soils (personal observation). Based on this we suspect there is an element present in the native soil that is not being supplied in sufficient quantity in pine bark substrates. Earlier research has shown that little-leaf of *Loropetalum* is caused by a deficiency of copper (1,2). Since repeated foliar applications of copper compounds did not consistently solve the problem, incorporation of soluble copper sulfate and insoluble cuprous oxide into the substrate were considered.

On 14 September, 2005, a study was initiated at Monrovia Growers in Grady County, GA. Cultivars selected were *Loropetalum chinense var. rubrum* 'Sizzling Pink' and 'Suzanne'. Uniform liners not showing symptoms of little-leaf were shifted into #5 containers (GL 2000 (14.9 liters), Nursery Supplies, Chambersburg, PA.). The control treatment was the standard proprietary Monrovia substrate with 13.6 g of copper sulfate (CS) per cubic yard incorporated as mixed by the local bark supplier. All other treatments were added to the standard Monrovia substrate in which CS was not added by the bark supplier. Treatments included the incorporation (in grams per cubic yard of substrate) of different rates of CS (25.2% Cu, Fisher Scientific, Pittsburg, PA) and CO (cuprous oxide, 97% Cu, American Chemet, East Helena, MT). Additional treatments included 2) the Monrovia substrate without CS added (MS), 3) MS plus 15 g of CS, 4)

MS plus 30 g of CS, 5) MS plus 45 g of CS, 6) MS plus 4.2 g CO, 7) MS plus 8.4 g of CO, 8) MS plus 16.8 g of CO), and 9) MS plus 15 g of CS and 4.2 g of C). The plants were arranged using a randomized complete block design with nine treatments and six blocks with single plant replicates. Plants were grown using standard nursery practices. Plants were rated for little-leaf in May, 2006, November, 2006, and at the termination of the study in June of 2007 using the following rating scale: 1 = no normal growth, 2 = <50% normal growth, new growth showing little-leaf, 3) >50% normal growth, new growth showing little-leaf, and 4 = normal new growth. Growth indices [(height + width 1 + width 2/3)] were measured on 21 Aug., 2006 and 5 June, 2007. Shoots of all plants were pruned back to the edge of the container and to a uniform height on 21 Aug., 2006. All prunings were collected to determine the dry mass of shoots removed by trimming. Final shoot dry mass was determined by cutting off the tops of the plants just above the substrate on 11 June, 2007. Dry mass of the shoots was determined after drying in a forced air oven at 66C (150F) for 72 hours. Quality index was determined by dividing shoot dry mass by the growth index, thus giving an index of canopy density. Samples for foliar analysis were collected from new growth and substrate samples were collected on 11 June, 2007 and were sent to Waters Laboratory (Camilla, GA) for standard analysis.

Data was analyzed using SAS (version 8; SAS Institute, Cary, NC). Mean separations were by LSD and Dunnett's *t* tests where appropriate.

Results and Discussion: There were no interactions between cultivar and copper treatments for little-leaf ratings and shoot growth (data not shown). At all three dates, little-leaf symptoms were worse on 'Suzanne' compared with 'Sizzling Pink' (data not shown). Plants grown in the MS substrate without copper consistently had severe little-leaf symptoms. At all three dates, plants treated with the medium to high rates of CS, CO, or the combination treatment had less little-leaf compared to plants grown in the standard Monrovia substrate. Treatments showing no little-leaf after 21 months were both high rates of incorporation for CS and CO.

Growth indices were not different among cultivars at both measurement dates (data not shown). In August of 2006, 'Suzanne' had a 9% increase in shoot trimmings compared to 'Sizzling Pink' and a greater quality index. At the end of the study there was no difference in shoot dry mass between cultivars, however the final quality index was higher for 'Sizzling Pink' compared with 'Suzanne'. Growth indices for plants in all substrate treatments were greater than the control plants in August of 2006. Shoot dry mass of trimmings increased compared to the control for all three CS treatments, the two highest rates of CO, and the combination treatment (data not shown). Quality indices followed the same trend as did shoot dry mass. Final growth indices, shoot dry mass and quality indices were all greater for the three rates of CS, the two highest rates of CO, and the combination treatment.

There was an interaction between cultivar and treatment for final foliar nutrient analysis (data not shown). In general, foliar micronutrients in the cultivar 'Suzanne' appeared to be elevated in treatments one and two compared to 'Sizzling Pink'. Foliar micronutrient concentrations were within published sufficiency ranges for this species (3). Final substrate copper ranged from 0.75 mg/L for the MS substrate compared to a high of 6.9

mg/L for the highest rate of CO (data not shown). These values are considerably higher than recommended values for substrate copper (4). There was no correlation between final copper concentrations in the foliage and little-leaf ratings (data not shown); however, there was a significant linear relationship between final substrate copper concentration and final little-leaf ratings ($P=0.0002$, $r^2=0.87$).

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Physical Properties and Microbial Activity in Forest Residual Substrates

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Index Words: pine bark, peat moss, clean chip residual, CCR, container-grown plant production

Significance to Industry: Many growers have expressed concern that switching from growing in a pine bark-based substrate to one with a significant wood content will increase microbial activity, resulting in nitrogen (N) immobilization. This study evaluated four growth substrates (pine bark, peat moss and two hammer mill screen sizes of clean chip residual or CCR) in a simulated 60-day production cycle. Physical properties of each substrate were different, though pine bark and CCR had more air space and less container capacity than peat moss, in general. Results of the incubation study indicate that CCR has only slightly more microbial activity than pine bark. Peat moss had the least microbial activity. This data shows that while there is a slight but significant difference between pine bark and CCR the disparity is minimal and will likely have nominal effects for fertilizer requirements as growers switch to crop production in CCR.

Nature of Work: Clean chip residual is a by-product of the pulp industry. Forest operators harvest small caliper pine trees during thinning operations and sell the 'clean chips' (99.9% wood) to pulp mills for the production of paper products. The material remaining after trees have been harvested for clean chips is either sold for boiler fuel at the pulp mill or spread back across the plantation due to lack of a market. This residual material (CCR) is composed of approximately 50% wood, 40% pine bark and 10% needles, etc. Clean chip residual has been evaluated in several studies (3, 4, 5, 6) as a replacement for pine bark since the latter is becoming increasingly difficult to obtain in production horticulture. A study by Boyer et al. (2) indicated that perennial plants (*Buddleia davidii* 'Pink Delight' Franch., *Gaura lindheimeri* 'Siskiyou Pink' Engelm. & A. Gray and *Coreopsis rosea* 'Sweet Dreams' Nutt.) exhibited similar growth whether grown in pine bark or CCR and did not require supplemental N during production. Nevertheless, tie up of nutrients in a wood-based substrate is a significant concern for many nursery crop producers. Jackson and Wright (7) reported less plant growth in a pine tree-based substrate (approximately 95% wood) due to severe N-immobilization. Therefore, the objective of this study was to measure microbial activity in pine bark, peat moss and two screen sizes of CCR (3/8-inch and 3/16-inch) over the course of 60 days in a soil incubation experiment. Substrate air space, container capacity, and total porosity were determined following procedures described by Bilderback et al. (1). Substrate bulk density (measured in g·cm³) was determined from 347 cm³ (21 in³) samples dried in a 105°C (221°F) forced air oven for 48 hours. Four rates of supplemental N (0, 1, 2, and 3 mg N) were added to each of the four substrates in the

study. The incubation procedure consisted of weighing 20 g (dry weight basis) of substrate into plastic containers. Samples were adjusted to similar moisture contents, treated with fertilizer (0, 0.5, 1.0 or 1.5 ml of 2000 ppm stock solution of NH_4NO_3) and placed in a sealed glass jar containing 10 ml water to maintain humidity and a vial containing 10 ml of 1 M NaOH as a CO_2 trap. Jars were placed in a dark incubation chamber at 25°C (77°F) for 60 days. Four samples of each treatment were removed at 7, 15, 30 and 60 days after treatment (total data, from 0 to 60 days, is presented) and evaluated for microbial activity. Carbon mineralization, which is a direct measurement of microbial respiration, was measured in this study. Carbon dioxide in the NaOH traps was determined by titrating the excess base with 1 M HCl in the presence of BaCl_2 . All traps were measured at each sampling date. Data were analyzed using Waller-Duncan k ratio t tests ($P \leq 0.05$) using a statistical software package (SAS[®] Institute, Cary, NC).

Results & Discussion: Physical properties of the four substrates tested varied (Table 1). Percent air space among substrates was significantly different: 3/16-inch CCR having the greatest (48%) and peat moss having the least (11%). Container capacity was also different for each substrate, with peat moss having the greatest container capacity (87%) and 3/16-inch CCR having the least container capacity (42%). Both CCR treatments were similar in total porosity and were between the high of 98% for peat moss and 79% for pine bark. Bulk density was greatest for 3/8-inch CCR ($0.22 \text{ g}\cdot\text{cm}^3$) and least for peat moss ($0.11 \text{ g}\cdot\text{cm}^3$).

Initial substrate pH was 4.1 for pine bark, 5.0 for 3/8-inch CCR, 5.5 for 3/16-inch CCR and 4.8 for peat moss (data not shown). Initial substrate electrical conductivity ($\text{mS}\cdot\text{cm}^{-1}$) was 0.23 for pine bark, 0.21 for 3/8-inch CCR, 0.15 for 3/16-inch CCR and 0.29 for peat moss.

Microbial respiration (as measured by carbon mineralization) was evaluated at each rating date (Table 2). Peat moss consistently had the least microbial respiration regardless of rating date or supplemental N rate. The greatest microbial respiration occurred with the CCR treatments. As N rate increased, microbial respiration increased in CCR and pine bark.

Clean chip residual consistently had the greatest amount of microbial respiration among the substrates over the course of the incubation (0-60 days) (Table 2). At 0 mg N rate, 3/8-inch CCR had greater microbial respiration than 3/16-inch, but at 1 and 2 mg N they were statistically similar. At 3 mg N 3/16-inch CCR had more microbial respiration than 3/8-inch CCR. Across the N rates for 3/8-inch CCR, microbial respiration increased with increasing N rate. For 3/16-inch CCR, microbial respiration increased with increasing N rate, though 2 and 3 mg N were similar. Pine bark and peat moss were different from each other and less than CCR treatments for microbial respiration. Pine bark was statistically similar at 1, 2 and 3 mg N rates, only 0 mg N had less microbial respiration. There was no difference in microbial respiration across N rates for peat moss.

These data support the results of plant growth studies (2, 3, 4, 5, 6) which demonstrated that under similar production systems a variety of annuals, herbaceous perennials, and woody nursery crops, in general, can have similar plant growth when grown in either CCR or pine bark. Since microbial respiration in CCR and pine bark is

relatively similar during a 60-day production cycle, it can be inferred that plant production in the high wood-fiber content substrate CCR will not result in N-immobilization.

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Table 1. Physical properties of clean chip residual, pine bark and peat moss substrates.^z

Substrates ^y	Air space ^x	Container capacity ^w (% Vol)	Total porosity ^v	Bulk density (g·cm ⁻³) ^u
3/8-inch CCR	28 b ^t	57 b	85 b	0.22 a
3/16-inch CCR	48 a	42 d	90 b	0.19 b
Pine bark	31 b	48 c	79 c	0.18 b
Peat moss	11 c	87 a	98 a	0.11 c

^zAnalysis performed using the North Carolina State University porometer.

^yCCR = clean chip residual.

^xAir space is volume of water drained from the sample , volume of the sample.

^wContainer capacity is (wet weight - oven dry weight) , volume of the sample.

^vTotal porosity is container capacity + air space.

^uBulk density after forced-air drying at 105°C (221.0 °F) for 48 h; 1 g·cm⁻³ = 62.4274 lb/ft³.

^tMeans within column followed by the same letter are not significantly different based on Waller-Duncan k ratio *t* tests at $\alpha = 0.05$ (n = 3).

Table 2. Accumulated microbial respiration (0-60 days) in clean chip residual, pine bark and peat moss substrates incubated with different nitrogen (N) rates (as estimated by Carbon mineralization).

<u>Substrate^z</u>	Carbon mineralization (mg/kg)				<i>MSD N-rate^x</i>
	0 mg N^y	1 mg N	2 mg N	3 mg N	
	<u>Total: 0-60 days</u>				
3/8-inch CCR	12,360	13,414	13,778	14,108	609
3/16-inch CCR	11,016	13,110	14,377	14,624	799
Pine bark	8,954	10,097	10,313	10,484	422
Peat moss	2,989	2,922	2,762	2,781	440
<i>MSD Substrate</i>	668	405	662	409	

^zCCR = clean chip residual.

^y2000 ppm stock solution of NH₄NO₃ (0, 0.5, 1.0, 1.5 ml).

^xMSD (minimum significant difference) based on Waller-Duncan k ratio t tests ($\alpha = 0.05$).

Arbuscular Mycorrhizal Fungi and Organic Fertilizer Influence Photosynthesis, Root Phosphatase Activity, Nutrition and Growth of Bush Morning Glory [*Ipomoea carnea* N. von Jacquin ssp. *fistulosa* (K. von Martinus ex. J. Choisy) D. Austin]

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Index Words: best management practices (BMP), bush morning glory, gas exchange, mycorrhiza, organic slow release fertilizer

Significance to Industry: There is a potential niche for U.S. Nursery growers to market organically produced, mycorrhizal plants. A greenhouse study was conducted to determine the effect of arbuscular mycorrhizal fungi (AMF) inoculation and organic fertilizer on the physiology, growth, and phosphatase activity of *Ipomoea carnea* subsp. *Fistulosa* (bush morning glory). The AMF treatment consisted of a commercial isolate of *Glomus intraradices* and a noncolonized (NonAMF) control. The organic fertilizer [Nitrell[®] 5-3-4 (5N-1.3P-3.3K)] was applied at 10%, 30% and 100% of the manufacturer's recommended rate, which were respectively, 2, 6 and 20 lbs · yd⁻³ (1.2, 3.6 and 12 kg · m⁻³). AMF significantly enhanced the growth index, plant height, stem diameter, root, leaf, shoot and total plant dry mass of *I. carnea* at the different fertilizer rates. In addition, AMF increased leaf number, leaf area, leaf area ratio and net photosynthesis. Nutrient uptake of N, P, K, Fe and Cu was higher in AMF plants. AMF inoculated plants had 27 to 79% colonization. The commercial AMF isolate was effective in enhancing growth and mineral ion uptake even at 100% organic fertilizer rate. Enzymatic root activity of acid phosphatase (ACP) and alkaline phosphatase (ALP) increased in AMF plants. The correlation between ACP activity and total P uptake in AMF plants was higher than NonAMF plants. A high correlation between ACP and ALP activity was also found in AMF than NonAMF plants. AMF inoculation with an organic fertilizer source increased mineralization of organic nutrients, in part due to an enhancement of root phosphatase activity (ACP and ALP) — thus enhancing nutrient uptake, increasing photosynthetic levels and improving overall plant growth.

Nature of Work: In the effort to meet increased environmental federal, state and local regulations, some U.S nursery and greenhouse growers are considering organic production (3). Organic production in conjunction with the use of 'environmentally friendly' biological microorganisms can enhance plant growth, minimize plant stress, reduce chemical application and nutrient runoff (1). Biological microorganisms include arbuscular mycorrhizal fungi (AMF) for inoculation of nursery and greenhouse crops. Organic sources of phosphorus (_oP) are made available to plants largely after its mineralization or hydrolyzation into inorganic phosphorus (_iP). This is mediated by the enzymatic activity of phosphatase in the rhizosphere. Phosphatase activity in the rhizosphere of mycorrhizal plants originates from plant roots, bacteria, and AMF (7).

Greater enhancement of enzymatic acid phosphatase (ACP) and alkaline phosphatase (ALP) activity occurred with AMF roots compared to NonAMF roots (2). Pacovsky (5) reported that ACP activity in AMF *Glycine max* L. roots was elevated compared to nonAMF roots, and it was associated with the effective release of iP from organic sources. There was a 38% greater ACP activity than ALP in the response of corn roots to soil P availability. ACP and ALP activities were shown to be closely related to the level of fungal colonization in *Zea mays* L. roots (2). However reports of differences in root phosphatase enzymatic activities between AMF and nonAMF roots are contradictory. Thus, the objectives of this research were to evaluate the effect of AMF inoculation and organic fertilizer on the physiology, gas exchange, growth, and phosphatase activity of *I. carnea*.

Uniform rooted cuttings of *Ipomoea carnea* subsp. *fistulosa* were grown in #3 (9.6 L) containers with a substrate mixture of 1 sandy loam: 1 sand, v/v. The AMF treatments consisted of a commercial isolate of *Glomus intraradices* Mycorise® Pro [AMF] (Premier Tech, Riviere-du-Loup, Quebec, Canada) and a noncolonized [NonAMF] control. The fertility treatments consisted of an organic fertilizer [Nitrelli® 5-3-4 (5N-1.3P-3.3K) Fertrell Co., Bainbridge, PA] at 10%, 30% and 100% of the manufacturer's recommended rate, which were respectively, 2, 6 and 20 lbs · yd⁻³ (1.2, 3.6 and 12 kg · m⁻³).

Plant Growth and AMF Analysis: At the termination of the experiment (day 60), plant growth index, number of leaves, stems, bloom number, and individual flowers at anthesis were recorded (n=12). Leaf area ratio and specific leaf area were calculated. At harvest, total leaf surface area, shoot and root dry mass (DM) were determined. Leaf tissue analysis was conducted on an inductively coupled plasma atomic emission spectrometer (J.R. Peters/Scotts Testing Lab., Allentown, PA) Assessment of AMF were taken at 15, 30 and 60 days after treatment and arbuscule, vesicle, intraradical hyphae, and total colonization were determined (4).

Total leaf chlorophyll (CHL *a* + *b*) was estimated at 60 days with a nondestructive method (8) using a portable chlorophyll meter (SPAD-501; Minolta, Japan). Gas exchange measurements were taken at 0, 30 and 60 days from four random plants per treatment. Determination included net photosynthesis (*A*), stomatal conductance (*g_s*), and transpiration rate (*E*) performed on physiologically mature, fully expanded leaves (n= 8, at 2 leaves per plant) with a LI-6400 Portable Photosynthesis System (LI-COR Inc., Lincoln, Nev.).

The activity of root acid phosphatase enzyme (ACP) and alkaline phosphatase enzyme (ALP) [soluble and wall bound] were determined in samples of four plants per treatment at the same time that AMF colonization samples were taken, i.e. 15, 30 and 60 days after inoculation. The procedure was a modification of that described by Tabatabai (6), based on the hydrolysis of *p*-nitrophenyl phosphate substrate to yield *p*-nitrophenol and inorganic phosphate. Experimental Design: The factorial experiment included: 2 [commercial inoculum (AMF) and (NonAMF)] X 3 [organic fertility levels] = 6 treatments in randomized design with each plant as an experimental unit (n=12). The data was analyzed using analysis of variance (SAS Institute Inc. 1996) and Tukey's ($\alpha=0.05$ %) and \pm SE for statistic differentiation among means.

Results and Discussion: Inoculation with the commercial isolate of AMF, *G. intraradices*, generally produced greater shoot, and root plant DM than NonAMF plants (Table 1). AMF also enhanced leaf and total plant DM, plant height, diameter, growth index, leaf number, leaf area ratio (LAR), and total leaf area at all the organic SRF rates (Tables 1 and 2). AMF increased, leaf number, leaf area, leaf area ratio, net photosynthesis ($P < 0.05$), and nutrient uptake of N ($P < 0.05$), P ($P < 0.001$), K ($P < 0.05$) and Cu ($P < 0.05$). AMF increased root acid phosphatase [ACP] ($P < 0.05$) and alkaline phosphatase [ALP] ($P < 0.01$) of bush morning glory.

In summary: 1) AMF significantly enhanced, growth index, height, diameter, root, leaf and total plant DM at the different organic SRF rates, 2) AMF increased, leaf number, leaf area, leaf area ratio, net photosynthesis, and nutrient uptake of N, P, K, and Cu, 3) the AMF commercial inoculum produced high levels of colonization ranging from 27% to 79% and 4) AMF increased root acid phosphatase [ACP] and alkaline phosphatase [ALP], and a higher correlation between ACP and ALP activity was found in AMF than NonAMF plants. AMF inoculation with an organic fertilizer source increased mineralization of organic nutrients, in part due to an enhancement of root phosphatase activity (ACP and ALP) — thus enhancing nutrient uptake, increasing photosynthetic levels and improving overall plant growth.

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Table 1. Growth (plant dry matter [DM], height, caliper and growth index) of *Ipomoea carnea* grown for 60 d with different rates of organic slower release fertilizer (OSRF) and inoculated (AMF) or not (NonAMF) with arbuscular mycorrhizal fungi.

AMF	Fert. ^x Rate (lbs.yd ⁻³)	Root DM (g)	Leaf DM (g)	Shoot DM (g)	Total plant DM (g)	Plant height (cm)	Stem caliper (cm)	Growth index ^w (cm ³)
NonAMF ^y	2	2.3 ± 0.2 ^z	1.3 ± 0.1 ^z	10.1 ± 0.4	12.5 ± 0.5	54.9 ± 1.0 ^z	8.6 ± 0.2	6168 ± 206
	6	2.8 ± 0.1	1.6 ± 0.1	10.7 ± 0.4	13.6 ± 0.4	54.1 ± 1.8	8.3 ± 0.2	6720 ± 446
	20	2.7 ± 0.1	2.3 ± 0.2	11.0 ± 0.3	13.7 ± 0.3	54.3 ± 1.3	8.1 ± 0.2	9347 ± 443
AMF	2	2.9 ± 0.2	1.5 ± 0.1	10.1 ± 0.3	13.0 ± 0.4	62.6 ± 1.5	8.8 ± 0.2	7965 ± 755
	6	2.8 ± 0.1	1.7 ± 0.1	11.1 ± 0.4	13.9 ± 0.4	60.3 ± 1.6	9.1 ± 0.2	10805 ± 1263
	20	3.0 ± 0.1	2.8 ± 0.2	12.6 ± 0.6	15.6 ± 0.7	66.0 ± 1.8	9.2 ± 0.5	11912 ± 1010
Significance (p < F)								
AMF		*	**	**	*	***	***	***
Fertility		NS	***	***	***	***	***	***
AMF x Fertility		*	NS	*	NS	NS	NS	***

^zValues are means ± SE; n=12.

^yNonAMF= non-inoculated controls; AMF = *Glomus intraradices* (MycorisePro®, Premier Tech Inc., Rivière-du-Loup, Québec, Canada).

^xOSRF= organic slow release fertilizer [Nitrell® 5-3-4 (5N-1.3P-3.3K)].

^wGrowth Index = (height x diameter₁ x diameter₂ / 3).

NS, *, **, *** Nonsignificant or significant at p < 0.05, 0.01, 0.001, respectively.

Table 2. Effect of arbuscular mycorrhizal fungi (AMF) and an organic slow release fertilizer (OSRF) on leaf number, leaf area, leaf area ratio (LAR) and chlorophyll of *Ipomoea carnea* during a 60-day containerized study.

AMF	Fert. ^x Rate (lbs.yd ⁻³)	Leaves (no.)	Leaf Area (cm ²)	LAR (cm ² g ⁻¹)	Leaf chlorophyll (µg cm ⁻²)
NonAMF ^y	2	7.6 ± 0.4	257.9 ± 42.4 ^z	21.5 ± 0.6	81.0 ± 0.8
	6	7.7 ± 0.5	279.3 ± 28.6	21.5 ± 1.2	84.1 ± 1.0
	20	9.6 ± 0.5	442.2 ± 28.9	34.4 ± 0.9	89.7 ± 0.6
AMF	2	8.7 ± 0.2	289.9 ± 14.6	23.4 ± 0.8	84.4 ± 0.5
	6	9.0 ± 0.6	332.3 ± 18.1	31.4 ± 1.7	84.2 ± 0.6
	20	10.5 ± 0.7	525.3 ± 42.4	35.4 ± 0.9	89.2 ± 0.3
Significance (<i>p</i> < F)					
AMF		**	**	*	NS
Fertility		***	***	***	***
AMF x Fertility		NS	NS	NS	NS

^zValues are means ± SE; n=12.

^yNonAMF= non-inoculated controls; AMF = *Glomus intraradices* (MycorisePro, Premier Tech Inc., Rivière-du-Loup, Québec, Canada).

^xOSRF= organic slow release fertilizer [Nitrell[®] 5-3-4 (5N-1.3P-3.3K)].

NS, *, **, *** Nonsignificant or significant at *p* < 0.05, 0.01, 0.001, respectively.

Nitrogen Immobilization in a Pine Tree Substrate During Short Term Crop Production

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Index Words: Container Media, Nursery Crops, Fertilization, Loblolly Pine, Pine Chips, *Pinus taeda* L., Wood Substrate

Significance to Industry: Pine tree substrate (PTS), peat-lite (PL), and pine bark (PB) were tested for nitrogen (N) immobilization during a 10 week experiment. Results indicate that PTS has a higher occurrence of N immobilization over 10 weeks compared to PL and PB, which helps to explain the additional N requirement in PTS during crop production compared to PL and PB. Despite the higher fertilizer requirement, the potential for PTS to be successfully used in greenhouse and nursery crop production is evident in the promising results that have been reported in recent years.

Nature of Work: Alternative substrates have been evaluated in the U.S. and throughout the world for many years. The need for new substrates is in response to the increasing costs, reduced availability, and environmental issues surrounding the use of traditional PL and PB substrates. Many of the currently researched substrates are derived from wood-based materials. The biggest concern with wood substrates is their requirement for higher N fertilizer applications to achieve optimal plant growth (3). Jackson et al., (3) reported that Japanese holly and azalea required an additional $1.8 \text{ kg}\cdot\text{m}^{-3}$ ($4 \text{ lb}\cdot\text{yd}^3$) of controlled release fertilizer when grown in PTS to achieve comparable growth to plants grown in PB. Greenhouse crops have also shown the need for additional fertilizer based on work by Wright et al., (7) who reported that chrysanthemums grown in PTS required an additional 100 ppm N to perform as well as plants grown in a commercial PL substrate. It has been hypothesized that N immobilization is the primary reason for the lower nutrient levels that are reported in growth trials when using PTS, but it has not been proven (6, 7). Numerous authors have reported that N immobilization occurs in wood substrates during the production of horticulture crops (1, 2) however, no studies have been conducted on PTS to evaluate its N immobilization occurrence.

The objective of this work was to determine the amount of N immobilization occurring in PTS compared to PL and PB. Pine tree substrate was produced by taking pine chips from coarsely ground pine logs (freshly harvested) and further grinding them in a hammer mill (Meadows Mills, Inc., North Wilkesboro, NC) to pass through a 2.36-mm (3/32 inch) screen. Pine tree substrate was pre-plant incorporated with $0.6 \text{ kg}\cdot\text{m}^{-3}$ ($1 \text{ lb}\cdot\text{yd}^{-3}$) calcium sulfate (CaSO_4). Pine bark and PL were pre-plant incorporated with $2.7 \text{ kg}\cdot\text{m}^{-3}$ ($6 \text{ lb}\cdot\text{yd}^3$) dolomitic lime and $0.6 \text{ kg}\cdot\text{m}^{-3}$ ($1 \text{ lb}\cdot\text{yd}^{-3}$) CaSO_4 . Pine tree substrate was not amended with lime due to its inherently high pH (6.0-6.5). Eighteen plastic 2 liter (2 quart) containers were filled with each of the substrates in Aug. 2007 and placed on a greenhouse bench in Blacksburg VA with average day and night temperatures of 24/19 °C (75/66 °F). All containers were equally fertilized once weekly with 300 ppm N

derived from calcium nitrate [Ca(NO₃)₂] which supplied 150 ppm N, and potassium nitrate (KNO₃) which supplied the remaining 150 ppm N, as outlined by Handreck (2). Every two weeks, three containers (reps) of each substrate were prepared for nitrate determination and then incubated for four days at room temperature. After incubation, nitrate concentrations were determined again on substrate samples from the same containers. The difference between day 0 (initial) and day 4 is the amount of nitrate immobilized during incubation of the substrate samples. Daily and weekly immobilization levels were determined from this data. Data were collected for 10 weeks and the experiment concluded in late Oct. 2007. The experimental design was completely randomized with 18 replications per substrate for a total of 54 substrate filled containers. Data were tested using the analysis of variance procedures of SAS (version 9.1 SAS Institute, Inc. Cary, NC). Data were also subjected to regression analysis using SigmaPlot (version 9.01 SPSS, Inc., Chicago, IL)

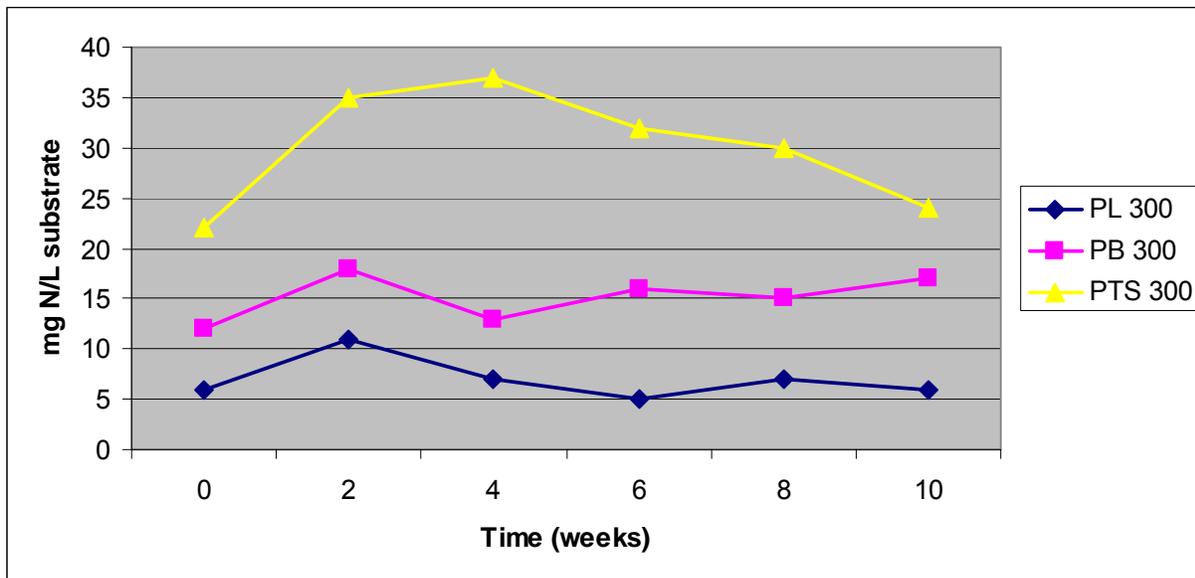
Results and Discussion: Results show that PTS has significantly higher levels of N immobilization occurring over 10 weeks than does PL and PB substrates (Figure 1). Peat-lite had the least amount of N immobilization occurring over the course of the experiment followed by PB. Peat-lite had increased immobilization between weeks 0 and 2 and then levels decreased through the end of the experiment (Figure 1). Immobilization in PB increased slightly over the duration of the 10 week experiment while immobilization in PTS increased through 4 weeks and then decreased through the end of the experiment. Even though immobilization levels decrease in PTS over time, levels remain higher than those of PL and PB throughout the 10 week experiment. The trend indicates that over a longer production period, the amount of N immobilized in PTS may be reduced to levels observed for PB substrates. This data helps to explain the lower substrate solution nutrient levels previously reported in PTS (3, 5, 6, and 7). The reason for decreased immobilization in PTS is likely due to a decreased rate of decomposition of the wood in PTS over time. The early stage of wood decomposition generates a large microbial biomass that consumes the easily degraded wood components (hemicellulose, soluble carbohydrates, etc.), but later in the decomposition process the amount of easily degraded wood components decreases resulting in decreased microbial populations, thereby decreasing the amount of N needed for microbial activity (less N immobilization) (4).

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Figure 1. Calculated nitrogen immobilization in peat-lite (PL), pine bark (PB), and pine tree substrate (PTS) over 10 weeks when fertilized weekly with 300 ppm N.



Pine Tree Substrate Construction for Optimal Water Holding Capacity and Air Space

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Index Words: container media, nursery production, loblolly pine, air space, container capacity

Significance to the Industry: This research demonstrates that amendments of peat moss, pine bark (PB) and sand to a pine tree substrate (PTS) can be used to improve the physical properties of PTS and plant growth in PTS. In this way PTS with larger particles (reduces grinding costs) can be used as the base for the substrate with the addition of other materials that increase water holding capacity. Another approach is to mix PTS of different particle sizes to produce a substrate with optimal physical properties.

Nature of Work: The use of a PTS produced by grinding loblolly pine trees (*Pinus taeda* L.) for the production of a wide variety of nursery and greenhouse crops has been demonstrated (1, 3, 6, 7, 8). The effect of the particle size of PTS—easily altered by the degree of grinding—on plant growth and physical properties such as container capacity (CC) and air space (AS), has been demonstrated (4, 5). Depending upon the particle size of PTS, blending materials such as peat moss, aged PB or sand with PTS should alter, CC, AS, and cation exchange capacity, pH and a number of other factors that could affect plant growth. This approach has not been investigated. Therefore, the purpose of this work was to evaluate the influence adding peat moss, PB, and sand to PTS with different particle sizes on substrate physical properties and the growth of marigold (*Tagetes erecta* Big. 'Inca Gold').

Substrates differing in particle size were prepared by further grinding coarse pine chips from loblolly pine (*Pinus taeda* L.) in a hammer mill fitted with different screen sizes: 4.76, 6.35, 9.54, and 15.8-mm (3/16, 1/4, 3/8, 5/8 inch). Each PTS was then amended with either, 25 % sand, 25 % peat, 25 % PB or 25 % PB and 10% sand by volume. Control treatments included peatlite (PL) (80% peat moss / 20% perlite (v/v) and 100% PB. Each substrate was amended with calcium sulfate (CaSO_4) at $0.6 \text{ kg}\cdot\text{m}^{-3}$ (1 lb/yd³). The peat moss and PB used for each substrate was amended with dolomitic limestone at $3.5 \text{ kg}\cdot\text{m}^{-3}$ (6 lbs/yd³). Physical properties of each substrate were determined pre-plant on three replicate samples of each substrate using the North Carolina State University Porometer Method (2). On April 16 marigold seedlings (*Tagetes erecta* Big. 'Inca Gold') from 144 units plug trays were transplanted into 10-cm square (1 L) plastic containers with the different substrates. Plants were glasshouse grown in Blacksburg, VA and fertilized at each watering with $300 \text{ mg}\cdot\text{L}^{-1}$ N from a Peters 20N-4.4P-16.6K Peat-Lite Special (The Scotts Co., Marysville, OH). On 14 May shoots were severed at the substrate surface, oven dried, and weighed.

Results and Discussion: Container capacity was higher in PTS 3/16 than in PTS 5/8, but AS was higher in PTS 5/8 than PTS 3/16 (Fig. 1). This reflects the finer particle sizes for PTS 3/16 versus PTS 5/8. Adding peat moss and PB, to PTS 3/16 and PTS 5/8 increased CC and decreased AS. However, adding sand did not affect CC but did decrease AS. Adding PB and peat moss to PTS 3/16 elevated CC to levels comparable to PL and above that of PB. Adding PB and peat moss to PTS 5/8 increased CC to that of PB but not to that of PL. Plant growth was reflective of the substrate's CC as affected by particle size and amendments. For example, shoot dry weight in PTS 3/16 and 5/8 was increased by the addition of sand, peat or PB (data not shown) and for PTS 3/16, growth was equal to PL and PB with the addition of peat, PB and PB/sand. Shoot dry weight was less with PTS 5/8 but the additions of sand, peat and PB increased growth above that of PTS 5/8. Why sand additions to PTS increased growth, but not CC is not understood. These results confirm previous work relating PTS particle size and growth (5) and show that growth can be improved by amending PTS with either sand, peat, and PB. The reason for this improvement in growth is most likely due to an increased CC of PTS (5) and in the case of PTS amended with peat moss and PB, increased growth may also stem from an increase in cation exchange capacity and improved nutrient availability in PTS.

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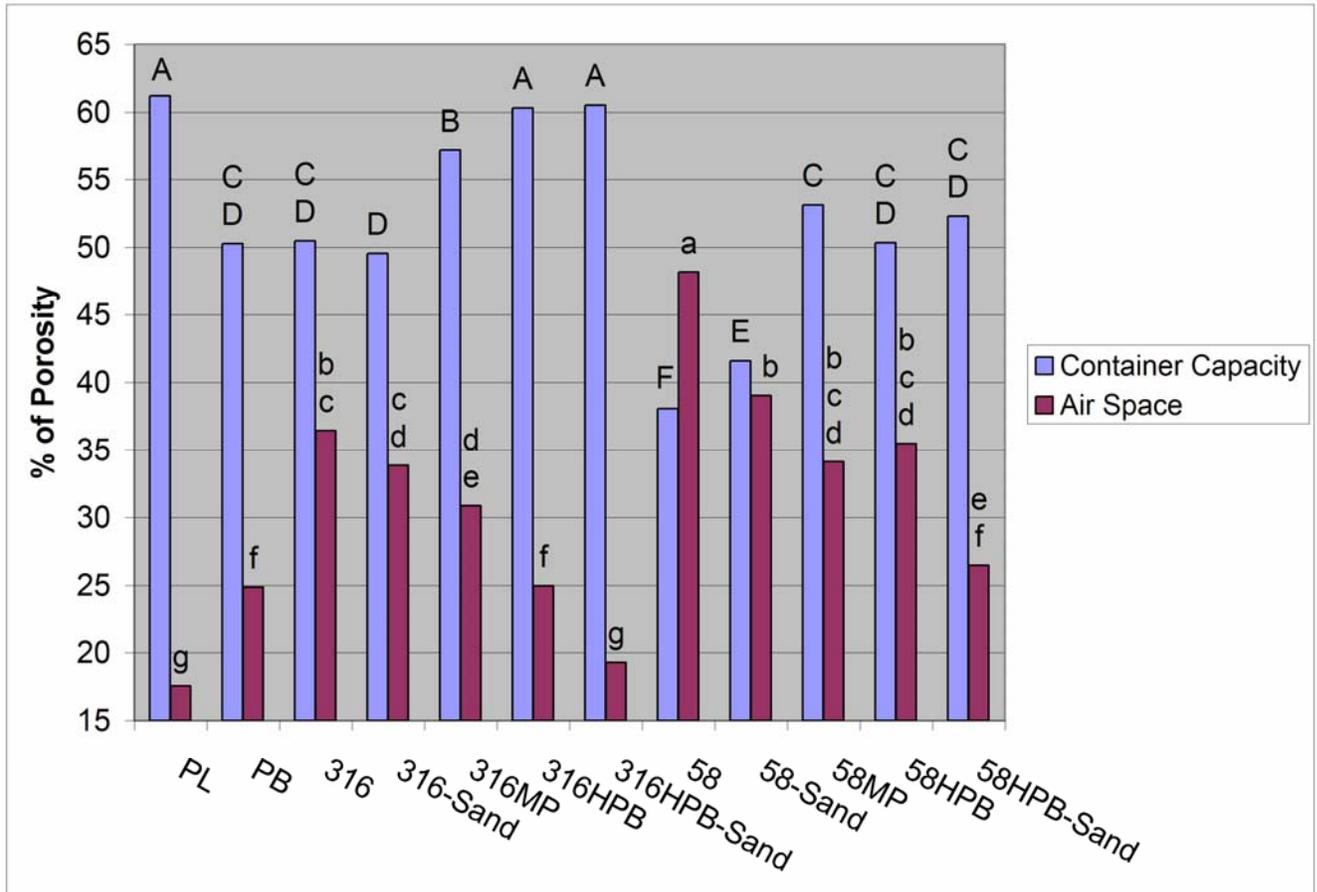


Figure 1. Effect of pine tree substrate (PTS) particle size and amendments of sand, pine bark (PB) and peat moss to PTS on percent container capacity and airspace. PL = peatlite (80% peat moss: 20% perlite, v/v); PB = aged PB; 316 and 58 = PTS ground to pass a 3/16 and 5/8 inch screen respectively; S =10 % sand by volume; MP = PTS mixed with 25% peat by volume; HPB = PTS prepared by hammering pine chips with 25% PB by volume; HPB-S = hammered with 25% PB and subsequently amended with 10% sand by volume. Bars with different letter indicate significant difference at $P \leq 0.05$ by Duncan's multiple range test. Upper case letters apply to container capacity and lower case letter apply to air space.

Nutrient Uptake and Use Efficiency of Four Mid-Atlantic Native Species Under Different Nutrient Rates and Urea

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Index Words: Nitrogen, phosphorus, alternative crops, container production.

Significance to Industry: This research investigates issues of both the sustainability of alternative crop production and physiological adaptation of mid-Atlantic native species to fertility in container production. Some of the species under investigation are commonly grown in the nursery industry, primarily as ornamentals, while others, less commonly grown, serve as fruit crops or crops for mitigation and restoration of degraded land. While agronomic row-crop values have recently improved, the increasing cost of production offsets sustainable profits for smaller farms. Increasing the palette of alternative crops and their uses may be one way to keep small family farms solvent and in production, in light of pressures from encroaching suburban development. Container production is resource intensive and this research investigates efficient nutrient application rates for native species which are claimed to be nutrient efficient. This research is but a part of a sustainable alternative crop production research program.

Nature of Work: "Native plants" still offer a variety of opportunities as alternative crops for potential growers. With creativity and an idea of potential local markets, a single species may have a variety of marketable qualities and characteristics, including ornamental value, alternative fruit production as a value added product, mitigation and restoration or medicinal/herbal values.

Nutrient uptake efficiency is defined as the fraction of applied nutrient assimilated by plants (8). Nutrient use efficiency is defined as the amount of biomass produced per unit of nutrient (3). Studies of natural systems have shown many native plants are biologically adapted to compete well in low nutrient environments (2) because of high nitrogen and phosphorus use efficiencies (NUE and PUE). Nutrient use efficiency also gives insight into the maximal efficiency of a species under nutrient limitation. The higher nutrient use efficiency, the less nutrient required for biomass production

There is a general consensus that native plant species can be utilized as low input ornamental plants, needing little fertilizer, water or pesticides after establishment in the landscape (11). This may be true if these species have high nutrient use efficiencies. However, in the nursery environment, can these same native species be produce with low nutrient input? It is feasible to assume that many native plants with aesthetic and marketable horticultural characteristics may be identified and utilized as alternative crops for highly sustainable, low input nurseries. While some varieties of native plant species are commonly grown by the nursery industry, little effort has been placed on

studying their minimum cultural requirements, including fertilizer and water use. This research investigates the nutrient requirements of four selected mid-Atlantic native plants under container culture. Additionally, a low-biuret foliar urea treatment was used as a third treatment to determine if it was an effective and efficient method to apply nitrogen. Foliar urea is a common method for applying N to citrus (6) and is effective for supplemental N fertility in peach (5).

The four plants selected were Black Chokeberry (*Photinia melanocarpa* Michx., K.R.Roberstson and Phipps, until recently in the genus *Aronia*), Coastal Sweetpepperbush (*Clethra alnifolia* L.), Virginia Sweetspire (*Itea virginica* L.) and Salt Marsh Hay (*Spartina patens* (Aiton) Muhl.). Each have multiple niche markets that may be exploited for profit. This study was performed at the University of Maryland Research Greenhouse Complex in College Park, Maryland. One year-old seedlings were transplanted into #2 trade containers with an 80% pine bark and 20% sphagnum peat potting medium. Due to a shortage of one-year old *P. melanocarpa* seedlings, some 18 month old seedlings were included in the experiment. Lab analysis of available N and P in the potting medium was analyzed to be less than 20 mg N and 5 mg P in each container at study initiation.

Prior to study initiation, a baseline harvest was performed on 5 plants from each species. Harvesting is a destructive sampling process in which the plant is removed from its container, and separated into leaf, stem and washed root tissues (8). These tissues are then dried in an oven at 60 °C for 48 hours, weighed, and milled through a 100 µm screen. Finally, tissue samples are analyzed for N and P concentrations and then normalized for nutrient content using dry weights.

Application of the three fertility treatments in a completely randomized design began in early March 2007. The first two treatments consisted of applications of 250 mL of nutrients dissolved in distilled water. The nutrient solute was made with ammonium nitrate and soluble 0:4.4:34 P:K fertilizer with a full compliment of micronutrients. There was a high rate (150 mg nitrogen (N) and 15 mg phosphorus (P)) and a low rate (75 mg N and 7.5 mg P). The nutrient solution was poured onto the potting medium of each plant once per week. During the 20 week study period, *C. alnifolia*, *I. virginica*, and *S. patens* received a total of 3.0g N (high treatment) and 1.5 g N (low treatment). During the longer 34 week study period for *P. melanocarpa*, the plants received a total of 5.1 g N (high treatment) and 2.6 g N, (low treatment). The third treatment was a spray application of a low-biuret foliar urea solution. Foliar urea is a common method for applying N to citrus (6) and is effective for supplemental N fertility in peach (5). The urea contained 46% N and less than 0.25% biuret. The foliar spray solution contained a 1% concentration of urea. The volume of spray administered was based on relative leaf area, as follows. *Clethra alnifolia* received 3 doses of 0.9 mL twice weekly for a total of 0.25 g N. *Itea virginica* and *S. patens* received 2 doses of the same volume twice weekly for a total of 0.17 g N. *Photinia melanocarpa* received 2 doses of the same volume twice weekly for a total of 0.28 g N during the 34 week study period. However, since the total amount of urea spray actually coming into contact with the leaves of each plant was not measured, nutrient efficiencies were not calculated for this treatment. In addition to the foliar urea spray, a nutrient solution was poured onto the potting medium of each plant once per week. The solution was the same as the high rate described for the first two treatments, without the N. Irrigation (spray stakes) was carefully adjusted

throughout the study so that plant needs were met while keeping leachate to 15% or less. Leachate volume was monitored by placing a drip tray below randomly selected containers. This equates to 85% of applied nutrients being available in the plant container. Nutrient uptake efficiency and use efficiency calculations are based on this 85% availability.

Three additional harvests were performed in May, June and July on *C. alnifolia*, *I. virginica* and *S. patens* for a study period total of 20 weeks. Five additional harvests were performed on *P. melanocarpa* in June, July, August, September and a final in October, for a study period total of 34 weeks. Each species had five replicates per treatment at each harvest. Dry weights, nutrient uptake and nutrient use efficiency at study end were statistically analyzed using ANOVA (SAS Institute Inc., Cary, NC) with only the results of the final harvest presented in this paper.

Results and Discussion: Dry mass for the four species and 3 treatments are shown in Table 1. As expected, all plants responded with significantly greater biomass under the high nutrient rate compared to the other treatments. Additionally, the foliar urea treatment was limiting for all species and significantly less biomass was acquired by plants under this treatment. This may be because of the amount of N available to the plants was far below the amount delivered in the other treatments, or that the plants did not utilize the applied urea. Significant differences in the transformed data of *P. melanocarpa* and *S. patens* root dry mass suggested that roots responded better to higher fertilization rates (Table 1). This is different than other studies showing root mass greater in lower nutrient rates (7, 10, 13). *Clethra alnifolia* and *I. virginica* did not exhibit significant increased root growth under the high fertility rate compared to the low fertility rate. The foliar urea treatment did not provide enough N to elicit root growth. While the above cited literature and many others suggest that low fertility increases root growth and root:shoot ratios, there seems to be a minimum amount of nutrients needed for root growth and limiting rates in this study limited root biomass production.

The species investigated in this study had nutrient uptake efficiencies (Table 2) that fell within the range of other species in previous studies (10, 9, 4, 1). In all cases, nitrogen uptake efficiency was significantly lower in all plants under the foliar urea. Nitrogen uptake efficiency was not significantly different in *P. melanocarpa* between rates (transformed data), however, the variability in the data was large and a few plants exhibited nitrogen uptake efficiencies of over 40%. This may be due to the maturity (size) of some plants at the onset of the study, lending well to the need for fertilizing according to size and age of plant. *Clethra alnifolia* and *S. patens* had significantly greater nitrogen uptake efficiency with the high rate compared to the low rate, but *I. virginica* was not different between the two rates. It is unusual that under the high nutrient rate, plant nitrogen uptake efficiencies were higher or not different than plant nitrogen uptake efficiencies under the low rate. This is often not the case in container culture where lower rates usually elicit higher efficiencies in plants (10). It is evident that the culture system itself lends to poor uptake efficiencies, most likely due to microbial competition and other nutrient loss mechanisms (10).

Nutrient use efficiencies were calculated to determine the how efficient the plants are utilizing the nutrients based on their biomass (see Table 2). Greenhouse studies of the partial evergreen azalea cultivar 'Karen' showed very similar NUE and PUE as the

four species in this study (8). As expected, these species also show an increase in NUE and PUE as fertilizer rate is decreased. As with uptake efficiencies, this may be due to the cultural environment.

The 150 mg N and 15 mg P treatment can be considered a medium industry rate for a #2 container in terms of controlled release fertilizer application, even though nutrients were applied via soluble sources. This was used as the high rate treatment, and based on previous studies (10, 9, 1), this medium industry rate is sufficient for many species.

This study suggests that native plant species require similar nutrient inputs as any other ornamental species in container culture and that claims of low input culture for native plant species cannot be transferred from the landscape to the container during production.

Table 1. Average total dry mass and root dry mass of four mid-Atlantic native species under two fertility rates and foliar urea.

	<i>P. melanocarpa</i>			<i>C. alnifolia</i>			<i>I. virginica</i>			<i>S. patens</i>		
	High ^z	Low ^y	Urea ^x	High	Low	Urea	High	Low	Urea	High	Low	Urea
Total DM (g)	114.7 ± 2.38 ^w	45.6 ± 4.33	6.17 ± 1.09	78.1 ± 4.59	42.6 ± 1.66	28.3 ± 2.50	58.6 ± 4.00	34.4 ± 1.85	10.9 ± 2.18	64.5 ± 7.38	22.8 ± 3.33	4.06 ± 0.48
Root DM (g)	42.4 ± 5.62	18.2 ± 1.35	2.07 ± 0.36	14.7 ± 1.29	9.5 ± 0.60	8.0 ± 0.56	9.6 ± 0.82	8.2 ± 0.56	3.9 ± 0.98	24.2 ± 5.32	9.5 ± 1.65	2.3 ± 0.34

^z High fertilizer treatment corresponds to 150 mg N and 15 mg P per week.

^y Low fertilizer treatment corresponds to 75 mg N and 7.5 mg P per week.

^x Urea treatment was a 1% foliar urea rate applied two times per week, application volume based on leaf area of species.

^w Standard error for each average presented under each value (n=5).

Table 2. Average nitrogen uptake efficiency (NUpE), phosphorus uptake efficiency (PUpE), nitrogen use efficiency (NUE), and phosphorus use efficiency (PUE) of four mid-Atlantic native species under two fertility rates and foliar urea.

	<i>P. melanocarpa</i>			<i>C. alnifolia</i>			<i>I. virginica</i>			<i>S. patens</i>		
	High ^z	Low ^y	Urea ^x	High	Low	Urea	High	Low	Urea	High	Low	Urea
NUpE (%)	34.5 ± 3.45 ^w	26.1 ± 1.95	---	29.9 ± 1.05	21.7 ± 0.86	---	23.7 ± 1.29	19.8 ± 1.79	---	19.7 ± 1.27	11.9 ± 2.17	---
PUpE (%)	36.2 ± 3.76	36.0 ± 2.73	5.7 ± 0.93	30.5 ± 1.17	29.6 ± 2.70	8.49 ± 046	30.2 ± 1.78	29.1 ± 2.53	3.62 ± 1.41	62.9 ± 5.46	41.0 ± 6.70	0.7 ± 0.40
NUE	66.0 ± 2.23	71.6 ± 2.74	88.7 ± 0.95	95.5 ± 4.97	133.0 ± 5.93	196.3 ± 7.20	89.0 ± 2.83	114.9 ± 7.26	169.0 ± 2.87	123.7 ± 10.2	136.1 ± 5.09	215 ± 9.05
PUE	629.7 ± 20.3	517.9 ± 15.0	346.9 ± 3.04	1003 ± 39.1	1157 ± 91.3	1298 ± 57.7	690.9 ± 15.9	780.9 ± 38.4	683.7 ± 38.6	465.6 ± 32.5	735.9 ± 98.1	2638 ± 340

^z High fertilizer treatment corresponds to 150 mg N and 15 mg P per week.

^y Low fertilizer treatment corresponds to 75 mg N and 7.5 mg P per week.

^x Urea treatment was a 1% foliar urea rate applied two time per week, application volume based on leaf area of species.

^w Standard error for each average presented under each value (n=5).

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Root Scoring of Container-Grown Maples and Oaks

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Index Words: Root pruning, root circling, tree growth, container production, *Acer rubrum* 'Summer Red', *Quercus lyrata*, overcup oak

Significance to the Industry: Root pruning prior to transplanting into larger containers or into field or landscape plantings is often touted as beneficial for subsequent re-growth (6). Our results indicate no benefit when comparing moderate pruning to no pruning. Severe pruning to remove all circling roots induced too much immediate stress to be beneficial. Follow up experiments on timing of the root pruning and landscape performance are ongoing.

Nature of Work: Landscape tree mortality from girdling roots has become a major concern to many landscapers and urban foresters that have experienced losses. Of particular concern is the increased number of circling roots with container-grown trees as opposed to field-grown trees. Arnold (1) reported that circling roots were reduced when root tips reached the inside of the nursery container surface treated with cupric hydroxide. This potentially reduced or eliminated incidences of girdling roots in the landscape (1). Nursery container designs that physically root prune during the production phase have shown reduction in circling roots, however, plants that are left growing in the container for extensive periods often develop circling roots (5).

Current recommendations by Extension (Florida, Colorado, and Maine) for planting container grown plants suggest scoring the root ball of container grown trees with vertical slits at least 1.0-inch deep into the root ball (2, 7). Some urban foresters recommend that all bark be removed from container grown trees prior to planting and use corrective pruning to improve root structure. To eliminate circling roots on the periphery of the root ball, University of Florida Extension Service recommends edge pruning to remove all roots on the outside edge of the root ball (4). The objective of this research was to evaluate root pruning techniques for container grown trees.

Acer rubrum L. 'Summer Red' maple and *Quercus lyrata* L., overcup oak, were potted May 5, 2006 and July 3, 2006, respectively from #3 nursery containers (maples) and #5 containers (oak) into #15 nursery containers. Container substrate was pine bark amended with 0.9 kg Micromax (O.M. Scotts Co., Maryville, OH), 7.0 kg Osmocote Pro 19-5-9 (19N-2.2P-7.5K) (O.M. Scotts Co.), 0.6 kg (1.0 lb) Aqua-Gro (Aquatrols, Paulsboro, NJ), and 0.6 kg dolomitic limestone (Oldcastle Stone Products, Charlotte, NC) per cubic yard.

Prior to potting into the #15 containers, the root systems of the plants in #3 containers were 1) left intact (control), 2) scored with one-inch deep slits from top to bottom six times equidistance around the perimeter of the root system (light root pruning), 3) scored with one inch deep slits from top to bottom six times equidistance around the perimeter then roots were straighten to prevent circling (moderate root pruning), or 4) pruned to remove any circling roots and improve the root structure, by first removing the bark substrate completely (severe root pruning).

Daily irrigation was applied cyclically with micro spray stakes and was increased to maintain a 20% leaching fraction as plant water use increased. Plant height and stem caliper (measured at 15 cm (6 in) above the substrate surface) were measured at the onset of the test (9 May and 9 July for the maples and oaks, respectively) and at the end of the growing season (Oct 25, 2006). Shoot ratings were taken on 5 June (data not shown), 29 June, 13 July, 28 July and 14 September with the following scale: 1: healthy, 2: slight tip dieback, 3: moderate tip dieback, 4: severe dieback down stem, and 5: plant dead. Plants were harvested Oct 25-26, with shoots and roots harvested separately. Root system ratings were taken after termination of the experiment, with the following scale: 1: few roots exposed on the outside of the root ball, 2: up to 25% coverage of the root ball, 3: up to 50% coverage of the root ball, 4: up to 75% coverage of the root ball, and 5: 100% coverage of the root ball.

Treatments were replicated five (maple) or six (oak) times in a completely randomized design by species and data were statistically analyzed using SAS 9.1 using the general linear model. Mean separation was using Fisher's protected LSD with $\alpha = 0.05$.

Results and Discussion: Severe root pruning significantly affected height and caliper growth for both maples and oaks, as well as shoot and root dry weight accumulation (Table 1). The severely root pruned maples had 54% and 57% reductions in height and caliper growth, respectively compared to the control. Due to the late planting date for the oaks, the severe root pruning treatment induced additional stress resulting in reductions in height and caliper growths of 94% and 81%, respectively. The severe pruning treatment resulted in reductions of accumulated shoot dry weight by 69% and 78% in maples and oaks, respectively. Our results support findings in which root pruning adversely affected growth and fruiting of grapevines (3). There were no differences in growth or dry matter accumulation between the control and the light or moderate root scoring treatments for either maple or oak species. This is similar to Gilman (4) whose results suggest that root slicing the outside surface of 25 gallon maple root balls at planting does not affect growth one and two years after planting.

Shoot ratings taken during the summer indicate severe root pruning at the time of potting stressed the trees to cause major dieback in the tips and occasionally caused tree death (Table 2). Four weeks after potting, there was severe stem dieback on the maples which were most drastically root pruned. The stress-induced damage was visible on the oaks after 10 days. By the end of the test, maple roots in the control, light, and moderate root pruning treatments had about 75-100% coverage while the severely

pruned treatment, on average had about 50% coverage on the periphery. Two maples from the severe pruning treatment died during the experiment. Overcup oaks, less vigorous growers than Summer Red maples, averaged about 50% coverage of the root ball with the control, light and moderately pruned treatments. The severely pruned treatment, on average, achieved less than 25% root coverage of the root ball. The stress caused by severely pruning the root systems of the oak when they had already leafed out and in active growth resulted in the death of two trees. Although water stress was not measured, the plant ratings in this study support prior findings that removing increased root mass during transplant from Shumard oak grown in containers resulted in increased water stress and decreased field performance (1).

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Table 1. The effect of root pruning methods on height, caliper and dry weights of *Acer rubrum* L. 'Summer Red' maple and *Quercus lyrata* L., overcup Oak grown in #15 nursery containers.^Z

Root pruning treatments ^Y	'Summer Red' maple			
	Height(cm)	Caliper(mm)	Shoot Dry weight(g)	Root dry weight(g)
Control	380 a ^X	37.0 a	2052 a	638 a
Light root pruning	365 a	36.5 a	2090 a	660 a
Moderate root pruning	371 a	36.7 a	2103 a	539 a
Severe root pruning	259 b	24.4 b	643 b	148 b
	Overcup oak			
Control	297 a	34.7 a	1178 a	548 a
Light root pruning	281 a	34.0 a	1186 a	593 a
Moderate root pruning	311 a	33.9 a	1298 a	530 a
Severe root pruning	194 b	25.0 b	254 b	201 b

^ZHeight and caliper measured Oct 25, 2006.

^YRoot pruning treatments: control = no root pruning; light root pruning = scored with one-inch deep slits from top to bottom six times equidistance around the perimeter of the root system; moderate root pruning = scored with one-inch deep slits from top to bottom six times equidistance around the perimeter of the root system and the roots were straighten out around the perimeter; and severe root pruning = pruned to remove any circling roots by first removing the bark substrate completely.

^XTreatments followed by the same letter are not significantly different. Means separated using Fisher's protected LSD, $\alpha \leq 0.05$.

Table 2. Foliar and root ratings of *Acer rubrum* L. 'Summer Red' maple and *Quercus lyrata* L., overcup oak, grown in #15 nursery containers.

Root pruning treatments ^Z	'Summer Red' maple			
	Average Shoot Rating ^Y			Root Rating ^X
	29-Jun	28-Jul	6-Sep	
Control	1.0 a ^W	1.0 a	1.0 a	4.3 a
Light root pruning	1.0 a	1.0 a	1.0 a	4.8 a
Moderate root pruning	1.0 a	1.0 a	1.0 a	4.5 a
Severe root pruning	4.1 b	4.2 b	3.2 b	2.7 b
	Overcup oak			
Control	1.0 a	1.0 a	1.0 a	2.7 a
Light root pruning	1.0 a	1.0 a	1.0 a	3.6 a
Moderate root pruning	1.0 a	1.0 a	1.0 a	3.2 a
Severe root pruning	3.8 b	4.3 b	2.8 b	0.8 b

^ZRoot pruning treatments: control = no root pruning; light root pruning = scored with one-inch deep slits from top to bottom six times equidistance around the perimeter of the root system; moderate root pruning = scored with one-inch deep slits from top to bottom six times equidistance around the perimeter of the root system and the roots were straighten out around the perimeter; and severe root pruning = pruned to remove any circling roots by first removing the bark substrate completely.

^YShoot rating scale: 1: healthy, 2: slight tip dieback, 3: moderate tip dieback, 4: severe stem dieback, and 5: plant dead.

^XRoot system rating scale: 1: few roots exposed outside of the rootball surface, 2: up to 25% coverage of the root ball, 3: up to 50% coverage of the root ball, 4: up to 75% coverage of the root ball, and 5: 100% coverage of the root ball.

^WTreatments followed by the same letter are not significantly different. Means separated using Fisher's protected LSD, $\alpha \leq 0.05$.

Tolerance of *Sedum* spp. to Various Ratios of Crumb Rubber Amendments in Green Roof Substrate

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Index Words: Urban, storm water, runoff, zinc, toxicity.

Significance to Industry: Increased environmental and political interest in green roof systems for urban storm water management has promoted recent research activities determining green roof plant / substrate interactions and efficacy for urban storm water remediation. The potential demand for extensive green roof systems in our urban landscapes will bring about increased market demands for green roof plant species and substrates for the horticultural and landscaping industries, along with continued research in this new area. The use of crumb rubber (recycled car tire) amendments would decrease the weight of a green roof substrate and may increase the longevity and permeability of substrates over the long-term. The zinc (Zn) content of these substrates however may preclude large additions to traditional shale green roof substrates, unless *Sedum* species can tolerate or hyperaccumulate this cation in large quantities. This study demonstrated that additions of crumb rubber to a green roof substrate affected dry mass, but did not interfere with establishment and sustained growth of several *Sedum* species.

Nature of Work: Extensive green roof systems are designed primarily to mitigate storm water runoff from impervious surfaces in dense urban areas. A key design component of extensive green roof systems are light-weight substrates made from heat-expanded shale, clay and slate. Quality guidelines for these substrates have been published in the 2002 German FFL Greenroof Guidelines (2). These substrates are an important part of a system, able to absorb a large portion of a typical rainfall event, whereby mitigating runoff from urban areas replete with impervious surfaces. The physical properties of the substrates used in extensive green roofs, primarily particle size, are an important factor for water holding capacity and air-filled porosity. Crumb rubber, a recycled tire product, is a potential substrate amendment, currently available in large quantities throughout North America. Crumb rubber's low bulk density may reduce substrate loads, resulting in decreased engineering costs for buildings (1) and may improve porosity and longevity of green roof substrates, reducing maintenance and renovation costs. It has been noted however, from one greenhouse production study using soilless potting media that recycled crumb rubber released toxic levels of Zn that were deleterious to the growth of *Petunia* (3). It is possible that certain green roof substrates may be able to adsorb Zn (4) or that certain species of *Sedum* may be able

to hyper-accumulate Zn (5). This research investigates the usefulness of crumb rubber as an amendment for improving physical characteristics of the green roof substrates and the potential phytoremediation of *Sedum* species by first determining Zn leached from crumb rubber and then examining the tolerance of several *Sedum* species to various crumb rubber amendment rates.

In the first experiment, the objective was to quantify the rate and total release of Zn that could potentially leach out of crumb rubber in two different water treatments over a 384 hour (16 day) period. The water treatments included untreated reverse osmosis (RO) water (pH 5.5), and RO water with added sulfuric acid, to give a pH of approximately 4.1, since the pH of rainfall in the region be as as low as 4 on occasion (6), and this can influence the solubility and availability of Zn both in the substrate and for uptake by plants (3). Exactly 10 grams of crumb rubber (8-12 sieve mesh) was weighed and placed in 10 replicate 125 ml Erlenmeyer flasks for each sample time (12, 24, 48, 96, 192 and 384 hours) totaling 60 experimental units. Half the flasks were filled with 50 ml of RO water treatment and the other half were filled with 50 ml of the acidified water and all sealed with parafilm. At each sample time, ten replicate flasks (5 acidified water; 5 plain RO water) were filtered, and the resulting supernatant decanted into 20 ml scintillation vials, and then frozen until analyzed for free Zn by Inductively Coupled Plasma (ICP) spectrometry at the University of DE Soils Testing Program. Leachate results from each sample period were analyzed by ANOVA.

In the second experiment, which was designed to evaluate the tolerance of several *Sedum* species to various ratios of crumb rubber amendments, three *Sedum* species including *S. album* L, *S. reflexum* L, and *S. kamtschaticum* Fisch., were grown in a green roof substrate (rooflite™, Skyland USA, Avondale, PA) containing 80% calcined clay and approximately 12% organic material. Amendments were with 0%, 6%, 12%, 18%, 24%, or 30% crumb rubber by volume. Ten replicate *Sedum* plugs per species and crumb rubber treatments (180 experimental units) were placed in 10 cm (4 inch) pots in a completely randomized block design and allowed to become established for one month. During the first 6 weeks of the study, plants were fertilized weekly with 200 ppm N using a soluble 20-4.4-16.6 (N-P-K) fertilizer with minors. The fertilization applied less than 50 µg chelated Zn to each plant during this period. Five months after study initiation a Foliar Volume Index (FVI) was estimated by using the following formula: $FVI (cm^3) = (H \times W \times L) \times QF$, where height (H) width (W) and length (L) were measured in cm, and “QF” represented a subjective quality factor to express the degree of leaf coverage inside the tridimensional figure. The *quality factor* ranged from zero (no foliar area) to 0.099. At study termination (immediately after FVI determination) plants were harvested, with top growth dried in an oven at 60 C degrees for 96 hours and weighed for dry mass. The final leaf volume index measurement was subjected to regression analysis and dry mass results were analyzed by ANOVA.

Results and Discussion: The analysis of the water samples indicated that Zn leaches from crumb rubber in a relatively linear fashion over time after the first 12 hours (Fig. 1). Final cumulative release of Zn averaged 647 µg (± 65 SE) and 540 µg (± 46 SE) with the acidified and non-acidified RO water, respectively. After the initial 12 hours, there is no significant difference in cumulative Zn leached between either pH treatments. This

experiment also shows that Zn is initially released from crumb rubber at an average rate of 7.4 µg/hr during the first 12 hours in the acidified RO water treatment (Figure 2). This initial rate of release is significantly different from crumb rubber soaked in non-acidified RO water, at a rate of 2.2 µg/hr. However, after 12 hours, release rate of zinc in the two water treatments decreased and stabilized. Note that while the acidified RO water treatment averaged a higher release (both cumulative and rate) than that of non-acidified RO water treatment, there was no significant difference between the two water treatments. Despite an initial high release rate in the acidified water treatment during the first 12 hours, leaching the crumb rubber in an acid wash before use as an amendment would not significantly reduce the amount of Zn to which the plants are exposed since the amount of Zn released between 12 and 368 hours is consistent. Also, the lack of significance in the amount of Zn released after the initial 12 hours between the water treatments could imply that the proportion of Zn released from the crumb rubber would not be affected by low pH rain water. The release rate of Zn was lower after the initial 12 hours, yet cumulative Zn concentrations after 384 hours are equivalent to potentially toxic concentrations of Zn for many plant species. Finally, there was large sample to sample variation, which may possibly reflect the variability of analysis, variability of sampling, or most likely, the variability of Zn in the rubber crumb samples (e.g. different brands or origins of tires).

In the second experiment, low R-squared values for the regression analyses of FVI and crumb rubber percentages indicated an insignificant treatment effect on growth quality at the end of the study for all *Sedum* species (Fig. 3a, b and c). The apparent downward trend of Figs. 3a and 3c is not significant. During the study period, growth quality treatment response of each species was highly variable for each treatment combination. While the high variability was equal across treatments, something other than the crumb rubber treatment was affecting the *Sedum* growth quality, possibly natural growth variability. However, ANOVA results on final top-growth dry mass indicated some significant effects of percent crumb rubber for each of the species (Figure 4). *Sedum album* dry mass was negatively affected by all crumb rubber proportions to the same degree. Crumb rubber effects on *S. reflexum* dry mass varied, and in general, *S. kamtschaticum* dry mass decreased with increasing proportions of crumb rubber.

The disagreement between growth quality represented by the FVI and dry mass warrants more research with crumb rubber as a light-weight amendment for green roof substrates such as rooflite™. Unlike dry mass, the FVI could not discriminate crumb rubber treatment differences on *Sedum*. Past research has shown one species, *Sedum alfredii* Hance, can hyper-accumulate Zn (5). Further analysis will provide information about the phytoremediation potential a *S. album*, *S. reflexum* and *S. kamtschaticum* by analyzing the concentration of Zn in dry mass samples.

Acknowledgements: We would like to thank Maryland Environmental Services for their contributions toward this research.

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Figure 1. Cumulative release of zinc over time for crumb rubber exposed to acidified (pH 4.1) or non-acidified (pH 5.5) RO water solutions.

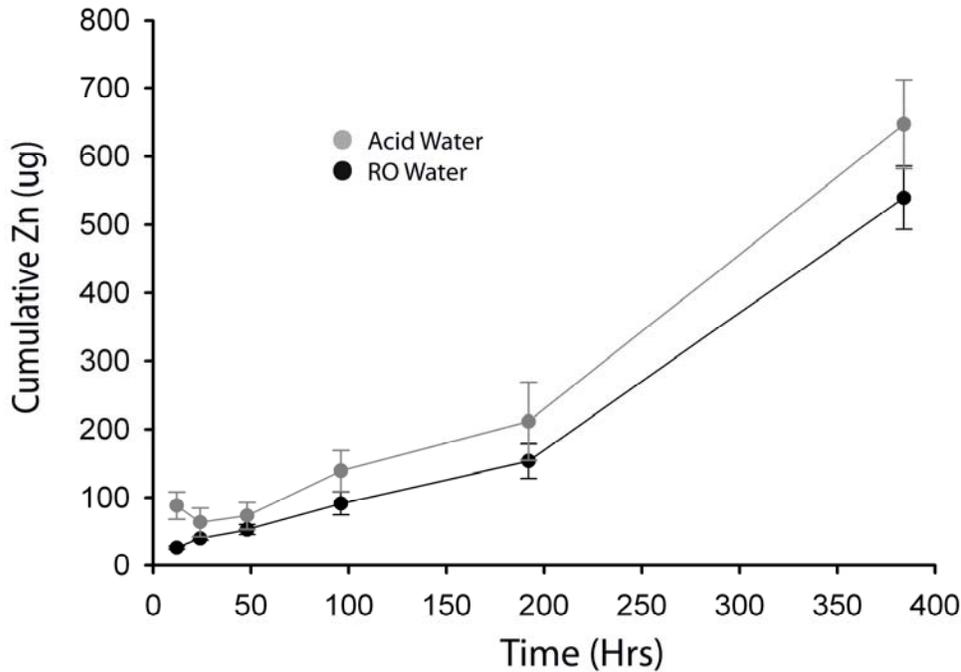


Figure 2. Rate (μg) of zinc released from crumb rubber exposed to different times in acidified (pH 4.1) or non-acidified (pH 5.5) RO solutions.

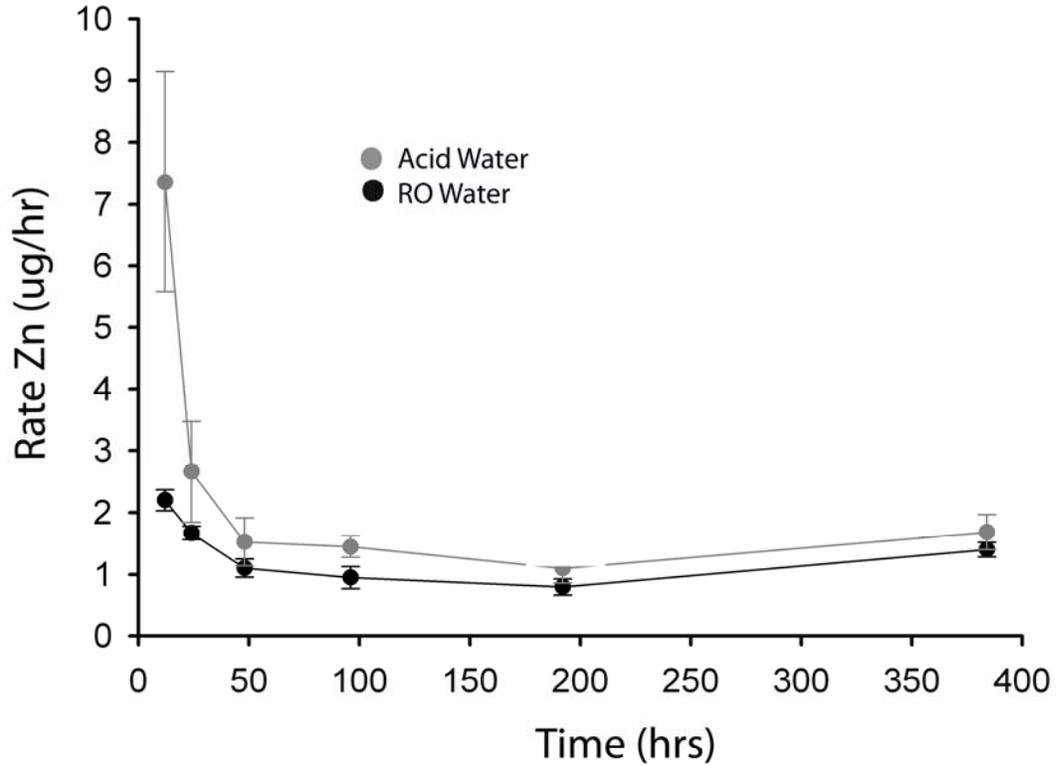


Figure 3. Foliar Volume Index (FVI) regression of three species (a) *Sedum album*, (b) *Sedum reflexum*, and (c) *Sedum kamtschaticum* under six different levels of crumb rubber. Graphs include 95% prediction bands ---, 95% confidence bands ----, and the regression line.

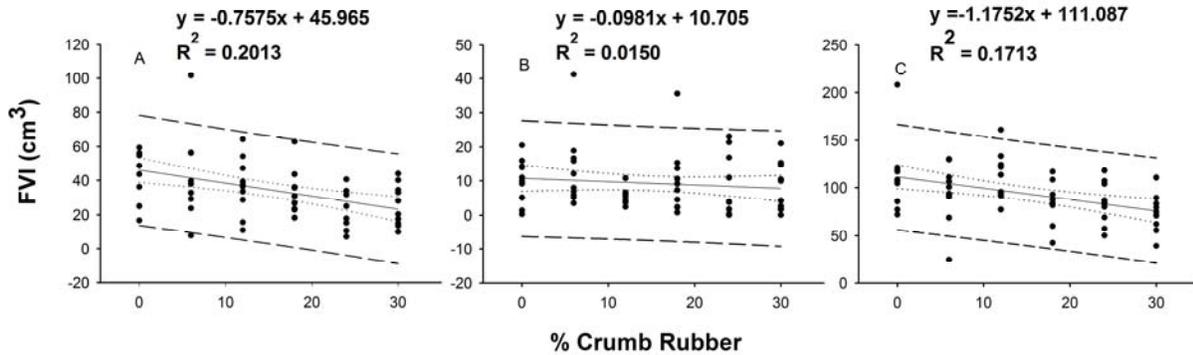
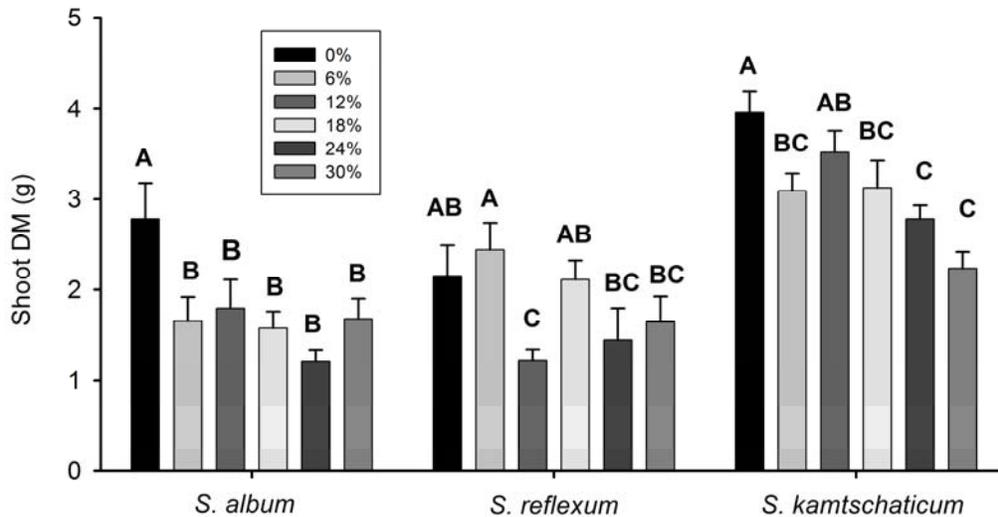


Figure 4. Average shoot dry mass, by species, for each crumb rubber treatment. Mean values within columns followed by a different letter indicate significant differences using LSD ($\alpha = 0.05$).



Effect of Biofertilizer and Beneficial Organisms on the Growth of Container-grown Ornamental Plants

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Index Words: spirea, crapemyrtle, arborvitae, controlled-release, organic fertilizer

Significance to industry:

Rapid increases in fertilizer costs are forcing growers to evaluate alternatives to current methods that will increase nutrient use efficiencies (3). A number of studies have been conducted looking at the use of organic fertilizers (1,4,5,6) and beneficial organisms (2) in container plant production. Results from this study on granular and liquid biofertilizers suggest that alternatives to conventional controlled-release fertilizers can be used successfully in the container production of woody ornamentals.

Nature of Work:

Research was conducted at a commercial nursery in central Arkansas. Plants included in this study were *Lagerstroemia* x 'Natchez' (Natchez crapemyrtle), *Spiraea* x 'Goldmound' (Goldmound spirea), and *Thuja plicata* D.Don 'Green Splendor' (Western arborvitae). Liners were received by the nursery on 15, April 2006 and immediately planted into #2 containers with a 6 pine bark (fine grade) :1 peat moss (vol:vol) amended with 8 lbs lime/yd³. The container-grown plants were planted in the nursery on a landscape fabric covered gravel bed and the plants were watered as needed by spray stakes (Roberts Spot Spitter, San Marcos, CA). Weed control was accomplished with one application of Pendulum 2G (150 lb/Acre) pre-emergent herbicide applied to the media surface one week after potting. Fertilizer treatments are summarized in Table 1. Treatments consisted of 10 single plant reps. The design was a completely randomized design. Containers were initially spaced can-tight, but spread to a 1X spacing when necessary.

Plants were harvested for data collection when a crop was considered saleable (significant visible roots at the edge of the substrate rootball). Crapemyrtles were evaluated after 88 days (13, July). Five fully mature leaves were scanned using the Minolta (Osaka, Japan) SPAD-502 Chlorophyll meter for relative leaf 'greenness' and the five values averaged for a single plant. This process was repeated on three plants. The shoot was removed at the substrate level, weighed (data not shown), and then dried in an oven for 48 hrs at 65°C to get a dry weight. For the roots, the substrate was removed by hand, the root system carefully washed with water, and then dried in an oven at 65°C for 48 hrs. A similar process was performed on different dates for the spirea and arborvitae, however, a SPAD reading was not recorded since significant visual differences in leaf color were not apparent at the end of the experiment.

Results and Discussion:

Based on final growth data for 'Natchez' crapemyrtle, it appears that the amount of controlled-release fertilizer (CRF) when combined with a low rate of a commercially available biofertilizer containing beneficial organisms, can be reduced by one-half without a significant reduction in shoot growth (Table 2; treatments A and B).

Application of a biofertilizer (treatment C) at 0.6 lb N/yd³ produced crapemyrtles with a shoot mass equal that for plants fertilized with CRF (treatment A) at twice the nitrogen rate. Fertilizer treatments did not affect final root growth of crapemyrtle, however, fertilizer treatments did influence leaf color ('greenness'). Leaves from plants fertilized with treatment 'B' were significantly 'greener' than those from treatment 'C'.

Fertilizer treatments did not influence final root or shoot growth for spirea, nor final shoot growth of arborvitae (Table 3). Overall, results suggest that the use of a biofertilizer and beneficial organisms can reduce the nitrogen input from CRF in container production of woody ornamentals.

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Table 1. Fertilizer treatments evaluated and total nitrogen amounts applied.

Treatment Code	Fertilizer	Total N applied (lb N/yd ³)
A	Harrells 16-6-11 ^z , topdress	1.2
B	Harrells 16-6-11, topdress plus Turf Vigor 9-3-6 ^y liquid feed	0.6
C	Turf Food 15-3-8 ^x , topdress, plus Turf Vigor 9-3-6 ^y liquid feed	0.6
D	Turf Food 15-3-8, topdress, (0.6 lb N) plus Harrells 16-topdress (0.6 lb N)	1.2

^zHarrells (Agrium Inc, Calgary) 16-6-11 (16N-2.6P-9.1K) with minors, 5-6 mo.

^y Roots Turf Vigor (Novozymes Biologicals, Fergus, Ontario) 9-3-6 (9N-1.3P-5.0K) ; Turf Vigor was injected weekly (7 oz/15.5 gal, 1:150 dilution) with a total accumulation of 0.002 lb N). TurfVigor 9-3-6 combines six microbial strains (*Bacillus* and *Paenibacillus* species), biostimulants and macro and micronutrients in one liquid fertilizer.

^x Roots Turf Food 15-3-8 (15N-1.3P-6.6K). Turf Food is derived from a combination of three component technologies: organic-based nutrients (bone, blood, and feather meals), Roots biostimulant complex which is a proprietary formulation of amino acids, vitamins, humic acids, sea kelp extracts and other ingredients, and six strains of Novozymes naturally-occurring microbes (*Bacillus* and *Paenibacillus*).

Table 2. The effect of fertilizer treatments on the root and shoot growth and relative leaf 'greenness' of 'Natchez' crapemyrtle. Data was collected on 13, July 2006 (88 days).

Fertilizer Treatment ^z	Mean Shoot DW (gm)	Mean Root DW (gm)	Mean SPAD ^x
A	43 ab ^y	14 a	54 ab
B	37 b	9 a	62 a
C	55 ab	16 a	43 b
D	64 a	11 a	53 ab

^z Fertilizer treatment: refer to Table 1

^y Numbers within a column followed by the same letter are not significant at the 5% level.

^x SPAD = relative leaf 'greenness'; 5 leaves per plant/3 plants per treatment were measured Using a Minolta SPAD-502 Chlorophyll meter

Table 3. The effect of fertilizer treatments on the growth of 'Goldmound' Spirea and 'Green Splendor' arborvitae. Data for spirea was collected on 24, July 2006 (99 days) and on 4, October 2006 (172 days) for arborvitae.

Fertilizer Treatment ^z	Spirea		Arborvitae
	Mean Shoot DW (gm)	Mean Root DW (gm)	Mean Shoot FW (gm)
A	26 a ^y	27 a	68 a
B	30 a	18 a	60 a
C	27 a	26 a	58 a
D	28 a	27 a	64 a

^z Fertilizer treatment: refer to Table 1

^y Numbers within a column followed by the same letter are not significant at the 5% level.

