Container Grown Plant Production

James A. Robbins
Section Editor and Moderator

Potential Adsorption of Zinc in Crumb Rubber-Amended Green Roof Substrates

S. Lorelly Solano[1], Andrew G. Ristvey[2], John D. Lea-Cox[1] and Steven M. Cohan[1]
[1]Department of Plant Sciences and Landscape Architecture
University of Maryland, College Park, MD 20742
[2]University of Maryland Cooperative Extension
Wye Research and Education Center, Queenstown MD 21658

lorellys@umd.edu

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Significance to Industry: Extensive green roof systems have numerous proven ecological and economic benefits including storm water management, energy conservation, mitigation of the urban heat island effect, and improvements in urban aesthetics. The increasing interest 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. Quality guidelines for these substrates have been published in the 2002 German FFL Greenroof Guidelines (4). Most substrates presently used in extensive green roof systems consist primarily of heat-expanded shales, clays and slates, which sometimes represent a substantial load problem when retrofitting older buildings. Crumb rubber (CR), a recycled tire product, is a potential light-weight amendment that may reduce substrate loads, decreasing engineering costs for buildings (1) and may also improve the porosity and longevity of many green roof substrates. However, CR may release potentially toxic levels of zinc (Zn) for ornamental plants (6) and many other plant species under certain growing conditions. Soluble Zn also represents a pollutant for aquatic environments at relatively low concentrations. This study demonstrates the ability of the commercial green roof substrate (rooflite^{TM}, Skyland USA, Avondale, PA) to adsorb Zn released from CR amendments.

Nature of Work: Two important questions arise when considering the use of CR as potential amendment for extensive green roof substrates. Firstly, is the amount of Zn released from CR deleterious to the growth of plants used for extensive green roofs (*Sedum* spp.) and secondly, how much Zn can be expected to leach from a commercial green roof substrate amended with CR? A previous study revealed that growth quality in three *Sedum* species was not affected by various proportions of CR-amended substrates, however dry mass was negatively affected (8). The results of that study were highly variable imposing restrictions for inference on *Sedum spp.* response to CR Zn.

Zinc oxides are the principle form of Zn in rubber tires. Tire-tread formulations are known to contain between 2.5% (2) and 5% Zn (3), primarily as Zn oxide, which is used as an activator in the vulcanization process (5). This Zn is available for leaching from the CR into the environment, representing an anthropogenic contamination input. Since

many green roof substrates are made from chemically reactive parent minerals (clays), some cation adsorption qualities would be expected. Shales are sedimentary rocks formed from compressed clay particles and slates are metamorphic rocks formed from compressed and heated shales. Thus, some green roof substrates may be able to adsorb and retain Zn (7).

In this study, five different volumetric proportions of CR (0%, 6%, 18%, 30% and 100%) and rooflite™ were prepared in 300 ml flasks, with 10 replicates per treatment to be tested at 4 time periods. The weight of CR was constant (10 g) and the quantity of rooflite™ was adjusted according to the treatment specification. One hundred mls of reverse osmosis (RO) water was added to each flask (200 ml for the 6% treatment). The pH of the water was 5.5 before addition to treatments. Water samples were taken from the replicate flasks at 0, 2, 8 and 16 days, each sampling day having a separate set of treatment replicates. Flasks were agitated 2 hours before sampling. Water sample analysis was performed at the University of Delaware Soil Testing Laboratory (Newark, DE) and Zn concentration results were determined by Inductively Coupled Plasma Mass Spectrometry. Concentration values were normalized (by expressed solution volume) for Zn content.

The null hypotheses established for this experiment are: 1) there is not a significant difference in the availability of Zn between treatments and the 100% Zn reference control; 2) the availability of Zn is not significantly lower with increasing proportions of rooflite™. ANOVA was used to determine statistical significance between treatments (SAS v. 9.1; SAS Corporation, NC).

Results and Discussion: Heterogeneous variances in the total average release of Zn and average release rate required log10 data transformation. Figure 1 shows that the total available Zn released from each of the proportional treatments was significantly less than the reference control (100% CR) throughout the experiment. Based on transformed data, after 16 days, only the 18% and 30% treatment proportions, releasing 1.0 and 1.1 ug Zn/g CR respectively, were not different from each other. Excluding the 100% CR control, significantly more Zn was available from the 6% CR treatment averaging 1.7 ug Zn/g CR compared to the 18% and 30%. Since the 6% treatment contained substantially more rooflite™ than other treatments this possibly explained the greater availability of additional exchangeable Zn. The potential release of Zn from green roof systems is dependent upon the plant uptake potential and the adsorption ability of the substrate. The averaged release of available Zn from the 30% proportion after 16 days was 1.1 µg per gram of CR, nearly 100 times less than the reference control's value of 99.5 µg per gram of CR. In practical terms, a green roof with a 30% proportion of CR could release approximately 15.4 mg of Zn per square meter in 16 days if consistently saturated. Plant uptake and rainfall volume would have an additional effect upon Zn release. Based exclusively on these results, it is not possible to project the long-term Zn release from CR-amended substrates. A greater understanding of the substrate's chemistry is needed. However, if a relatively constant release rate was assumed, the release of Zn could be estimated. Figure 2 depicts the rate of Zn released for each treatment over the 16 day period and expressed as ug of

Zn per gram of CR per hour. Figure 2 shows the rates of which Zn was released during the study period for each treatment. Zinc concentrations were measured at each sampling period, and normalized for Zn content. Rates were extrapolated by dividing the Zn content by the intervals of time between samples. According to results shown in Figure 2, Zn release rates at the initiation of the experiment were significantly higher compared to the following sampling periods, and the 100% CR reference control was significantly higher than the other treatments levels. The rates for all of the treatment levels significantly decreased to over ten-fold their initial value, yet the 100% CR control continued to have a significantly higher release rate than the other treatment levels. During the final 8 day period (day 9 through day 16), the 30% CR proportion exhibited an average release rate of 29 ng Zn/g/hr. It is expected that Zn would leach out in its totality after time, but when it would occur under saturated conditions cannot be precisely predicted. The results of this study could be used as a practical reference for estimating approximate amounts of zinc released from a green roof installation. However, under real conditions, release of Zn would be affected by several external factors, including weathering and exposure, storm water pH, frequency and duration of the rainfall events, and total cation adsorption ability of rooflite™.

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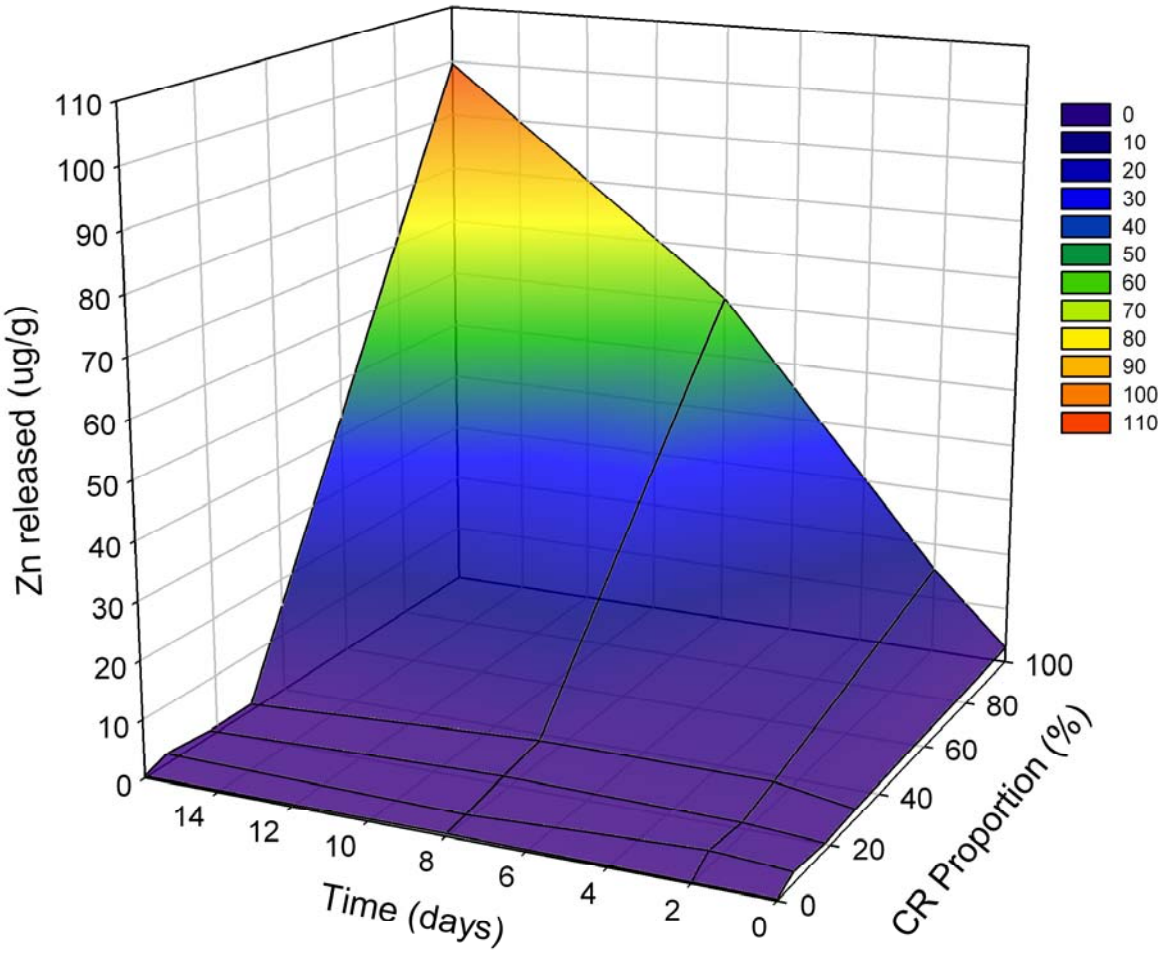

Figure 1. Surface response curve showing Zn released from five volumetric proportions of Zn (CR) and rooflite™ during sixteen day study period.

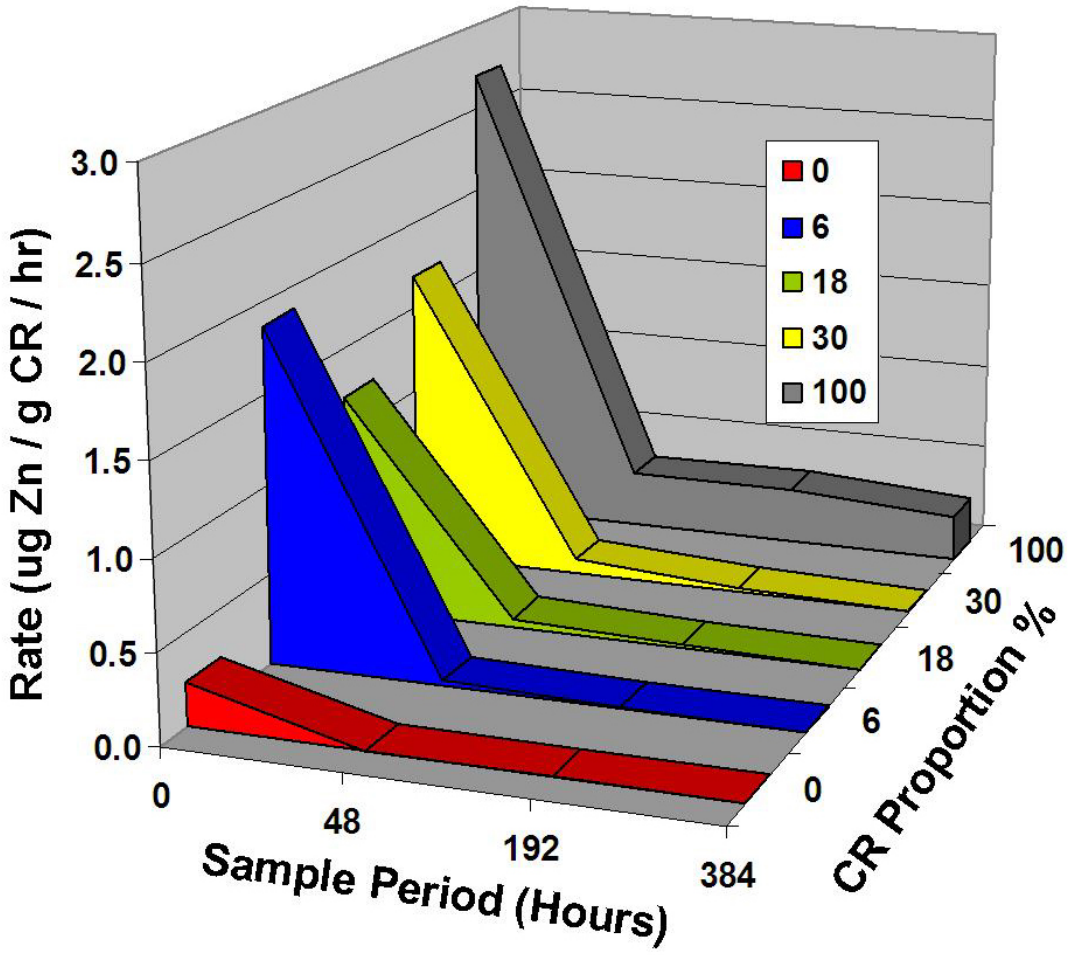

Figure 2. Rate (ug/hr) of Zn released per gram of CR extrapolated over each sampling period from five volumetric proportions (%) of CR and rooflite™ during a sixteen day (384 hour) study period.

Effects of Organic and Inorganic Fertilizers on Marigold Growth and Flowering

Guihong Bi, William. B. Evans and Dennis Rowe
Mississippi State University, Department of Plant and Soil Sciences
Truck Crops Station, Crystal Springs, MS 39059

gb250@msstate.edu

Index Words: natural fertilizer, organic fertilizer, broiler litter, nitrogen, *Tagetes patula*

Significance to Industry: This study evaluated the growth and flowering responses of container-grown greenhouse marigold plants to four rates of two non-composted broiler chicken litter-based organic fertilizers 4-2-2 at 1%, 2%, 4%, and 6% (by volume) and 3-3-3 at 1.34%, 2.67%, 5.34%, and 8.0% (by volume) and a commonly used synthetic controlled release fertilizer 14-14-14 at 0.99, 1.98, 3.96, and 5.94 $kg \cdot m^{-3}$. For the fertilizer rates used in this study, in general, increasing 14-14-14 fertilizer rate increased plant growth and flowering performance. However, low to intermediate rates of 4-2-2 and 3-3-3 produced the highest plant growth index, shoot dry weight, number of flowers per plant, total flower dry weight, and root rating. Plants grown in high rates of 4-2-2 and 3-3-3 showed symptoms associated with excessive fertilizer. Results from this study indicated that 4-2-2 and 3-3-3 have the potential to be used as organic fertilizer sources for container production of marigolds in greenhouses. However, growers need to be cautious with the rate applied. Since different crops may respond differently to these natural fertilizers, it is important for growers to test new fertilizers before incorporating them into their production practices.

Nature of Work: Standard fertilizer practices for greenhouse and nursery crops include the use of slow release fertilizer, periodic application of water-soluble fertilizer during production or both, but recent movements toward naturally managed gardens and growing interest in managing the environmental impacts of agriculture have led to the development of organic and natural fertilizers that may be suitable for commercial use. Many of these fertilizers are manure based, including chicken manure.

Annual broiler chicken litter production is estimated at more than 750,000 tons in Mississippi alone (1), so there is an adequate supply of this material available for fertilizer and other uses. A Georgia- and Mississippi-based company produces and markets two broiler litter-based fertilizers, one a balanced formula 3-3-3 and the other a more nitrogen-rich 4-2-2 formula. Despite having lower nutrient concentrations than many synthetic fertilizers, similar broiler litter-based fertilizers have been shown to be effective plant fertilizers (4). For growers wishing to use these and other natural fertilizers in their production systems, the biggest question is how the fertilizers need to be managed compared to their synthetic counterparts. For example, Hartz et al (5) found in an incubation study that only about 20% of the nitrogen in a pelleted broiler litter product they tested was available in the first twelve weeks after application. Whereas, the University of Georgia extension service recommends growers consider 50% of the N, 90% of the P and 100% of the K in raw poultry litter as available the first

year after field application (6). How litter-based fertilizer behaves in an actual greenhouse setting remains a significant question. The objective of this study was to evaluate the growth and flowering responses of container-grown greenhouse marigold plants to four rates of two broiler litter fertilizers in comparison to a commonly used synthetic controlled release fertilizer.

Material and Methods: This study was conducted in a greenhouse at the Truck Crops Experiment Station in Crystal Springs, MS. Two non-composted broiler litter-based organic fertilizers TOP 4-2-2 (4N-0.9P-1.7K, Organic Growing Systems, Alpharetta, GA) at four rates of 1%, 2%, 4%, and 6% (by volume) and TOP 3-3-3 (3N-1.3P-2.5K, Organic Growing Systems) applied at rates of 1.34%, 2.67%, 5.34%, and 8.0% (by volume) were compared with one commonly used synthetic controlled release fertilizer 14-14-14 (14N-4.2P-11.6K, 3-4 months, Osmocote, Scotts Co., Marysville, OH) applied at rates of 0.99, 1.98, 3.96, and 5.94 $kg \cdot m^{-3}$. The equivalent total N from each fertilizer rates is listed in Table 1. Rates of the organic fertilizer were selected based on an estimated 50% of the total N being available (6). The substrate used in this study contained peat moss, vermiculite and perlite (75:10:15 by volume). Each substrate blend was incorporated with 0.89 $kg \cdot m^{-3}$ (1.5 $lb \cdot yd^{-3}$) Micromax (Scotts) and 2.97 $kg \cdot m^{-3}$ (5 $lb \cdot yd^{-3}$) dolomitic limestone. A control treatment contained only Micromax and lime. French marigold (*Tagetes patula* L. 'Janie Deep Orange') seedlings were transplanted from 1206 cell pack into round azalea plastic pots [(one plant/pot) (15 cm outside diameter, 11 cm height)] (ITML Horticultural Products, Inc. Brantford, Ontario, Canada).

Plants were arranged in a completely randomized design with each treatment replicated ten times, watered as needed and harvested 40 d after transplanting. At harvest, leaf chlorophyll content was estimated using a SPAD-502 Chlorophyll Meter (Minolta Camera Co., Ramsey, NJ). Plant growth index [(height + widest width + perpendicular width) ÷ 3] and number of open flowers were recorded. Plant height was measured from substrate surface to the tallest plant part. Root quality was assessed using a 0 to 5 scale with 0 indicating no visible roots on the bottom or side surfaces of the root ball, and 5 indicating visible roots were matted on the bottom and on a major portion of the sides of the exposed root ball. Plants were separated into shoots (stems and leaves) and flowers. The samples were placed into a 60°C forced-air oven and dried. Dry weight was recorded for each tissue type. Substrate pH and EC were measured at 4 and 28 d after planting (DAP). EC was directly measured using the Field Scout® Soil EC Probe & Meter (Spectrum Technologies, Inc., Plainfield, IL) (7), and pH was directly measured using the IQ 150 pH Meter (Spectrum Technologies, Inc.). Plants were watered to saturation then allowed to drain for 30 minutes before measurements of EC and pH.

Data were analyzed by analysis of variance (ANOVA) using Statistica (Statsoft, Inc., Tulsa, OK). Comparisons of means among treatments were conducted using Tukey's Honestly Significant Difference test at $P<0.05$ ($HSD_{0.05}$). Plant response to each fertilizer source was evaluated using linear and quadratic polynomial contrasts based on the fertilizer rate in the substrate.

Results and Discussion: At 4 DAP (Table 1), pH was similar among treatments containing different rates of 14-14-14, however, pH increased with increasing fertilizer rate for substrates containing 4-2-2 and 3-3-3. At 28 DAP, pH decreased with increasing fertilizer rate for all three fertilizers. At both 4 and 28 DAP, there was no significant difference in EC between substrates containing different rates of 14-14-14, however, EC increased with increasing fertilizer rate for substrates containing 4-2-2 and 3-3-3. In general, substrates containing 4-2-2 and 3-3-3, especially at higher fertilizer rates, had higher EC than substrates containing 14-14-14.

In general, increasing 14-14-14 fertilizer rate increased growth index (GI), shoot dry weight, the number of flowers per plant, total flower dry weight, and root rating (Table 2). Whereas plant GI and shoot dry weight responded quadratically with increasing fertilizer rate for 4-2-2 and 3-3-3. Plants grown in the low to intermediate rates of 4-2-2 and 3-3-3 produced the highest GI and shoot dry weight. There was no significant difference in the number of flowers among plants receiving different rates of 4-2-2, but there was a decreasing trend in total flower dry weight or root rating with increasing fertilizer rate. Increasing 3-3-3 fertilizer rate resulted in a decreased number of flowers, total flower dry weight, and root rating. For plants grown in 4-2-2 and 3-3-3, the root ratings were the lowest for plants in substrates with very high ECs (those receiving the highest rates of fertilizer), suggesting a possible high salt concentration in the substrate resulting poor root growth (3). Leaf SPAD reading increased with increasing fertilizer rate for all three fertilizers. As expected, plants grown in substrates without fertilizer (control) had the smallest GI, shoot dry weight, the number of flowers per plant, total flower dry weight, and SPAD value.

These results indicate that broiler litter-based 4-2-2 and 3-3-3 fertilizers have the potential to be used as organic fertilizer sources for container production of marigold in greenhouses. Growers need to be cautious with the rate applied, as high rates can lead to high substrate ECs, and have been linked with plant symptoms associated with excess fertilization (2). It is also of note that different crops may respond differently to these natural fertilizers and it is important for growers to test new fertilizers before incorporating them into their production practices.

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Table 1. pH and electrical conductivity (EC) of substrates containing different types and rates of fertilizers.

	Fertilizer total N rate	pH		EC ($dS \cdot m^{-1}$)	
Fertilizer[z]	($g \cdot m^{-3}$)	4 DAP[y]	28 DAP	4 DAP	28 DAP
Control	0	5.6	6.6	0.50	0.23
14-14-14	139	5.7	6.8	0.78	0.22
14-14-14	277	5.4	6.4	0.75	0.23
14-14-14	554	5.6	6.3	0.95	0.28
14-14-14	831	5.4	6.2	1.09	0.34
4-2-2	259	5.8	6.5	1.12	0.27
4-2-2	518	5.6	6.3	1.52	0.35
4-2-2	1036	6.0	6.0	1.93	0.83
4-2-2	1555	6.3	5.5	2.08	2.57
3-3-3	259	5.7	6.2	1.38	0.32
3-3-3	518	6.0	5.8	1.70	0.80
3-3-3	1036	6.2	5.2	2.95	2.70
3-3-3	1555	6.6	5.6	3.26	3.62
		Fertilizer rate response[x]			
14-14-14		NS	L**	NS	NS
4-2-2		L*	L***	L***	L**Q***
3-3-3		L***	L***Q**	L**	L**

[z]All treatments contained 0.89 $kg \cdot m^{-3}$ Micromax and 2.97 $kg \cdot m^{-3}$ dolomitic limestone. [y]Days after planting.
[x]Significant linear (*L*) or quadratic (*Q*) contrasts at $P \leq 0.05$ (*), 0.01 (**), or 0.001 (***) across fertilizer rates in each type of fertilizer. NS = Nonsignificant.

Table 2. Plant growth index (GI), shoot dry weight (DW), flower dry weight (DW), number of flowers per plant, SPAD value, and root rating of 'Janie Deep Orange' French marigold grown for 40 d in substrates containing different types and rates of fertilizers.

Fertilizer[z]	Fertilizer total N rate ($g \cdot m^{-3}$)	GI[y] (cm)	Shoot DW (g)	Flower DW (g)	Number of flowers	SPAD value[x]	Root rating[w]
Control	0	15.4	1.0	1.1	4.0	35.4	3.4
14-14-14	139	18.4	2.0	3.0	8.4	41.1	4.2
14-14-14	277	20.7	2.6	3.8	11.0	43.5	4.4
14-14-14	554	22.8	3.9	4.9	11.7	47.6	4.6
14-14-14	831	22.6	4.5	5.2	12.6	49.6	4.7
4-2-2	259	21.9	4.1	4.8	12.7	44.4	4.8
4-2-2	518	22.3	5.2	4.7	12.0	48.5	4.7
4-2-2	1036	22.2	5.1	4.0	11.4	49.8	4.0
4-2-2	1555	20.1	3.7	3.5	11.9	53.5	2.3
3-3-3	259	22.8	4.7	5.1	13.3	45.8	4.6
3-3-3	518	23.2	5.9	4.8	13.4	49.6	4.3
3-3-3	1036	18.9	3.4	3.2	10.7	51.9	2.5
3-3-3	1555	15.5	1.8	1.9	7.4	53.3	1.2
HSD[v]		2.7	0.9	1.0	2.7	4.8	0.8
				Fertilizer rate response[u]			
14-14-14		L***Q*	L***	L***	L***	L***	L*
4-2-2		L*Q*	Q***	L***	NS	L***	L**Q***
3-3-3		L**Q**	L**Q***	L**Q*	L***Q***	L***	L**Q**

[z]All treatments contained 0.89 $kg \cdot m^{-3}$ Micromax and 2.97 $kg \cdot m^{-3}$ dolomitic limestone.
[y]Plant growth index = [(height + width + perpendicular width) ÷ 3].
[x]SPAD reading using SPAD-502 chlorophyll meter (average of three leaves per plant).
[w]Root rating on a scale of 0 to 5 where 0 = no roots visible on the surfaces of root ball, and 5 = visible roots were matted on the bottom and on a major portion of the sides of the exposed root ball.
[v]Tukey's honest significant difference ($P = 0.05$, n = 10).
[u]Significant linear (*L*) or quadratic (*Q*) contrasts at $P \leq 0.05$ (*), 0.01 (**), or 0.001 (***) across fertilizer rates in each type of fertilizer. NS = Nonsignificant.

Utilization of Spent Tea Grinds as a Substrate Component in Container Production

Daniel E. Wells[1], Jeff L. Sibley[1], Jay L. Evers[2], Charles H. Gilliam[1], and William A. Dozier, Jr.[1]
[1]Auburn University, Department of Horticulture, Auburn, AL 36849
[2]Milo's Tea Company Inc., Bessemer, AL 35022

wellsda@auburn.edu

Significance to Industry: 'Tuscarora' crapemyrtle, 'Chang's Ruby' loropetalum, 'Fire Power' nandina, and 'Micrantha Pink' azalea were grown in pine bark (PB) substrates containing 0, 25, 50, 75, and 100% spent tea grinds (STG). Results indicate that STG could be used to replace up to 50% by volume of a PB substrate for container production of crapemyrtle, loropetalum, dwarf nandina, and azalea.

Nature of Work: Pine bark (PB) is the major substrate component used in the nursery industry for production of container-grown plants. Future availability of PB for horticulture production is predictably low (5). Another widely used substrate component is peat moss (PM). However, PM is typically the most expensive substrate component (1). These factors have led to a search for alternative substrate components. Many other waste products have been successfully used as substrate components in container production (2,3,4). Over the past twenty years commercial, ready-to-drink tea production has increased exponentially (6). Tea brewers are faced with disposal problems of their waste materials. These materials are most often dumped into landfills at the tea brewer's expense. This costly and inconvenient disposal of their byproduct has prompted tea brewers to search for a suitable avenue for its recapture or reuse. Finding an alternative use for this byproduct may alleviate unnecessary costs for the tea brewers and position them as more environmentally friendly. Spent tea grinds (STG) is a term used to describe the 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 a portion of the PB fractions of container-production substrates**.**

Materials and Methods: On 18 May 2007, crapemyrtles (*Lagerstroemia* x 'Tuscarora'), loropetalum (*Loropetalum chinense* 'Chang's Ruby'), dwarf nandinas (*Nandina* x 'Fire Power'), and azaleas (*Rhododendron* x 'Micrantha Pink'), were planted from trade gallon containers (3.2 L) into 3-gallon (10.6 L) containers filled with five substrates (100% PB, 75:25 PB:STG, 50:50 PB:STG, 25:75 PB:STG, and 100% STG by volume). All treatments were pre-plant incorporated with 9.9 kg/m^3 (16.7 lb/yd^3) of 18N-2.6P-9.9K (18-6-12 Polyon® NPK; 8-9 month release; Agrium Advanced Technologies, Sylacauga, AL), 0.9 kg/m^3 (1.5 lbs/yd^3) Micromax® (The Scotts Company, Marysville, OH), and 3.0 kg/m^3 (5 lbs/yd^3) dolomitic limestone. All plants were placed outside and were irrigated with 1 cm (0.4 inch) water daily. Substrate pH and EC were measured using the Virginia Tech pour-thru nutrient extraction method (7) at 28, 60, 91, 126, and 168 days after

potting (DAP). Growth indices [(height + widest width + perpendicular width) / 3] were measured at 1 DAP and 168 DAP. Chlorophyll content was estimated using the SPAD-502 Chlorophyll Meter (Konica Minolta Sensing Inc., Osaka, Japan) at 28, 60, 91, 126, and 168 DAP. Plants were arranged by species in a randomized complete block containing five single plant replications. Data was subjected to analysis of variance (ANOVA) in SAS and means were separated using Tukey's Studentized Range Test ($\alpha = 0.05$).

Results and Discussion:

pH and EC

Substrate pH measurements remained in an acceptable range of 5.0 to 6.0 (8) for substrates containing 50% or less (by volume) STG throughout the study (data not shown). Substrate pH measurements were within an acceptable range for substrates containing 75% or more (by volume) at the beginning of the study, but rose slightly above this level by the end of the study. Substrate EC measurements were within an acceptable range of 0.5 to 1.0 milliSiemens/cm (8) at the beginning of the study, but fell below an acceptable range in substrates containing 50% or greater (by volume) STG by the end of the study (data not shown).

Crapemyrtle

At 28 DAP, relative leaf chlorophyll content was lowest in crapemyrtles grown in 100% STG (Table 1). However, no differences existed in leaf chlorophyll content of crapemyrtle at 126 days after planting DAP.

Growth indices of crapemyrtle were highest in plants grown in 50:50 PB:STG and were similar in all other substrate treatments.

Loropetalum

There were no differences in relative foliar chlorophyll content of loropetalum grown in any treatment at 28 DAP or 168 DAP (Table 1).

All treatments containing 50% or more STG produced similar sized plants. Treatments containing 75% or greater STG produced plants that were smaller than those grown in 50:50 PB:STG.

Nandina

At 28 DAP no differences in relative foliar chlorophyll content of dwarf nandina were recorded (Table 1). At 168 DAP, plants grown in treatments containing 75% or less STG had similar SPAD readings, while those grown in 100% STG were similar to those grown in 25:75 PB:STG. Where different, nandina grown in 100% PB and 50:50 PB:STG had the highest leaf chlorophyll contents at 168 DAP. Nandina grown in 100% STG had similar SPAD readings to those grown in 75:25 PB:STG and 25:75 PB:STG.

Treatments containing 75% or less STG produced the largest plants (Table 1). Dwarf nandinas grown in the treatment containing 100% STG were similar in size to those grown in 25:75 PB:STG.

Azalea
SPAD readings were similar for azaleas grown in all treatments throughout the entirety of the study (Table 1). Azaleas grown in 100% STG were smaller than plants grown in 50:50 PB:STG, but were similar in size to those grown in 100% PB, 75:25 PB:STG, and 25:75 PB:STG.

For all four species, plant growth in substrates containing up to 50% by volume STG was similar to those grown in 100% PB. Leaf chlorophyll content was similar in all species grown in substrates containing up to 75% STG by volume. These results indicate that STG could be used to replace up to 50% by volume of a PB substrate for container production of crapemyrtle, loropetalum, dwarf nandina, and azalea.

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Table 1. Effects of various substrates on growth of four species.

Treatment[Z]	'Tuscarora' crapemyrtle			'Chang's Ruby' loropetalum		
	SPAD[Y]		Growth Index (cm)[X]	SPAD		Growth Index (cm)
	28 DAP[W]	126 DAP	168 DAP	28 DAP	168 DAP	168 DAP
100% PB	73.7a[V]	58.6a	56.9ab	44.7a	47.4a	73.4ab
75:25 PB:STG	77.7a	62.9a	54.1ab	43.5a	47.5a	73.9ab
50:50 PB:STG	73.5a	68.6a	62.0a	42.3a	51.8a	79.3a
25:75 PB:STG	71.4a	66.8a	49.9ab	45.3a	47.8a	56.2b
100% STG	62.4b	61.6a	40.8b	38.7a	45.9a	56.6b

	'Fire Power' nandina			'Micrantha Pink' azalea		
	SPAD		Growth Index (cm)	SPAD		Growth Index (cm)
	28 DAP	168 DAP	168 DAP	28 DAP	168 DAP	168 DAP
100% PB	32.3a	39.9a	25.6a	42.3a	51.8a	12.1ab
75:25 PB:STG	25.9a	37.8ab	29.7a	40.2a	53.3a	11.9ab
50:50 PB:STG	22.9a	41.3a	24.9a	39.2a	49.2a	12.8a
25:75 PB:STG	28.7a	35.3ab	21.1ab	36.8a	53.6a	11.6ab
100% STG	24.2a	29.9b	8.9b	35.0a	51.3a	7.9b

[Z]Treatments were: PB = pine bark; STG = spent tea grinds.
[Y]Leaf chlorophyll content was estimated using a SPAD-502 Chlorophyll Meter (Konica Minolta Sensing, Inc. Osaka, Japan).
[X]Growth Index = [(height + widest width + perpendicular width) / 3].
[W]DAP = days after potting.
[V]Values in column followed by different letters are significant according to Tukey's Studentized Range Test (α = 0.05).

Fertilizer Source and Application Time Impact Growth of Containerized Oak Liners

Sue Scholl and Donna Fare
US National Arboretum
TSU Nursery Research Center
472 Cadillac Lane
McMinnville TN 37110

Index Words: *Quercus palustris* Muenchh., Pin Oak, *Quercus lyrata* Walt, Overcup oak, fertilizer timing, fertilizer application, controlled-release fertilizer

Significance to industry: Results from this study suggest that split applications of a controlled-release fertilizer (CRF) produced plants which were of higher quality and minimized nutrient runoff compared to plants that received split applications with an agriculture grade fertilizer and controlled-release fertilizer. Applying half the recommended CRF rate at time of potting, reduced the ortho-phosphate and nitrate-nitrogen effluent concentration while maintaining plant quality compared to the recommended fertilizer application. Use of agricultural grade fertilizers, 13-13-13 or KNO_3 at potting, was detrimental to plant growth and resulted in excessive leaching of nitrogen for about 6 weeks.

Nature of Work: Time of potting and time of fertilizer application are concerns for container production managers. Often bare root or containerized tree liners are obtained in the fall of the year, and during repotting to a larger container, a question arises about whether to use a recommended full rate of fertilizer or to reduce that rate at potting and make a second application prior to spring bud break. Fall fertilization can nutrient-load plant tissues and lead to increased growth in the spring but can also delay the acquisition of winter hardiness and thus increase the chance of freeze injury. In a recent report, a higher rate of fertilizer applied in the fall as fertigation increased the LT_{50} (the temperature which causes 50% mortality) of azalea stems when compared to lower rates of fertigation (2). Splitting CRF application reduced leachate and soil nitrate-nitrogen concentrations while maintaining growth rate and quality of Aronia (1). This experiment was conducted to compare the effects of fertilizer type and fertilizer rate in conjunction with fall potting on growth of oak liners and subsequent leaching of nitrogen and phosphorus.

Uniform containerized liners of *Quercus palustris* Muenchh., Pin Oak, and *Quercus lyrata* Walt., Overcup oak, grown in Rootmaker^{tm} (Rootmaker, Huntsville, AL) propagation containers (11 in^3) were potted on 22 Nov 2005 into #3 nursery containers. Prior to potting, the pine bark substrate was amended with 0.6 kg (1.0 lb) Micromax (O.M. Scotts Co., Marysville, Ohio) and 1.0 lb AquaGro (Aquatrol, Paulsboro, NJ) per cubic yard. Plants were subjected to five fertilizer treatments: controlled-release fertilizer, Osmocote Pro 19-5-9 (19N-2.2P-7.5K) (O.M. Scotts Co., Marysville, OH) (CRF) was incorporated into the pine bark substrate at potting with either 1) 2.09 lb N/yd

(1x rate) or 2) 1.045lb N/yd (0.5x); 3) KNO_3 (13.5N-0P-46.2K) or 4) 13-13-13 were incorporated at a nitrogen rate of 1.045 lb/yd, and 5) plants received no fertilizer at potting. Plants were arranged in an overwintering house by species in a completely randomized design with 10 and 8 single plant replications for pin oak and overcup oak, respectively. Irrigation was applied as needed with overhead sprinklers. When ambient temperatures were forecast to be below 30°F a smudge pot was used. On 24 Apr 2006, all plants were moved to an outdoor container pad with overhead irrigation and were maintained in the randomization pattern by species. On 24 April, plants potted in substrate containing 1.045lb N/yd (0.5x rate) (treatments 2, 3, and 4) were topdressed with 27 grams of Osmocote Pro 19-5-9 (equivalent to 1.045 lb N/yd) and treatment 5 plants received a topdress application of 54 grams (equivalent to 2.09 lb N/yd, a 1x rate), so that all plants received the same total amount of applied nitrogen. Container leachate, via the Virginia Tech pour-through method (6), were collected from 3 replications weekly, for 47 weeks, and analyzed for pH, electrical conductivity, nitrate-N, ammonium-N and orthophosphate (only nitrate-N and orthophosphate data shown). Plant height and caliper were measured on 1 Dec 05, and at the end of the growing season, on 19 Oct 2006. Five plants per treatment from each oak species were harvested for shoot and root dry weights on 19 Oct 2006.

Data were analyzed using SAS 9.13 (SAS Institute, Cary NC). Means were separated using Fisher's LSD at $\alpha<0.05$. Specific treatments were compared using single degree of freedom contrasts.

Results and Discussion: Growth: Fertilizer treatment affected plant height, trunk caliper, as well as shoot and root dry weights of both oak species (Table 1). Plants potted with substrate containing Osmocote Pro were larger than those fertilized with 13-13-13 and KNO_3. Although the amount of total nitrogen received by the plants were the same, those that received KNO_3 at potting had less height growth, caliper increase, and dry weight compared to plants that received a single or split application of CRF.

Overcup oak had similar growth between plants receiving the 13-13-13 at potting and those treated with incorporated and topdressed with CRF. Pin oak had less caliper growth and shoot dry weight with plants that received 13-13-13 or KNO3 compared to plants that received only CRFs.

Plants fertilized with CRF (single or split application) were not significantly different in height growth, but there were significant differences in caliper growth and dry weight accumulation (Table 1). In general, a 1x CRF rate at fall potting resulted in higher caliper growths for both oak species than a .5x rate. Shoot and root dry weights of plants potted in substrate containing 1x CRF (trt 1) were significantly higher than plants which did not receive any fertilizer at potting. The lack of nutrient loading prior to bud break in the half rate and no CRF treatments caused a reduction in shoot dry weight of 9.6% and 34.9%, and 12.2% and 27.7% in overcup and pin oak, respectively. In addition, root dry weight was reduced by 12.0% and 32.4% for overcup oak, and 17.5% and 40.1% in pin oak.

The practice of incorporating half rate fertilizer at potting in the fall and topdressing the remaining half rate in the spring, has been recommended for increasing root growth in the fall (3, 4). The overcup oaks in this study attained height and caliper growths, and dry weight accumulation which were statistically similar to that of the full rate treatment. Pin oaks attained similar height and caliper growths but shoot and root dry matter accumulations were less.

Container leachate. Concentrations of nitrate-N and orthophosphate were similar with both oak species; thus only the overcup oak data will be discussed. At two weeks after potting (WAP), orthophosphate release of the 13-13-13 treatment was significantly higher than all other treatments (Table 2). Nitrate-N release was higher for the 13-13-13 and KNO_3 treatments than for the CRF treatments. There was no difference between the CRF treatments. A comparison of NO_3-N levels at two weeks after the spring topdress (WAST) showed no significant differences in the fertilizer types (p=.23429), but differences were seen in the CRF treatments. The 1x topdress treatment was lower than the non-topdressed treatment, 5.8 mg/L vs 10.8 mg/L, (p=0.04877).

Orthophosphate levels, 2 WAST, were significantly lower for the plants that received a 0.5x rate CRF (trt 2), KNO_3 (trt 3) or no fall fertilizer (trt 5) than plants that received a 1x at fall potting (trt 1) or plants that received 13-13-13 (trt 4) at potting. The phosphorus in the 13-13-13 treatment released immediately after potting and continued to release at high concentrations during the winter dormancy and into the spring, thus the orthophosphate levels were still higher than other treatments at 2 WAST. This suggests that the efficiency of an agricultural grade fertilizer is very poor in a container growing system due to the accelerated release of nutrients during a period of little plant growth. Schoene and Yeager (5) reported higher nitrogen rates negatively affected root growth. It is possible that root damage occurred with plants that received 13-13-13 and KNO_3, due to the rapid release of nitrogen shortly after fall potting.

Nitrate-N and orthophosphate levels were significantly higher for 13-13-13 during the experiment compared to the other treatments (Table 2). Release of nitrate-N for KNO_3 and 13-13-13 was immediate, and was statistically higher than the CRF treatments through the first 5 WAP. By 9 WAP, the nitrate-N concentration from the 1x CRF treatment, in general, was greater than the other 4 treatments and persisted until the spring topdress (data not shown). Two WAST, the 1x CRF (trt 1) was statistically similar to the 0.5x and KNO_3 treatments but significantly higher than the no fertilizer and 13-13-13 treatments. The amount of nutrients released from the topdress application was rapidly utilized by the actively growing plants and very little was leached. There were no differences in nitrate-N release 3 WAST (data not shown).

Though orthophosphate levels in the 13-13-13 treatment were very high compared to other treatments, the levels slowly declined through the experiment. The spring application of CRF at the 0.5x rate with this fertilizer had little influence on orthophosphate leachate levels. Orthophosphate levels in the CRF leachate steadily increased initially, corresponding to increases in minimum temperatures (data not shown) while the plants were still dormant and there was little plant uptake; the trend

continued through the winter until week 24 when plant utilization of available orthophosphate in the media exceeded fertilizer release.

Results from this study suggest that split applications of a controlled-release fertilizer produced plants which were of higher quality and minimized nutrient runoff compared to plants that received split applications with an agriculture grade fertilizer and controlled-release fertilizer. Applying half the recommended CRF rate at time of potting reduced the measured nutrient effluent concentration while maintaining plant quality compared to the recommended fertilizer application. Use of agricultural grade fertilizers, 13-13-13 or KNO_3 at potting, was detrimental to plant growth and resulted in excessive leaching of nitrogen and phosphorus.

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Table 1. The effect of fertilzer treatments on growth of *Quercus lyrata* Walt., Overcup Oak and *Quercus palustris* Muenchh., Pin oak grown in #3 nursery containers.

	Overcup Oak				Pin Oak			
Fertilizer Treatment[z]	Height Growth, cm[y]	Caliper Growth, mm[y]	Shoot Dry Wt., g[x]	Root Dry Wt., g[x]	Height Growth, cm	Caliper Growth, mm	Shoot Dry Wt., g	Root Dry Wt., g
1	100 a[w]	11.4 a	194 a	152 a	77 a	10.1 a	150 a	198 a
2	80 a	9.7 ab	175 a	129 a	85 a	8.9 a	126 b	164 b
3	44 b	5.1 d	71 c	58 c	39 c	3.8 c	51 e	70 d
4	71 ab	7.1 cd	103 bc	81 bc	52 bc	4.5 c	70 d	112 c
5	77 a	9.1 bc	126 b	89 b	72 ab	7.1 b	96 c	121 c
Contrasts:								
1 v 2 and 5	0.0959	0.0263	0.0125	0.0005	0.9000	0.0001	0.0001	0.0000
1 and 2 vs 5	0.3005	0.0866	0.0014	0.0001	0.2810	0.0000	0.0000	0.0000
1,2,5 v 3 and 4	0.0048	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1 vs 5	0.1197	0.0241	0.0013	0.0000	0.5802	0.0000	0.0000	0.0000
1 vs 2	0.1796	0.1058	0.3182	0.0648	0.4419	0.0511	0.0157	0.0006

[z]Fertilizer treatments: Treatment 1) Osmocote Pro 19-5-9 (19N-2.2P-7.5K) potted at 2.09 lb N/yd (1x rate) and not spring topdressed, 2) Osmocote Pro 19-5-9 at 1.045 lb N/yd (0.5x), 3) KNO_3 (13.5N-0P-46.2K) or 4) 13-13-13 [Treatments 2-4 potted at 1.045 lb N/yd (0.5x rate), and topdressed with Osmocote Pro 19-5-9 at 1.045 lb N/yd (0.5x)], and 5) plants received no fertilizer at potting and topdressed with Osmocote Pro 19-5-9 at 2.09 lb N/yd (1x).

[y]The height and caliper growth increase was the difference between measurements made 1 Dec 2005 and 19 Oct 2006.

[x]Shoot and root dry weights were recorded in November 2006.

[w]Treatments followed by the same letter are not significantly different. Means separated using Fisher's protected LSD, $\alpha < 0.05$.

Table 2. The effect of fertilzer treatments on NO_3 and $OrthoPO_4$ concentration in leachates from *Quercus lyrata Walt.*, Overcup Oak grown in #3 nursery containers.

Fertilizer Treatment[x]	Leachate concentration, ppm, 2 WAP[z], Dec 05		Leachate concentration, ppm, 2 WAST[y], May 06		Average Leachate Concentration, ppm, Dec 05-Oct 06	
	NO_3_N	$OrthoPO_4$	NO_3_N	$OrthoPO_4$	NO_3_N	$OrthoPO_4$
1	21.01 b[w]	9.21 b	10.81 a	16.29 b	9.52 b	7.91 b
2	9.04 b	3.54 b	6.65 ab	5.29 c	4.68 b	3.96 b
3	138.40 a	1.89 b	7.57 ab	1.98 c	21.18 ab	2.12 b
4	131.36 a	722.13 a	4.30 b	25.86 a	47.20 a	133.15 a
5	0.38 b	1.28 b	5.80 b	1.70 c	1.22 b	2.12 b
Contrasts:						
1 v 2 and 5	0.22654	0.82974	0.03928	0.00179	0.57823	0.65031
2 vs 1 and 5	0.89850	0.95685	0.41245	0.25000	0.95326	0.92184
5 vs 1 and 2	0.27385	0.87203	0.16079	0.01350	0.61893	0.72242
1, 2, 5 vs 3 and 4	0.00000	0.00000	0.23429	0.02142	0.00103	0.00000
1 vs 5	0.18817	0.82813	0.04877	0.00195	0.54310	0.64063
1 vs 2	0.43158	0.87647	0.09220	0.01054	0.72270	0.75019
2 vs 5	0.56641	0.95071	0.71134	0.33044	0.80001	0.88199

[z]WAS=Weeks after potting.

[y]WAST=Weeks after spring topdress.

[x]Fertilizer treatments: Treatment 1) Osmocote Pro 19-5-9 (19N-2.2P-7.5K) potted at 2.09 lb N/yd (1x rate) and not spring topdressed, 2) Osmocote Pro 19-5-9 at 1.045 lb N/yd (0.5x), 3) KNO_3 (13.5N-0P-46.2K) or 4) 13-13-13 [Treatments 2-4 potted at 1.045 lb N/yd (0.5x rate), and topdressed with Osmocote Pro 19-5-9 at 1.045 lb N/yd (0.5x)], and 5) plants received no fertilizer at potting and topdressed with Osmocote Pro 19-5-9 at 2.09 lb N/yd (1x).

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

Amending Pine Bark with Alternative Substrates

Anna-Marie Murphy, Charles H. Gilliam, Glenn B. Fain, H. Allen Torbert, Thomas V. Gallagher, Jeff L. Sibley, and Stephen C. Marble
Department of Horticulture, 101 Funchess Hall
Auburn University, AL 36849

Index Words: Clean Chip Residual, WholeTree, Container media

Significance to Industry: This data shows that with most species, nursery producers could amend their pine bark (PB) with up to 75% WholeTree (WT) or 75% Clean Chip Residual (CCR) with limited impact on crop growth. This process will also allow nursery producers the opportunity to become comfortable with alternative substrates before switching completely to 100% alternative substrates.

Nature of Work: Due to a number of factors, PB supplies have significantly decreased over the past few years (4). While alternative substrates are being evaluated (2,3), many growers are asking if these alternative substrates can be used to stretch existing PB supplies. In this study, two alternative substrates, CCR and WT were evaluated in varying ratios with PB to determine their effect on the growth of five different nursery crops. Both of these alternative substrates contain higher wood content than PB alone. CCR is a product composed of approximately 50% wood, 40% bark, and 10% needles (2). It is created when transportable in-field harvesters are used to process pines into 'clean chips' that can be used by pulp mills. This by-product is either sold for boiler fuel or more commonly spread back across the harvested area. WT is different in that it consists of the entire pine tree harvested from pine plantations at the thinning stage (3). This process consists of utilizing the pine tree in its entirety, and then modifying the large chips during the manufacturing process to meet individual nursery crop substrate specifications. WT is made up of about 80% wood, 15% bark, and 5% needles.

One concern nursery producers have expressed is the effect of these high wood content alternative substrates when mixed with PB. The objective of this study was to evaluate varying ratios of PB with CCR or WT, in order to assist growers with extending existing PB supplies.

Materials and Methods: Nine different substrates, formulated utilizing varying amounts of PB, WT, and CCR were used in this study. CCR and WT used in the study were each processed to pass through a 3/8 inch (0.95 cm) screen. Treatments consisted of 100% PB, WT, and CCR, 75:25 PB:WT, 50:50 PB:WT, or 25:75 PB:WT (by vol.). PB:CCR substrates had similar ratios as PB:WT. All substrates were blended with a 6:1 (v:v) ratio of sand, and amended with 8.3 kg/m^3 (14 lb/yd^3) 18N-2.6P-9.9K (18-6-12) Polyon (Harrell's Fertilizer, Inc., Lakeland, FL) control release fertilizer (9 month), 3.0 kg/m^3 (5 lb/yd^3) dolomitic limestone, and 0.9 kg/m^3 (1.5 lb/yd^3) Micromax (The Scotts Company, Marysville, OH).

Five species were used in the experiment, which was initiated on July 22, 2008. Species included New Gold Lantana (*Lantana camara* L. 'New Gold'), Spiraea (*Spiraea japonica* L.f. 'Gold Mound'), Azalea (*Rhododendron* x 'Amaghasa'), Tea Olive (*Osmanthus fragrans* Lour.) and Ligustrum (*Ligustrum japonicum* Thunb. 'Rotundifolia'). Liners (32 cell pack) were placed into #1 containers and watered using overhead irrigation. All species were placed in full sun, except azaleas, which were placed under a 30% shade structure.

The experimental design was a randomized complete block design with 7 single pot replications per treatment. Each species was treated as its own separate experiment. Electrical conductivity and pH of the substrates were measured using the pour-through method at 7, 15, 30, 60, 90 and 120 days after transplanting (DAT). Growth indices [(height + width + width)/3] (cm) were measured at 90 DAT. Means were separated in SAS 9.1 using Duncan's Multiple Range Test at α=0.05 (1). Studies were conducted at the AU Paterson Greenhouses at Auburn University, AL.

Results and Discussion: CCR and WT tended to raise the substrate pH compared to PB alone (Table 1). At 30 DAT, pH level for PB alone was 5.7, and tended to increase as WT volume increased in PB:WT treatments. While the pH of the 100% WT substrate (6.6) is slightly out of the desired range (4.5-6.5) (5), all of the PB:WT blends were well within range. Increasing amounts of CCR in PB:CCR treatments had relatively the same effect as that of WT. At 90 DAT, the 75:25 PB:CCR had the lowest pH level (5.9) of any ratio of PB:CCR. As CCR volume increased in subsequent substrates, pH steadily climbed (6.5). This data indicates that the CCR and WT additives may raise pH levels to the top of the desired range, rather than exceeding the limit overwhelmingly. This data may also indicate that lime may not be needed when alternative substrates are used.

At the initial 7 DAT, EC levels were elevated for all treatments (Table 1). The only treatment within the normal range (0.5-1.0 dS/m) (5) at 7 DAT was the PB:WT (25:75 v:v) (0.9). At 15 DAT, EC levels were beginning to decrease as a whole, however, most were still slightly above normal range. At 30 DAT, EC levels were within recommended BMP ranges. PB:CCR (75:25 v:v) tended to maintain the highest EC levels throughout the study. At both 90 and 120 DAT, the PB:CCR (75:25 v:v) proved to be the only treatment within the normal range (0.6 and 0.7, respectively). There were no statistical differences in EC levels within the PB:WT treatments and 100% PB at 90 or 120 DAT.

Azalea, Lantana, Ligustrum and Spiraea growth indices, in all substrates, were similar to, or larger than, plants grown in 100% PB (Table 2). Tea Olive tended to grow better in substrates with 50% PB or higher; however, only plants grown in PB:CCR (25:75 v:v) were statistically smaller than Tea Olive grown in 100% PB. All plants grown in 100% WT or CCR were similar in size to those grown in 100% PB. Data for growth indices was taken at 90 DAT. Growth indices will be taken again after the first growth flush in 2009 to determine long-term effects on plant growth.

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Table 1. Effect of substrate on pH and electrical conductivity (EC)[z].

	7 DAT[y]		15 DAT		30 DAT		60 DAT		90 DAT		120 DAT	
Substrate	pH	EC[x]	pH	EC	pH	EC	pH	EC	pH	EC	pH	EC
100% PB[w]	6.0 a	1.4 abc	6.5 b	1.1 ab	5.7 b	0.8 a	6.3 cd	0.6 abcd	6.0 ef	0.5 b	6.2 b	0.4 bc
75:25 PB:WT[v]	6.2 a	1.5 ab	6.3 b	1.1 abc	6.1 ab	0.7 a	6.3 d	0.6 ab	6.1 de	0.4 bc	6.3 ab	0.4 bc
50:50 PB:WT	6.3 a	1.2 abcd	6.4 b	0.9 bcd	6.1 ab	0.4 a	6.5 bc	0.4 cde	6.4 bc	0.4 bc	6.3 b	0.4 bc
25:75 PB:WT	6.4 a	0.9 d	6.5 b	1.0 abcd	6.4 ab	0.4 a	6.5 b	0.4 cde	6.6 a	0.4 bc	6.3 b	0.4 bc
100% WT	6.3 a	1.1 bcd	6.5 b	0.8 bcd	6.6 a	0.4 a	6.9 a	0.3 e	6.5 ab	0.3 c	6.3 ab	0.4 c
75:25 PB:CCR[u]	6.2 a	1.6 a	6.3 b	1.3 a	6.2 ab	1.0 a	6.3 cd	0.7 a	5.9 f	0.6 a	6.3 b	0.7 a
50:50 PB:CCR	6.3 a	1.3 abcd	6.3 b	1.0 abcd	6.4 ab	0.5 a	6.4 bcd	0.6 abc	6.2 cd	0.4 bc	6.3 ab	0.5 b
25:75 PB:CCR	6.4 a	1.2 abcd	6.7 a	0.6 d	5.7 b	0.7 a	6.5 b	0.4 bcde	6.5 ab	0.4 bc	6.4 ab	0.4 c
100% CCR	6.3 a	1.0 cd	6.5 ab	0.7 cd	6.3 ab	0.4 a	6.6 b	0.4 de	6.5 ab	0.3 c	6.6 a	0.4 c

[z]pH and EC of solution determined using pour-through method
[y]DAT = Days after transplanting
[x]EC = Electrical Conductivity (dS/m)
[w]PB = Pine Bark
[v]WT = WholeTree
[u]CCR = Clean Chip Residual
[t]Means separated in columns by Duncan's Multiple Range Test at P=0.05

Table 2. Influence of substrate on plant growth indices[z] at 90 DAT[y].

Substrate	Azalea	Lantana	Ligustrum	Spiraea	Tea Olive
100% PB[x]	15.2 a[u]	58.9 abc	21.6 b	30.6 b	24.9 ab
75:25 PB:WT[w]	14.6 a	67.4 a	22.0 ab	32.3 ab	26.3 a
50:50 PB:WT	14.9 a	61.8 abc	25.5 a	35.3 ab	23.0 abc
25:75 PB:WT	14.2 a	58.3 abc	22.2 ab	31.6 b	22.1 abc
100% WT	13.9 a	52.6 c	21.9 ab	33.9 ab	21.3 bc
75:25 PB:CCR[v]	14.5 a	64.2 ab	23.4 ab	38.7 a	23.0 abc
50:50 PB:CCR	14.7 a	66.4 a	21.9 ab	34.4 ab	24.5 abc
25:75 PB:CCR	14.0 a	62.3 ab	21.4 b	29.5 b	19.8 c
100% CCR	13.9 a	56.0 bc	22.8 ab	35.5 ab	23.2 abc

[z]Growth indices (in cm) = [(height + $width_1$ + $width_2$)/3]
[y]DAT = Days after transplanting
[x]PB = Pine Bark
[w]WT = Wholetree
[v]CCR = Clean Chip Residual
[u]Means separated in columns using Duncan's Multiple Range Test at P = 0.05

Fertilizer Techniques for *WholeTree* and Clean Chip Residual Alternative Substrates

Whitney Griffin, Glenn Fain, Charles Gilliam, and Donald Eakes
Department of Horticulture, Auburn University, Auburn, Alabama 36849

Ben Richardson
Pursell Farms Nursery, Fayetteville, Alabama 35151

Index Words: Media, wood fiber, nursery production, pine bark, peat

Significance to Industry: Growers are increasingly interested in utilization of alternative substrates for container grown nursery crops. *WholeTree* is a new alternative substrate offering sustainability to the green industry(3,2) Clean Chip Residual is also a wood-based substrate offering an alternative for both greenhouse and nursery crop producers (1,2).These data indicate that as growers begin to utilize these alternative substrates, current nursery cultural practices will result in similar growth for *Chionanthus virginicus* and *Nyssa sylvatica*.

Nature of Work: The objective of this experiment was to evaluate dibble and incorporated fertilization practices as well as the need for lime in *WholeTree* and Clean Chip Residual substrates. Seventy-two each of *Chionanthus virginicus* and *Nyssa sylvatica* were planted in #3 containers on a full-sun nursery pad. The experiment was set up as a three x two x two factorial; with three substrate treatments, two fertilizer treatments, and two lime treatments. Three substrate treatments were pine bark, *WholeTree*, and CCR. All substrates were incorporated with 1.5 lbs/yd^3 Micromax (Scott's Co., Marysville, OH) at mixing. The two fertilizer treatments were dibble (30g per #3 container) and incorporated (14 lbs/yd^3); both utilized nine month control release 15-6-12 fertilizer (15N-2.6P-9.8K, Murfreesboro, TN). The incorporated treatment utilized 14 lbs/yd^3. For the dibble treatment a 3/4" bamboo stake was used to develop a hole about 5" below the surface on alternate sides of the container in which 15 grams of fertilizer were placed in each hole. The two lime treatments were 5 lbs/yd^3 incorporated at mixing or no lime. The CCR came from a twelve year old *Pinus taeda* L. plantation located in Flomaton, AL. *WholeTree* was harvested and chipped from a twelve year old *Pinus taeda* plantation in Lumpkin, GA. *WholeTree* and CCR were further processed through a hammer mill to pass through a 1/4" or 3/8" screen respectively. Aged pine bark was obtained from The Pineywoods Mulch Co., Alexander City, AL. The substrates were mixed on 30 April 2008 and 2 May, 2008. The experiment was installed at Pursell Farms Nursery Fayetteville, AL on a full sun nursery pad. Plants were watered as needed using overhead irrigation

Electrical conductivity (EC) and pH measurements for substrates for *Chionanthus virginicus* were recorded at 15, 66, 125, and 167 days after planting (DAP) using a Myron L Waterproof UltraMeter II 6P (GWP Company, Hacienda Heights, CA) using the pour-through method. Shrinkage was measured at 15DAP and 167 DAP as well. Foliar samples of *Nyssa sylvatica* were taken on 22 September , 2008 and analyzed for macro

and micro nutrient content by the Auburn University Plant Diagnostics and Research Laboratory.

Results and Discussion: At 15 DAP, CCR EC was significantly lower than pine bark EC (Table 1). This difference continued until 125 DAP, when no significant differences between substrate EC was found. Similarly, at 66 DAP, pine bark pH was significantly lower than that of *WholeTree* or CCR; however, this difference was not evident at any other date. Dibble fertilization resulted in significantly lower EC throughout the entire test, and gave significantly higher pH for all but one test day (Table 1). Addition of lime resulted in significantly higher EC values throughout the entire test, but lime did not significantly change substrate pH (Table 1). There were significant interactions between the substrate and fertilizer treatments for both 66 DAP and 125 DAP for EC values, and for pH values at 167 DAP. There were significant interactions between fertilizer and lime for pH values at 66 DAP (Table 1).

Substrate treatments showed no significant differences for height, caliper, or substrate shrinkage for *Chionanthus virginicus*, and only significantly affected shrinkage for *Nyssa sylvatica* (Table 2). There were no significant differences between dibble or incorporated methods of fertilizer application in height, caliper, or shrinkage of either species, nor were there significant differences from the application of lime for either species. Significant interactions between substrate and lime and substrate-fertilizer-lime were found for height measurements of *Chionanthus virginicus*.

Nyssa sylvatica grown in *WholeTree* had significantly lower leaf Al content than those grown in pine bark (Table 3). Plants grown in pine bark had significantly lower leaf Mn content than either *WholeTree* or CCR. Dibble fertilization caused significantly lower P, B, Fe, and Mn in leaf tissue (Table 3) compared to incorporated fertilizer. The addition of lime caused significantly lower amounts of Al, B, Fe, Mn, Z, and N in leaf tissue.

While minor differences existed throughout the study, results were generally similar among treatments. These data demonstrate that *WholeTree* and CCR substrates provide similar results to pine bark substrate in container production of nursery crops.

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Table 1. Effect of substrate type, fertilizer placement and lime rate on substrate EC and pH for *Chionanthus virginicus*

	Chionanthus virginicus							
	EC[x]				pH			
Substrate	15 DAT	66 DAT	125 DAT	167 DAT	15 DAT	66 DAT	125 DAT	167 DAT
Pine Bark	391.3a	640.9a	294.8a	347a	6.9a	7.2b	7.6a	7.6a
Wholetree	352.4ab	350.3b	295.3a	316.8a	6.6a	7.4a	7.5a	7.6a
CCR	280.6b	481.3b	277.7a	386.7a	6.9a	7.4a	7.4a	7.5a
Fertilizer placement								
Incorporated	439.5a	640.9a	355.6a	401.7a	6.6b	7.2b	7.4b	7.5a
Dibble	246.4b	336.7b	220.9b	298.7b	7.0a	7.4a	7.6a	7.6a
Lime Rate (lbs/yd3)								
5	402.4a	556.5a	313.7a	394.9a	6.9a	7.3a	7.5a	7.5a
0	280.4b	427.3b	263.9b	305.4b	6.7a	7.3a	7.5a	7.6a
Interactions								
Sub-fert	NS[x]	**	***	NS	NS	NS	NS	**
Sub-lime	NS	NS	NS	NS	NS	NS	NS	NS
Fert-lime	NS	NS	NS	NS	NS	*	NS	NS
Sub-fert-lime	NS	NS	NS	NS	NS	NS	NS	NS

[z]Electrical conductivity (μmhos/cm) of substrate solution using the pour through method.

[y]Means followed by same letter within columns do not differ significantly ($P < 0.05$, Tukey's Honest Significant Difference).

[x]Non Significant (NS), or significant at $P < 0.05$ (*), 0.01 (**) or 0.001 (***).

Table 2. Effect of substrate type, fertilizer placement, and lime rate on plant height, trunk caliper, and substrate shrinkage for two plant species

	Chionanthus virginicus			*Nyssa sylvatica*		
Substrate	Height	Caliper	Shrinkage	Height	Caliper	Shrinkage
Pine Bark	41.8a[z]	4.6a	7.1a	186.5a	9.4a	3.3b
Wholetree	41.5a	4.9a	6.4a	119.3a	8.7a	4.5a
CCR	40.4a	4.9a	3.9a	123.9a	9.0a	3.7ab
Fertilizer Placement						
Incorporated	40.1a	5.1a	6.6a	158.3a	9.3a	3.8a
Dibble	41.1a	4.5a	4.9a	128.2a	8.8a	3.8a
Lime Rate (lbs/yd3)						
5	40.4a	4.9a	4.2a	120.8a	9.3a	4.0a
0	42.1a	4.7a	7.4a	165.7a	8.8a	3.6a
Interactions						
Sub-fert	NS[y]	NS	NS	NS	NS	NS
Sub-lime	*	NS	NS	NS	NS	NS
Fert-lime	NS	NS	NS	NS	NS	NS
Sub-fert-lime	**	NS	NS	NS	NS	NS

[z]Means followed by same letter within columns do not differ significantly ($P < 0.05$, Tukey's Honest Significant Difference).

[y]Non Significant (NS), or significant at $P < 0.05$ (*) or 0.01 (**).

Table 3. Effect of substrate type, fertilizer placement and lime rate on leaf tissue nutrient content of *Nyssa sylvatica*.

	Tissue Analysis for *Nyssa sylvatica*											
Substrate	N	Ca	K	Mg	P	Al	B	Cu	Fe	Mn	Na	Zn
	%					ppm						
Pine Bark	2.3a	0.51a	.9a	.27a	.18a	141.9a	16.8a	17.8a	271.4a	478.6b	216.3a	41.9a
Wholetree	2.3a	.52a	.9a	.27a	.19a	87.4b	12.5a	18.8a	250.5a	406.0b	197.65a	35.4a
CCR	2.4a	.56a	1.1a	.28a	.22a	120.9ab	12.8a	18.3a	281.8a	915.0a	205.13a	39.5a
Fertilizer placement												
Incorporated	2.5a	.55a	1.7a	.27a	.22a	132.9a	15.7a	19.2a	321.8a	715.1a	210.8a	44.2a
Dibble	2.2b	.51a	.9a	.27a	.17b	33.6a	12.2b	17.4a	211.2b	487.2b	201.6a	33.4b
Lime Rate (lbs/yd3)												
5	2.3b	.54a	.99a	.27a	.19a	75.1b	12.0b	18.4a	211.7b	344.2b	194.7a	31.7b
0	2.4a	.52a	1.0a	.28a	.19a	160.9a	16.1a	18.3a	327.8a	879.9a	218.7a	46.7a
Interactions												
Sub-fert	NS	NS	NS	NS	NS	NS	NS	NS	NS	*	NS	*
Sub-lime	NS	NS	NS	NS	NS	NS	NS	NS	NS	***	NS	NS
Fert-lime	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Sub-fert-lime	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

[z]Means followed by same letter within columns do not differ significantly ($P < 0.05$, Tukey's Honest Significant Difference).

[y]Non Significant (NS), or significant at $P < 0.05$ (*), 0.01 (**) or 0.001 (***).

Pruning Effects on Trade #1 Sweet Viburnum Growth and Leaf Area

Jeff Million[1], Tom Yeager[1] and Joseph Albano[2]

[1]Dept. of Environmental Horticulture, Univ. of Florida, IFAS, Gainesville, FL
[2]U.S. Horticultural Research Laboratory, USDA-ARS, Ft. Pierce, FL

jmillion@ufl.edu

Index words. biomass, root, shoot, size index, *Viburnum odoratissimum*

Significance to the Industry. Pruning of ornamental shrubs is commonly practiced to improve plant quality but little is known about the quantitative effects of pruning on subsequent growth. Under the conditions of this experiment, pruning sweet viburnum plants greatly reduced subsequent plant biomass and leaf area growth. This information will be incorporated into a crop model which simulates growth of pruned ornamental shrubs. Results indicate that research efforts to maximize pruning effectiveness are warranted.

Nature of Work. Pruning is employed by growers to control the size and shape of ornamental shrubs. In general, the objective of pruning is to create well-branched plants which will meet quality standards and demand a good price in the marketplace. Our research group is modeling the growth of ornamental crops in small containers (4) and realized that little is known about the influence of pruning on subsequent growth including leaf area development. Depending upon the species, frequent soft prunes can result in better quality plants of greater size than infrequent hard prunes (1). Early pruning greatly reduced root growth of *Ilex crenata* (3). Pruning that removes too much foliage can result in dead plants (2).

To find out how pruning affects subsequent growth and leaf area of an ornamental shrub, on 3 April 2008, sweet viburnum (*Viburnum odoratissimum* Ker Gawl.) liners were planted one per trade #1 container [16-cm (6.3 inch) top diameter] filled with a substrate composed of 2 pine bark: 1 sphagnum peatmoss:1 coarse sand (by volume). Liners had two main stems. An18N-2.6P-10K controlled-release fertilizer (Osmocote Classic 18-6-12, 8-9 month; Scotts Co.; Marysville, OH) was incorporated into the substrate at 20 g/container (2.7 lb N/yd^3). Shoot height and plant width measured in perpendicular directions were taken at planting and again 5 weeks later on May 5. Size on May 5 was used to distribute 96 plants into 12 pruning-harvest treatments (3 pruning schedules x 4 destructive harvests x 8 replications). Containers were initially placed pot-to-pot (290 cm^2 of production area per container) in a square pattern for 12 weeks then spaced in a triangular pattern with containers 5 inch apart (740 cm^2 of production area per container) until the end of the experiment. The three pruning schedules evaluated were: 1) pruned once May 15 (week 6), 2) pruned once on June 3 (week 9), and 3) un-pruned control. An electric hedge trimmer with a sickle bar cutting mechanism was used to make a horizontal cut at a height pre-determined to result in the removal of 1-2 of the uppermost nodes from main stems of most plants in the

treatment group. Destructive harvests were made on May 15, June 3, July 31 (week 17) and September 2 (week 21). The first two harvest dates coincided with the two pruning dates. For destructive harvests, shoot size (height and width), shoot and root biomass, and leaf area were determined. If pruned, size was measured before and after pruning and biomass and leaf area of prunings determined. An ANOVA was conducted for each harvest using a RCBD three pruning schedules, two blocks, and four replications per treatment-block.

Mechanical pruning at 6 weeks was too severe resulting in either stunted plants or plant death (27%); data not shown. Stunted plants that survived eventually grew back but quality was poor and this treatment was not included in subsequent destructive harvests. At the time of pruning, the 6-week pruning reduced plant height 40% [22 to 13 cm (9 to 5 inch)], leaf area 60% (437 to 176 cm^2), and shoot biomass 48% (5.5 to 2.9 g/plant). Relatively large variations in plant height at this early stage of growth provided little margin of error for a horizontal prune designed to prune the terminal nodes on main branches. As such, the result of this early pruning was that some plants were severely pruned while others were essentially unaffected.

Pruning at 9 weeks was more effective than the 6-week pruning. At the time of pruning, the 9-week pruning reduced plant height 24% [29 to 22 cm (12 to 9 inch)], leaf area 38% (724 to 451 cm^2), and shoot biomass 30% (9.3 to 6.5 g/plant) (Figs. 1-3). Greater reduction in leaf area compared to shoot biomass from pruning was due to the fact that leaf area is denser at the top of the canopy and woody stem growth is denser at the bottom of the canopy. By week 21 plants pruned at week 9 were 9 cm shorter than un-pruned plants; final plant width was unaffected by pruning. However, by week 21 the 9-week pruning reduced leaf area 26% (3333 vs. 4534 cm^2), shoot biomass 26% (45.5 vs. 61.8 g/plant) and root biomass 34% (12.1 vs. 18.3 g/plant). When you account for the biomass and leaf area of prunings, pruning at 9 weeks reduced collective leaf area 20% (3606 vs. 4534 cm^2) and shoot biomass 22% (48.3 vs. 61.8 g/plant). Root biomass was reduced 34% (12.1 vs. 18.3 g/plant) when measured at 21 weeks (Fig. 2).

Pruning of main stems 2 months after planting improved plant shape but set back subsequent growth of plants. While we mechanically pruned at a fixed height in this experiment, manual pruning would allow greater precision in cutting off terminal nodes and may reduce the impact that mechanical pruning had on shoot and root growth in this experiment. We are currently comparing mechanical and manual pruning in a similar experiment with trade #3 sweet viburnum. Until additional pruning experiments are conducted, relationships between pruning height and reductions in leaf area and shoot biomass observed in this experiment provide some useful, albeit preliminary, information for estimating pruning effects in our plant growth model.

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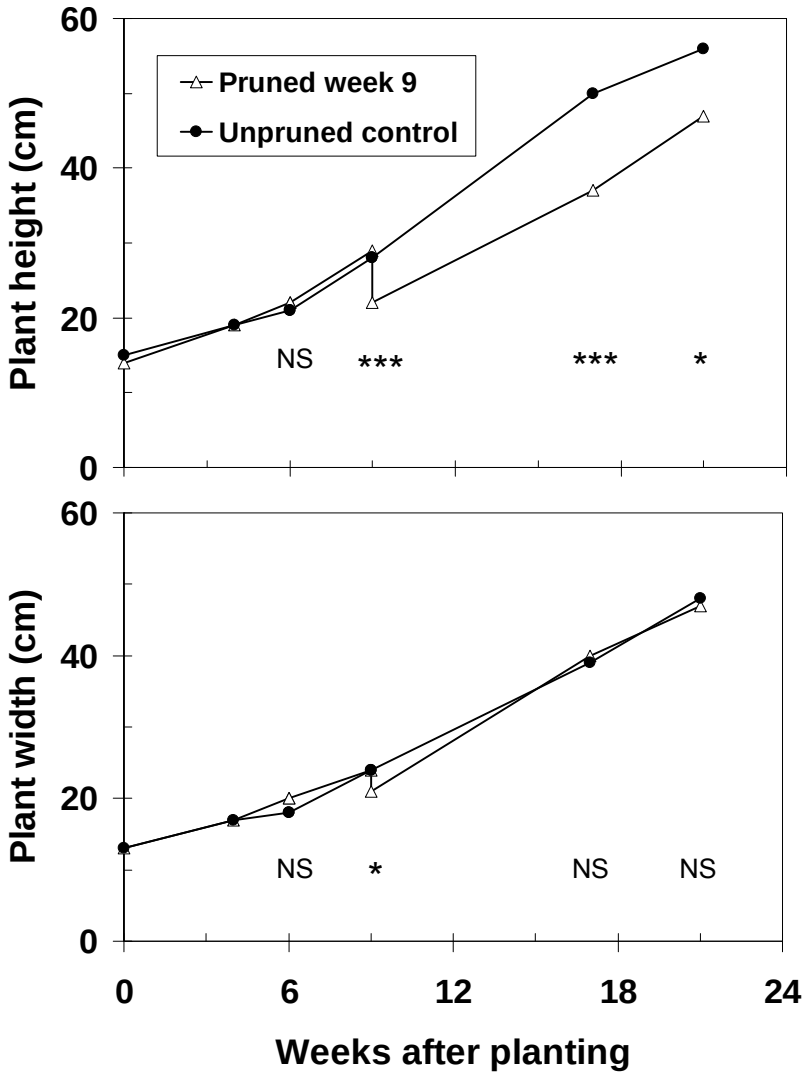

Fig. 1. Effect of shoot pruning at week 9 on height and width of sweet viburnum in trade #1 containers. Divide cm by 2.54 to calculate equivalent value in inches.

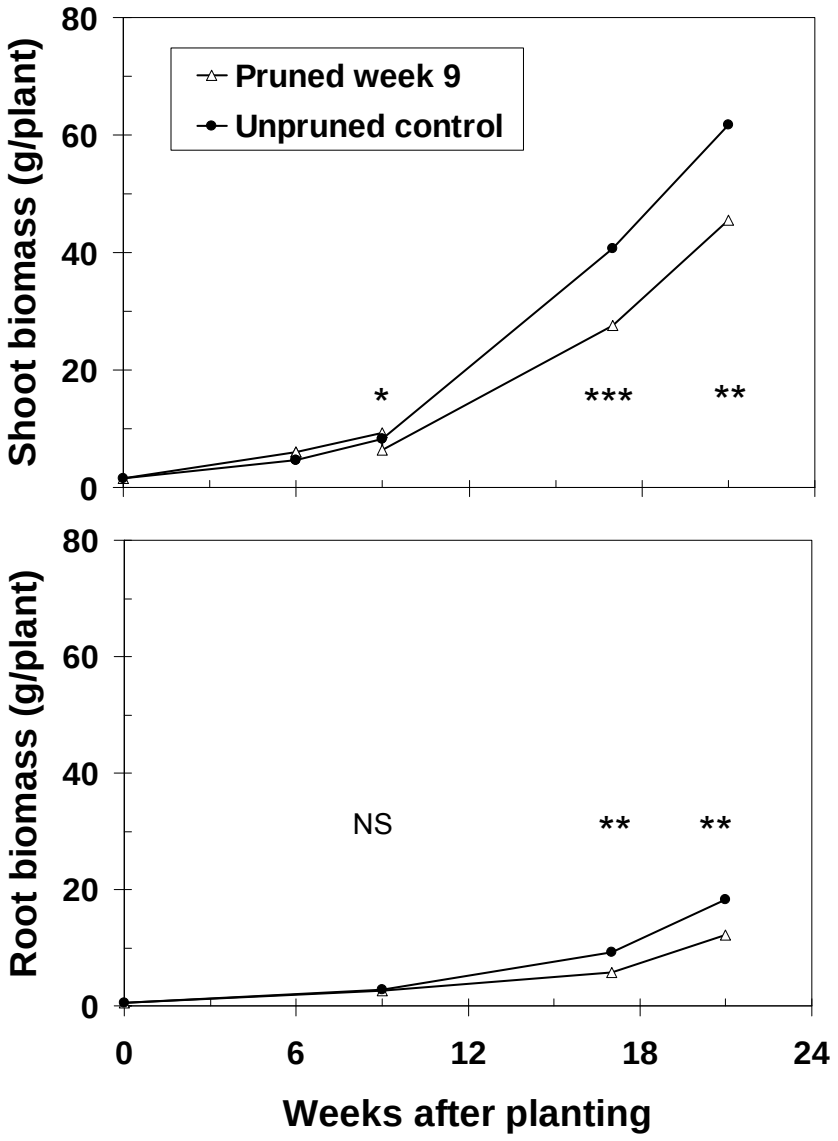

Fig. 2. Effect of shoot pruning at 9 weeks on shoot and root biomass (dry weight basis) of sweet viburnum in trade #1 containers.

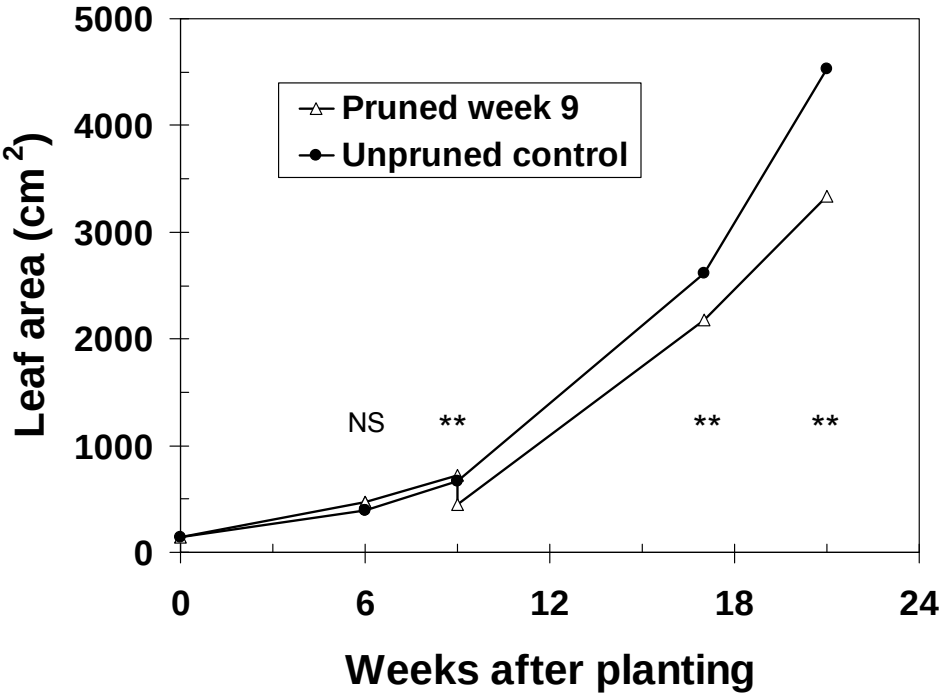

Fig. 3. Effect of shoot pruning at 9 weeks on leaf area growth of sweet viburnum in trade #1 containers.

Modeling Water and Nutrient Runoff from Nursery and Greenhouse Operations in Maryland

John Majsztrik[1*], John D. Lea-Cox[2], Andrew G. Ristvey[3] and David S. Ross[4]

[1] University of Maryland, Department of Plant Science and Landscape Architecture, 2120 Plant Sciences Building, MD. 20742
[2] University of Maryland, Department of Plant Science and Landscape Architecture, 2120 Plant Sciences Building, MD. 20742
[3] University of Maryland, Wye Research and Education Centre, 124 Wye Narrows Drive, Queenstown, MD. 21658
[4] University of Maryland, Department of Environmental Science and Technology, 1431AgEngineering Building, MD. 20742

jcmajsz@umd.edu

Index words: Nitrogen, phosphorus, greenhouse, container, field, decision tools

Significance to Industry: Many researchers have looked at various aspects of plant growth, nutrient requirements, and operational efficiency of nursery and greenhouse operations over the years, but few studies have looked at the water and nutrient efficiency of production systems. Few studies have brought together this information in a way that can inform management decisions, increase profits, and reduce the impact of these decisions on the environment. We are developing production system decision tools to help both growers and researchers identify ways to change practices, which will help achieve these outcomes.

Nature of Work: The Chesapeake Bay watershed has been negatively impacted by human activity, and is currently the target of a long-term multi-state cleanup effort. In 2007, the bay's health was rated at 28/100, with a score of 40 required to remove the bay from the impaired waters list by 2010, and avoid additional regulations (1). Nutrient pollution is considered the largest threat to the bay with nonpoint sources contributing approximately two-thirds of the nitrogen (N) and one-quarter of the phosphorus (P) (2). Much of the research on nutrient addition to the bay has focused on N and P inputs from point sources and agronomic crops, with minimal research on N and P inputs from the nursery and greenhouse industry (3,4).

Nursery and greenhouse production areas can range from extensive, field operations with low N and P input rates to highly intensive container-nursery and greenhouse operations, which can contribute varying quantities of N and P to the surrounding environment, if appropriate management and water-control structures are not in place. All wholesale greenhouse, field and container-nursery operations in Maryland are required to develop and implement an N and P-based nutrient management plan which incorporates nutrient, irrigation, and surface water runoff risk assessment components (5) For this project, three system models have been developed based on an extensive review of the nursery and greenhouse literature over the past 50 years. The goals of

this research project are to gain a deeper understanding of grower practices in Maryland, and develop decision tools that can aid this industry in reducing nitrogen and phosphorus runoff into the Chesapeake Bay.

Materials and Methods

Data collection: For this project, approximately 50 water and nutrient management plans (6) from cooperating growers are being used as real-world inputs. Data from participating operations will be entered into a database. Summary statistics will be derived from the database as model inputs (see model development below), and provide information on how nursery and greenhouse operations are collectively managing the plants they grow. One of the benefits of collecting this information is that we will be able to determine ranges of key variables, such as nutrient or water application rates, to get a better understanding of the efficiency of these practices and identify those points in the process which are key to production efficiency. We will also be able to identify gaps in our current knowledge.

***Model Development*:** The program Stella (7) is being used to develop three separate models (greenhouse, container, and field) but only the container model will be discussed in this paper. Each model takes all variables into account that affect plant growth, water, and nutrient runoff, as well as the unique operational factors associated with each production system (Figure 1). All factors in the model are either entered by the user, or based on values from published literature. Models can be run for a normal production cycle (e.g. outputs in Figs. 2 and 3 are for a 20 week growing cycle) or for extended periods of time, for forecasting purposes.

After each model has been fully developed, it will be calibrated by entering the inputs from appropriate published datasets and adjusting model variables to approximate those of the published dataset outputs (e.g. (8)). After calibration, additional research datasets will be used to further verify the model components, to increase the confidence of the model assumptions. After this verification process is complete, models will be used for operational data. Summary statistics (high, low, and mean) will be used as model inputs to determine the impact of each variable on model outcomes. For example, by looking at the range of fertilizer amounts in 1 gallon containers, the minimum, maximum, and average values can be input into the model, keeping other values the same, to look at the effect of different fertilizer rates on nutrient leaching and denitrification rates.

Results and Discussion

There are a variety of N and P rates in published literature, recommended by fertilizer companies, and applied by the grower. Ristvey et al. (8) noted that recommended N rate for 2-gallon-(7.6-L) container-grown azaleas (1963 lb/ac, 2200 kg/ha) is ten times higher than that for corn, but they found that 393 lb N/ac (440 kg N/ha) and 20 lb P/ac (22 kg P/ha) showed no significant growth differences compared to 981 lb N/ac (1100 kg N/ha) and 98 lb P/ac (110 kg P/ha). If we use the recommended rate of 1963 lb N/ac (2200 kg N/ha) for azaleas listed above, that equates to .70 oz (20g) of N /plant/year for 2 gallon (7.6 L) jammed pots at 44,500/ac (110,000/ha). Over a 40 week growing cycle,

this would equal 0.0176 oz/plant/week (500 mg/plant/week). Over a 10-week cycle, Ristvey et al. (8) found that azaleas took up approximately 0.01235 oz (350 mg). If we multiply this by 4 for 40 weeks of growth, and tripled it for plants that have higher nutrient requirements, this would equal 0.212 oz (6000 mg) of N uptake by the plant for the year. In this scenario, .5 oz (14 g) of N is unaccounted for. If we scale this up to an acre of 2 gal. jammed pots, there are 22,250 lb N/ac/yr (1540 kg N/ha/yr) which is not being used by the plant. This N is either immobilized by the substrate, denitrified by microorganisms or leaches from the container, depending on the conditions.

Numerous articles have shown that increasing fertilizer rates increases plant growth up to a point, but nutrient uptake efficiency typically decreases with increasing rates (9,10). It is important for growers to balance nutrient application rate, plant growth, irrigation, and uptake efficiency to get the fastest growth with the least amount of inputs and losses. The models being developed will help predict where applied N and P is allocated over the growing season, and help the grower gain insights into ways to reduce water and nutrient losses. The database being developed will allow us to quantify current practices in Maryland, and identify ways to economically reduce nutrient and water runoff without negatively affecting plant growth.

Conclusions and Future Developments

We are developing specific models for nursery and greenhouse production systems as tools to target water and nutrient efficiency. These models will be useful for growers, researchers, and extension agents to provide a better understanding of system water and nutrient efficiency, using a range of realistic resource inputs. This research will also provide a better understanding of the nutrient dynamics for specific scenarios, so we can better understand potential nutrient loss mechanisms by combining existing data resources with model prediction capabilities. With a greater understanding of the problem, we can be more effective at educating growers and implementing better nutrient reduction practices. This should lead to greater efficiencies, lower costs, and enhanced profitability for growers, which are usually the most important incentives for changing practices. These models also have the potential of being used in other states and countries to increase resource use efficiency in similar production systems.

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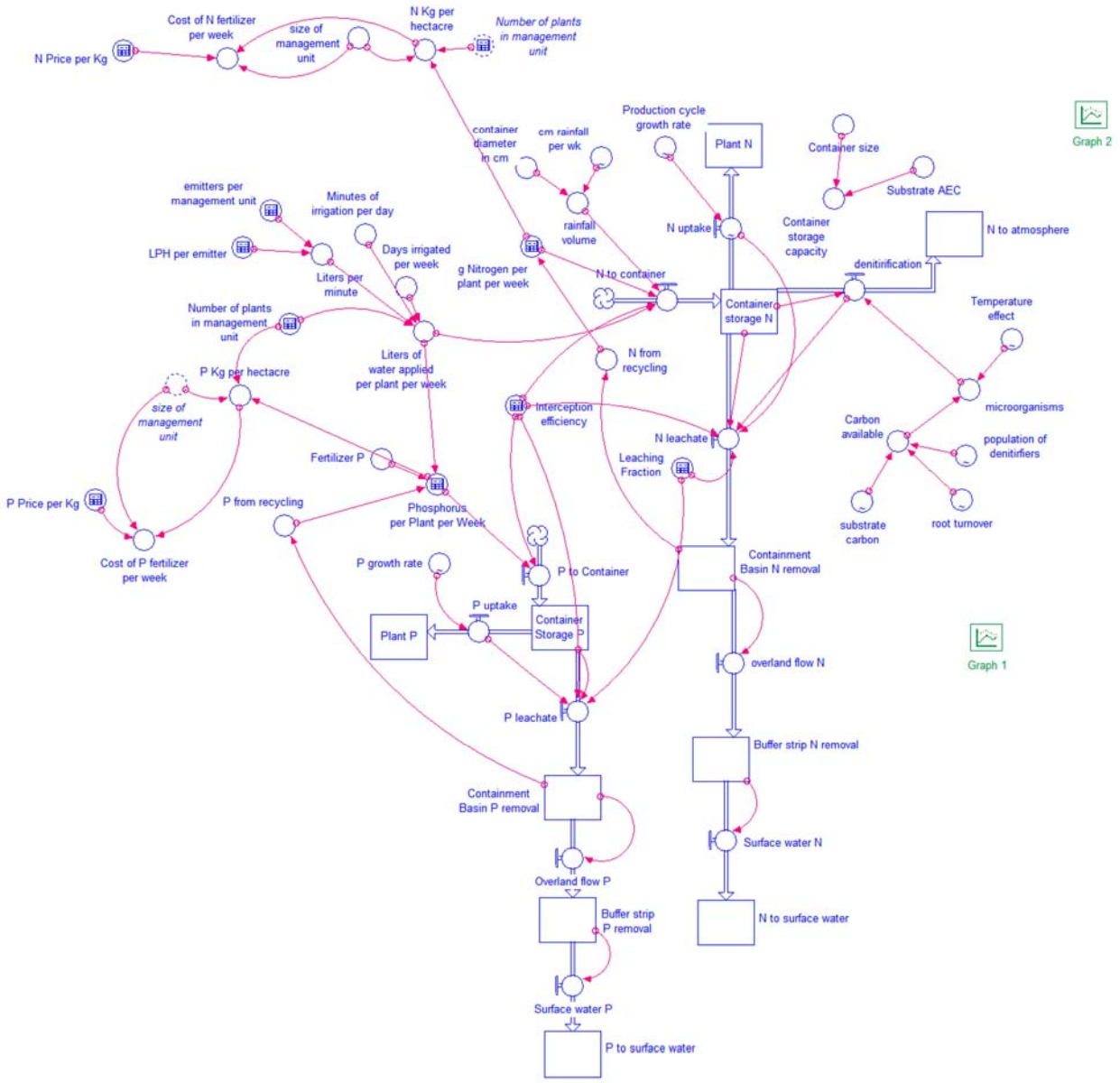

Figure 1. Graphical representation of the preliminary container-nursery model. When completed, each model will have a web-based interface where users can input variables such as container size, plant density (number per ft2), fertilizer type (soluble vs. slow-release), application rate and cost per unit, irrigation volume, leaching fraction and interception efficiency, etc. After the various inputs are entered (from pull-down menus), the user will be able to run the model to determine the allocation of applied nitrogen and phosphorus over the production cycle, based on that particular set of variables. In this way, the model will become a learning tool, to determine the impact of changes on the model outputs.

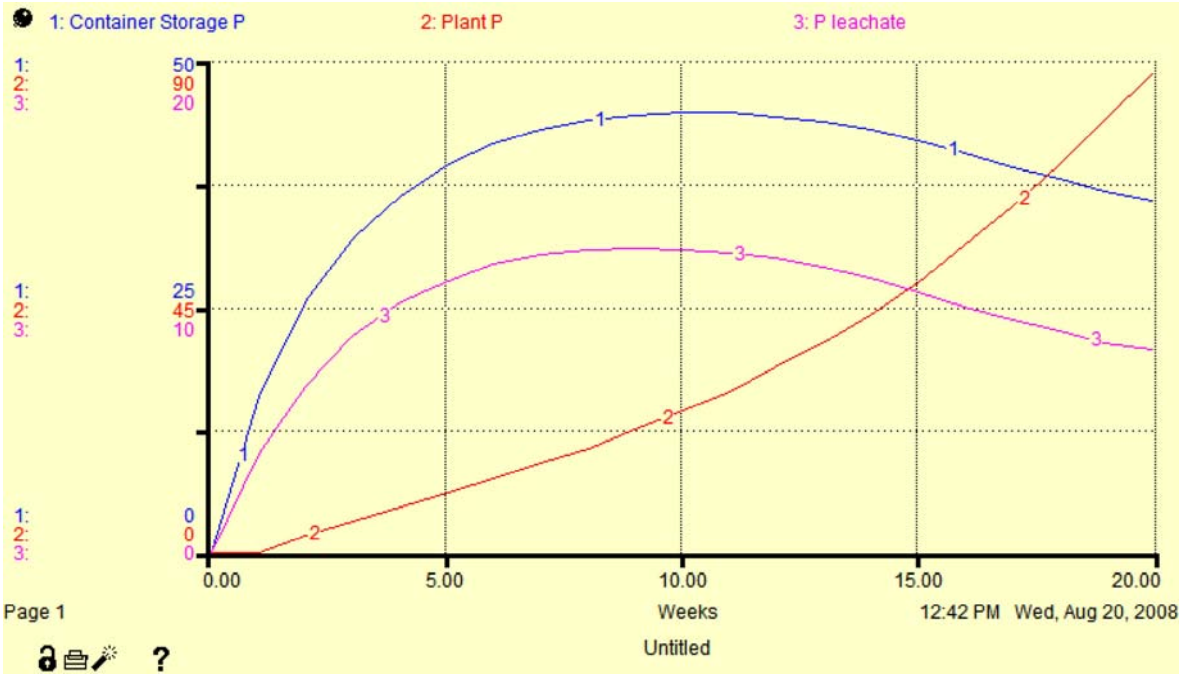

Figure 2: Hypothetical Stella container model output of phosporus over a 20-week growing cycle. Line 1 represents mg P stored in the container media during each week, line 2 is the mg of P stored in the plant per week, and line 3 is the P leached out per week. (Note different values on Y axis). Note that models are still being developed; graphical outputs are given only for visualization.

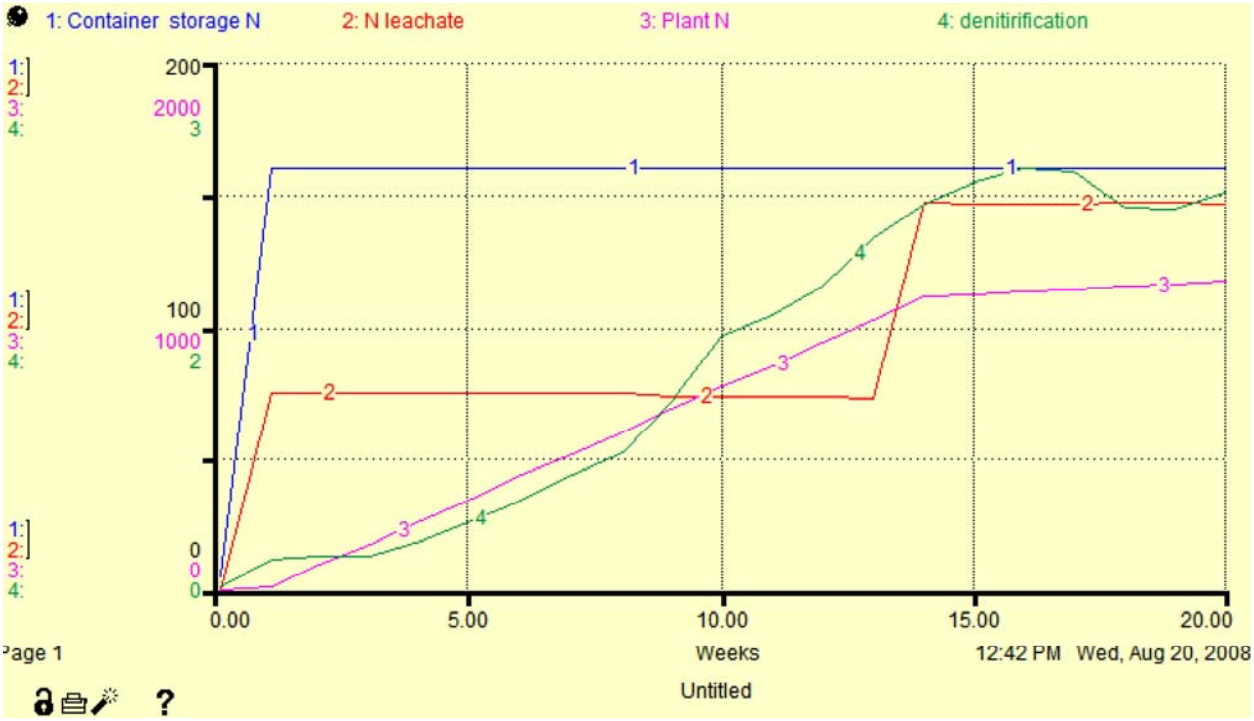

Figure 3: Hypothetical Stella container model output of nitrogen over a 20-week growing cycle. Line 1 represents mg N stored in the container media during each week, line 2 is the mg of N leached out each week, line 3 is the N taken up by the plant, and line 4 is N removed from the container by denitrification. (Note different values on Y axis). Note that models are still being developed; graphical outputs are given only for visualization.

Availability of Clean Chip Residual as a Growth Substrate in the Southeast United States

*C.R. Boyer[1, 2], T.V. Gallagher[3], C.H. Gilliam[2], G.B. Fain[2], H.A. Torbert[4], and J.L. Sibley[2]

[1]Kansas State University, Department of Horticulture, Forestry and Recreation Resources, Manhattan, KS 66506
[2]Auburn University, Department of Horticulture, Auburn, AL 36849
[3]Auburn University, School of Forestry & Wildlife Sciences, Auburn, AL 36849
[4]USDA-ARS National Soil Dynamics Laboratory, Auburn, AL 36832

crboyer@ksu.edu

Index Words: pine bark, CCR, container-grown plant production, alternative media, wood fiber, forestry, nursery

Significance to Industry: Residual chipping material (also called clean chip residual or CCR) has potential use as a growth substrate in the nursery industry. The objective of this study was to quantify the amount and type of CCR material available in the Southeast United States for possible horticultural use by surveying working chipping operations on pine plantations. Fourteen operators in four states were contacted to evaluate on site status of residual material including composition (wood, needles, bark), equipment use, and destination of the material. Results indicate that more than 40% of CCR is left in the plantation and that many chipping operations are willing to supply it to the nursery industry.

Nature of Work: Clean chip residual is a by-product of harvesting small-caliper trees on a plantation for use as pulp for the paper industry. Material not used as pulp (needles, bark, wood) is either left on the plantation or sold to a pulp mill as boiler fuel. If not sold, disposal of residual is an additional cost charged to the pulp (1). Recent work has evaluated this material for use as a substitute for traditional potting materials (generally pine bark) and demonstrated viability of CCR for use in some annual, perennial and woody crops. Boyer et al. (2) demonstrated that *Ageratum* and *Salvia* grown in CCR or combinations of CCR and peat produced similarly sized plants when compared to a traditional pine bark substrate. Later, Boyer et al. (3) evaluated eight perennial species in CCR and reported similar results among all treatments. Several woody crops were also evaluated for growth in CCR over the course of one year (4). Results for woody species were similar to growth responses of annual and perennial crops. Since the use of CCR as a nursery and greenhouse substrate is currently being evaluated for plant growth response, it is sensible to characterize the availability and properties of CCR.

Fourteen chipping operations were surveyed in person or by phone in the summer of 2007, though it is believed that there may be up to 30 such roving operations in the Southeast United States. Samples, if available and usable (processed twice in the field) were obtained by filling two 5-gallon buckets with fresh material, weighing, and

evaluating the age and height of the stand. Samples were further evaluated by sending subsamples to Brookside Laboratories, Inc. (New Knoxville, OH) for soil-less media nutrient analysis. Substrate N was determined by combustion analysis using a 1500 N analyzer (Carlo Erba, Milan, Italy) (data not presented). Remaining nutrients were determined by microwave digestion with inductively coupled plasma-emission spectrometry (ICP) (Thermo Jarrel Ash, Offenbach, Germany) (data not presented). Three subsamples from each location were dried in a 105 °C forced air oven for 48 h before being separated into components (bark, wood, needles and indistinguishable) by weight. Indistinguishable material consisted of particles too fine to determine whether they were bark, wood or needles. 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: Sites, operations and material varied greatly in this survey (Table 1). One was a woodyard operation (logs only; Cottondale, FL), another consisted of hurricane-damaged trimmings (Hattiesburg, MS), and one was operating on land where wildfire had destroyed plantations (Waycross, GA). Some locations did not have samples consistent with previously evaluated CCR (or were unsuitable material) and thus were interviewed, but data from these locations is not included in the composition analysis. Unsuitable material was of unknown origin and/or composed of mixed hardwood and softwood. Most locations were 'traditional' chipping operations and many loggers were willing to expand their market to the horticultural industries. Residual material varied depending on the plantation age, species composition, site quality, and natural actions such as fire or flood (5). Average substrate pH for all the samples ranged from 4.3 to 5.5 (data not shown). Electrical conductivity (salts) was low in all samples (0.16-0.41 mmhos/cm; data not shown). Iron was high at three locations while Mn was high at 4 locations (data not shown). Other locations maintained levels of micronutrients within suggested ranges for media and plants (as stated by Brookside Laboratories, Inc., New Knoxville, OH). Composition of wood, bark and needles varied according to the age and management of the plantation. Values for percent wood ranged from 14.2% (Waycross, GA) to 50.5% (Evergreen, AL), though none of the location samples were significantly different. For bark the highest percentage was 68.5% (at Waycross, GA) and the lowest 16.1% (Evergreen, AL). The greatest percentage of needles (19.2%) was found at Jasper, GA (a young plantation, 8-9 years) and the least (0.10%) at Cottondale, FL (woodyard operation). Overall, the composition of CCR evaluated in this study was 37.7% wood, 36.6% bark, 8.8% needles, and 16.9% indistinguishable (Table 1). Of the operations interviewed, an estimated 27.5% of the total site biomass is composed of CCR and 44.3% is left in the field (Table 1).

Several challenges to implementing CCR as a substitute for pine bark exist. The primary challenge is communication: the forestry industry is generally unaware of the potential use of their material in horticultural industries. Another challenge is delivery: will individual operators deliver to nurseries or will pine bark suppliers elect to carry CCR along with pine bark? Extra costs may be incurred for live-bottom trailers or processing through a hammer mill. Currently, CCR represents a more sustainable future for horticultural substrates as pine bark becomes less available and more expensive for growers. This study demonstrates that there are adequate amounts of CCR to supply

the needs of horticultural industries, and, while more study is needed to determine suitability of material from every chipping operation, CCR obtained from 'traditional' pine plantation thinning operations should perform well for production of many species.

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Table 1. Distribution of components and site biomass of CCR at several chipping sites.

Location of operation	Wood (%)	Bark (%)	Needle (%)	Indistinguishable (%)	Site biomass composed of CCR (%)[z]	CCR left in field (%)[z]
Cuthbert, GA	44.7 a[y]	35.7 bcd	12.1 b	7.5 a	25	0
Dothan, GA	--[x]	--	--	--	--	0
Cottondale, FL	38.9 a	48.8 abc	0.10 e	12.2 a	15	0
Waycross, GA	14.2 a	68.5 a	8.7 bcd	8.7 a	--	100
Greenville, GA	31.4 a	59.7 ab	0.96 e	8.0 a	20	100
Barnett Crossroads, AL	35.7 a	28.0 cd	5.3 cde	31.0 a	35	20
Lucedale, MS	49.2 a	22.9 cd	12.0 b	15.9 a	25	0
Hattiesburg, MS	--	--	--	--	35	0
Atmore, AL	50.4 a	18.8 d	14.2 ab	16.6 a	25	0
Clanton, AL	--	--	--	--	--	100
Jasper, GA	35.4 a	31.3 cd	19.2 a	14.1 a	50	100
Summerville, GA	--	--	--	--	20	100
Adairsville, GA	26.5 a	36.2 bcd	10.6 bc	26.7 a	--	100
Evergreen, AL	50.5 a	16.1 d	4.7 de	28.7 a	25	0
Total	*37.7*	*36.6*	*8.8*	*16.9*	*27.5*	*44.3*

[z]Estimate reported by loggers conducting chipping operation at each site.
[y]Means within column followed by the same letter are not significantly different based on Waller-Duncan k ratio t tests (α=0.05, n=3).
[x]No sample obtained, interview only.

A Nursery Friendly Method for Measuring Air Filled Porosity of Container Substrates

Ted Bilderback

NC State University, Dept. of Horticultural Science, Raleigh, NC 27695-7609

Index Words: Air Space, potting media, physical properties, container production

Significance to Industry: "Home Remedies" for measurement of air and water holding capacities of nursery potting substrates rarely provide consistent results, therefore, such measurements are infrequently attempted. The description for construction of a "home built" porometer apparatus to measure air-filled porosity (AFP) is described. If important steps for pre-moistening samples and for packing to match the weight of each replicate sample in porometers are followed, consistent results for air filled porosity can be accomplished.

Nature of Work: Growing plants in containers requires a growing substrate that provides acceptable aeration and moisture retention characteristics. Unfortunately, actual measurement of air and water holding capacities of nursery potting substrates are rarely attempted. Failure to measure physical properties of substrates is due to lack of appropriate equipment, adequate guidelines for procedures, and inconsistent results. Furthermore, few professional soil and plant analytical laboratories offer physical properties analyses of container substrates for the same reasons. Air-filled porosity is a very important physical characteristic of container substrates. Knowing the air-filled porosity of a potting mix provides knowledge useful for choosing containers suitable for a particular substrate, appropriate irrigation application, and nutrient management practices. The objective of this work was to present a “home remedy” procedure for measuring air-filled porosity of container substrates that can achieve “reasonably” consistent results.

Porometer construction: Measuring air-filled porosity requires an apparatus called a porometer. Therefore, the first step is to construct porometers. One-liter plastic drink containers or milk jugs can be used for this purpose. Tops of these containers can be removed to create a closed container of any height, however if cut to the same height as a # 1 nursery (2.6 L) container, the air-filled porosity measured will simulate air-filled porosity values for 2.6 L containers. At least three plastic carton porometers for each substrate to be simultaneously tested should be cut as closely as possible to the same height so they will hold the same volume of water. The volume of each container must be determined by measuring how much water is required to exactly fill each milk container before it overflows. Number each plastic carton porometer and record the number of milliliters required to fill each container. These numbers can be recorded on a data sheet and can also be written on each porometer using a permanent marker (recorded in Table 1 as total volume). For example, plastic carton porometers numbered 1, 2, and 3 have volumes of 719 ml, 720 ml, and 700 ml carton volume, respectively. The individual total volume for each porometer is used to determine the percent air-filled

porosity of the potting mix sample packed in each porometer. After determining the volume of each porometer, drill 3 or 4 small holes approximately 5 mm in diameter in the bottom of each container to allow drainage of water after saturation.

*Pre-moistening Substrate to Be Tested***.** Pre-moistening 12–24 h before testing is critical for achieving uniform and consistent results. Pre-moistening allows organic components to wet uniformly throughout their matrix. The potting substrate to be tested should be moistened to a consistency where if squeezed by hand, a drop or a few drops of water might be squeezed out between fingers. After premoistening, the potting medium should be left in a plastic bag overnight before testing. If organic potting components are used immediately after moistening, samples frequently do not become thoroughly moistened causing erroneous readings and inconsistency between replicated samples. It is critical for the substrate to have a structure that does not change during saturation. Pre-moistening reduces shrinking or swelling characteristics and therefore may eliminate repeating packing and saturation steps (1).

Packing Porometers with Substrate: After removing the plastic carton tops, individually weigh each porometer and record the weight. The weight of the plastic carton is subtracted from filled cartons as a “tare” weight to provide an accurate mass of substrate in each porometer. Next, overfill each porometer with potting substrate; tap each porometer firmly 3–5 times on a table or bench to eliminate air pockets and establish a bulk density. Carefully scrape excess potting substrate from the surface of the porometer, maintaining an even surface at the exact level of the top of the porometer. Weigh each filled porometer and subtract the weight of the plastic carton. The weight of the substrate in each porometer should be equal to achieve consistently similar air-filled porosity values. If considerable variability in weight is measured, re-pack porometers until the values are similar. [This step assumes that the total volumes of porometers are equal.]

Saturate Substrate in Porometers: After packing, porometers are set upright in a vessel large enough for all of the test porometers to stand erect and tall enough to add water to the top of the porometers. A household plastic paint bucket may be useful for this purpose. After placing porometers in the vessel, slowly add water until the level of the water outside of the porometers reaches just to the top of each porometer without overflowing onto the surface of the substrate. Precaution must be made to keep the porometers upright and to prevent substrate from floating out of the top of the porometers. Some innovations maybe required, however a weight placed on the top of the porometer that does not compress the substrate will stabilize the porometers and keep the potting medium inside the porometer. Saturate test samples for approximately 1 h or until free water glistens between substrate particles at the top of the porometer. Additional water may be needed as it is adsorbed by the substrates components being saturated. If the substrate in the porometers shrinks or swells more than 3 mm from the top of the porometer during saturation, the air filled porosity values are not valid. Multiple saturation and drainage cycles may be required to stabilize the substrate bulk density; however re-filling and packing porometers to identical weights will then be required.

Collecting and Measuring Drainage: Saturation of each porometer can be observed when water is seen at the surface of the substrate. Drainage from each porometer must be measured individually. This step may require practice. Fingers are used to prevent leaking from the drainage holes while the porometer is lifted from the saturation vessel and a pan is quickly placed under the drain holes. Porometers can be balanced on supports placed in the bottom of the drainage pan and allowed to fully drain. After draining has stopped, the drained volume is measured and recorded for each porometer (Table 1).

Calculating air filled porosity: The drainage volume is divided by the total volume for each porometer to determine a percent air-filled porosity (Table 1). Air-filled porosity measurements are added and divided by the number of porometers to obtain an average AFP for each test substrate. Changes in air filled porosity during a growing season or over a production cycle can be measured by placing porometers packed with substrate in containers which are set in nursery growing beds. Decomposition shrinkage should be measured and marked from the top of the porometer. The volume of the porometer marked at the surface of the substrate would be used as the new total volume and calculations followed as described above. If the important steps for pre-moistening samples and for packing to match the weight of each replicate sample in porometers are followed, consistent results can be accomplished.

Acknowledgements: The description for construction of a home constructed porometer apparatus described here was adapted from porometers observed during a visit with Chris Hughes, at BlueMountain Nursery, Tapanui, South Island, New Zealand.

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Table 1. Plastic carton porometer (PCP) data recorded for a container substrate[z]

Porometer	Pack weight[y] (g)	Carton volume (ml)	Drained volume (ml)	AFP %
PCP1	511.5	719	223	29.2
PCP2	505.0	720	232	32.2
PCP3	503.0	700	225	32.1

[z] N.Z. Peat Southland Tree and Shrub Mix is 35% peat moss (0–20 mm); 35% composted pine bark (0–13mm); and 30% medium pumice.
[y] Variation in AFP could be decreased by adjusting carton volume, and insuring consistency in pre-moistening substrates to create equal pack weight of PCP1 to PCP2 and PCP3.
[x] Air-Filled Porosity (AFP) calculated by dividing Drained volume by Total volume recorded. NCSU Porometer data mean of 3 replications was 29.5% AFP.

Real-Time Measurement of Electrical Conductivity in Soilless Substrates

Félix R. Arguedas[1], John D. Lea-Cox[1] and Andrew G. Ristvey[2]

[1]Department of Plant Sciences and Landscape Architecture, University of Maryland, College Park, MD 20740
[2]Maryland Cooperative Extension, Wye Research and Education Center, Queenstown MD 21658

fargueda@umd.edu

Index Words: bulk EC, pore water EC, Ech$_2$0-TE, Ech$_2$0-5TE, sphagnum peat

Significance to the Industry: The real-time measurement of electrical conductivity (EC) will enable growers to more effectively monitor the availability of nutrients in the root zone of plants. Up until now, EC sensors have not had the precision required for accurate monitoring of salt concentrations in soilless substrates. This capability will have profound consequences on precision nutrient management for nursery crop production, providing growers with an indication of when fertilizer salts are either unavailable (too few nutrients) or to avoid the unintended buildup of salinity in the root zone, compromising plant growth.

Nature of Work:

Background: Many sensors are now available that are apparently capable of reading instantaneous EC in soilless substrates, but the measurement of EC is not trivial. Most sensors measure bulk EC (EC_a), which is the total electrical conductivity associated with the surface soil / substrate ionic charge *plus* the ions in solution. Bulk EC measurements therefore overestimate the available ions *in solution*, measured as pore water electrical conductivity (σ_p). Obviously, the amount of water contained in the substrate at any one time has a profound effect on the concentration of salts in solution, and *vice versa* [4]; however, temperature also has an effect on ionic concentration, requiring that sensors have a temperature compensation ability for precise measurement [7]. It is therefore evident that a sensor needs the capability to simultaneously measure three variables – water content, temperature and EC_a – to provide precise measurement of pore water EC. However, to provide an accurate estimate of σ_p, we need to go a step further and provide an offset value, as described by [6, 3]. There is still an ongoing debate as to how best to estimate σ_p, but we chose to use the equation as [3] (see below) to estimate σ_p, since volumetric water content, temperature and bulk conductivity are read simultaneously by the Ech$_2$0-TE and Ech$_2$0-5TE sensors.

Materials and Methods: We used a modified methodology after [1], where the bulk density of the Sunshine LC1 (Sun Gro® Horticulture Distributions Inc., Bellevue, WA) substrate in each column was normalized at 0.12 g cm^{-3} [2]. This was to reduce the variation due to different air-filled porosities, and allowed for a direct comparison to commercial production situations. The substrate for each column (n=5 for each sensor)

was weighed and placed in individual 1 L beakers. Residual salt concentrations in each sample were leached by adding 600 mL of deionized water, vigorously stirring and pouring off the supernatant. Potassium chloride (KCl) was used to make up the salt solutions, similar to [6] and measured with a Traceable® Bench (Conductivity Control Company, Friendswood, TX) (Model 4163) EC meter. The LC1 substrate was then allowed to equilibrate with the desired electrical conductivity solution at 0.22, 2.0, 4.0, and 8.0 dS m^{-1} allowing the solution to stabilize for one day between flushes. New substrate was used for each salt concentration after the substrate moisture determinations were completed with the modified tension table, at incremental pressures of 1, 2, 4, 6, 8, 10, 15, 20, 40 and 60 kPa [1]. Every run made with the tension table had five repetitions of each sensor (Ech_20-TE and Ech_20-5TE) randomly assigned to different columns for each run. The expressed pore water EC from each column was collected at the end of every increment pressure gradient; the expressed leachate volume was recorded and the conductivity (EC_w) was measured.

Results and Discussion

A data-stream of three numbers was retrieved from the datalogger for each sensor, at 1-minute intervals. The first number was the raw dielectric output for the Ech_20-5TE sensor, or raw counts for the Ech_20-TE. The equations used to transform this raw data to bulk dielectric permittivity (ε_b) differ for each sensor. For the 5TE sensor, εb is calculated by dividing the raw dielectric output by 50. For the TE sensor, we have to apply an equation to the raw counts provided by the manufacturer, i.e.,

$$\varepsilon_b = 7.64*10^{-8} * Raw^3 - 8.85*10^{-5} * Raw^2 + 4.85*10^{-2} *Raw-10 \quad [1]$$

The raw electrical conductivity data (second number) and raw temperature data (third number) were similar for each type of sensor, and the conversion procedures for EC_a and ε_p from the raw data are equivalent for both sensors. The raw electrical conductivity data is divided by 100 to obtain σ_b in dS m^{-1}. A temperature correction is applied to the raw temperature data to obtain the dielectric permittivity of the pore water (ε_p), i.e.,

$$\varepsilon p = 80.3 – [0.37 * (Tsoil – 20)] \quad [2]$$

Finally, we used the equation described by [3] to determine the pore water electrical conductivity (σ_p), i.e.,

$$\sigma_p = \frac{\varepsilon'_p * EC_a}{\varepsilon'_b - \varepsilon'_{\sigma b=0}} \quad [3]$$

As stated in [3] clearly there is a necessity for an offset value ($\varepsilon'_{\sigma b=0}$) to estimate pore water electrical conductivity (σ_p), which is likely to be soil or substrate-specific. The exact value of this offset for soilless substrates needs to be determined since all the research published to date has been done with soils. This offset value ($\varepsilon'_{\sigma b=0}$) is calculated by plotting the bulk conductivity (EC_a) vs. the leachate electrical conductivity, EC_w. However, before that can be done, the data have to be normalized at the same volumetric water contents (θ). We chose to use Rhoades et al (1976) methodology to do this, since we deemed it to be the more precise method to estimate $\varepsilon'_{\sigma b=0}$. Values of EC_a / EC_w at the various measured water contents are shown for the Ech_20-5TE (Fig. 1A) and the Ech_20-TE sensors (Fig. 1B). A greater variation in EC_a / EC_w at higher volumetric water contents can be seen, especially with the 5TE sensor (Fig 1B), although the good fitness of the regression lines (r^2) are equal or greater to 0.945

(P>0.0001) for both sensors. Using the regression equations from Figs. 1A and 1B, it is then possible to estimate the EC_a / EC_w at specific combinations of substrate moisture (θ), to normalize the values of EC_a. The new estimated values of EC_a for each given value of θ were determined from the intersections of the vertical lines and regression curves in Figs 1A, B and are shown in Figs 2A and B, respectively for each sensor type. The offset value is the resulting intersection from the regression lines on the y-axis, which are now independent of substrate water content. The average offset values for ($\varepsilon'_{\sigma b=0}$) were -0.0204 for Ech$_2$0-5TE sensor, and -0.0167 for Ech$_2$O-TE sensor with standard error of the mean equal to 0.00464 and 0.00531 respectively. This is far lower than the published offset values of between 1.9 and 7 used for various soils [3]

Substrate moisture contents (θ) are shown at the right of Figs. 2A and B. From these data, it can be seen that as the substrate loses moisture, the precision of the EC sensor decreases. We think that this is primarily related to increasing proportions of air in the substrate, which increases the 'tortuosity' of the soil solution around the substrate particles, which increases the error in measuring pore water EC. This has an important practical implication as noted by [7] in that it is likely that these sensors will not be very accurate below a substrate moisture water content of about 35%. However, we should note that these moisture levels in this substrate equates to a matric potential of -15 to -20kPa (Figs. 1A, B), which is lower than the accepted soil moisture 'set point' of -10kPa for the optimal growth of plants in soilless substrates. It will be necessary to conduct further studies for different soilless substrates to further determine whether these offset values are applicable to other commercial soilless substrates, for the real-time measurement of electrical conductivity [5].

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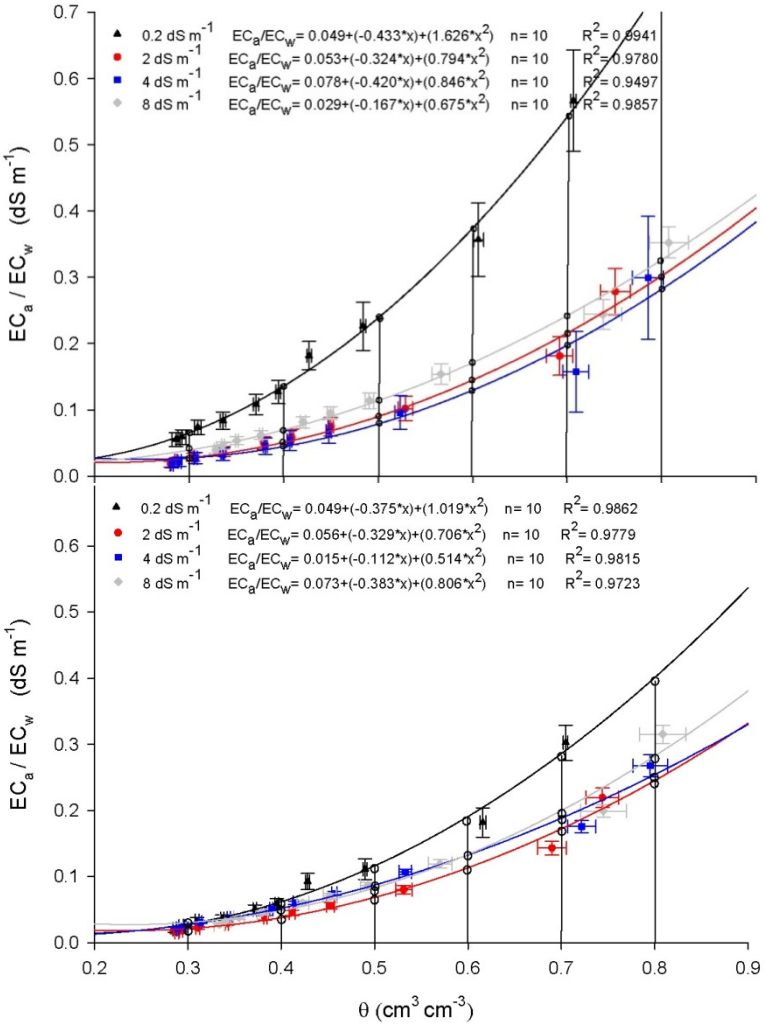

Figure 1. Bulk soilless electrical conductivity divided by leachate electrical conductivity, EC_a / EC_w vs. Volumetric water content for for Sunshine LC-1 sphagnum peat substrate. Data measured using Ech_20-5TE (1A) and Ech_20-TE (1B) sensors. Error bars as standard error about the mean (SEM).

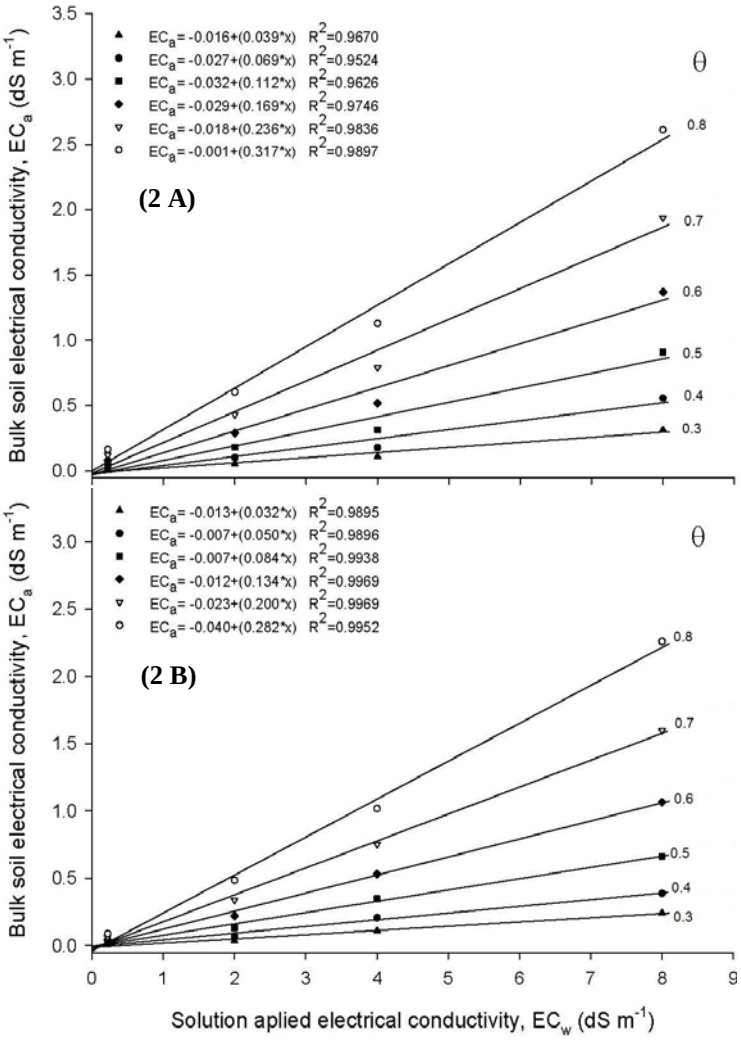

Figure 2. Bulk soilless electrical conductivity, EC_a vs. leachate electrical conductivity, EC_w for various fixed volumetric water content (□), using Ech_20-5TE (2A) and Ech_20-TE (2B) sensors. Data normalized from Fig. 1 for Sunshine LC-1 sphagnum peat substrate.

White Pine as a Pine Tree Substrate

Robert D. Wright, Brian E. Jackson, and Michael C. Barnes

Virginia Tech, Department of Horticulture, Blacksburg, VA 24061

wrightr@vt.edu

Index Words: alternative substrate, container media, nursery production, white pine, *WoodGro*™

Significance to the Industry: This research demonstrates that a pine tree substrate (PTS) produced from eastern white pine (*Pinus strobus* L.) can be a suitable container substrate when amended with peat moss for the production of greenhouse and un-amended for woody nursery crops. The use of PTS manufactured from eastern white pine is thus a possible container substrate throughout the northern part of the U.S where loblolly pine will not grow.

Nature of Work: The use of a pine tree substrate (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, 2, 4, 5, 6,). One advantage of PTS is that substrates can be produced locally where pine trees are grown, however, loblolly pine is typically limited to the southeastern states. We have evaluated a number of tree species for their desirability as container substrates and have found that eastern white pine shows promise as a species for PTS, even though growth of marigold seedlings was less in eastern white pine than in loblolly pine (3). Therefore, the purpose of this work was to evaluate the growth of marigold (*Tagetes erecta* Big. 'Inca Gold'), garden mums (*Chrysanthemum x morifolium* 'Mary') and spiraea (Spiraea *x bumalda '*Anthony Waterer') in PTS produced from eastern white pine tree substrate with or without peat moss. For the marigold and mum experiment PTS was prepared by further grinding coarse white pine chips through a hammer mill fitted with a 3/16-inch screen. The PTS was then amended with either 25 % or 50% peat moss by volume. A control treatments included peatlite [PL; 80% peat moss / 20% perlite (v/v)] amended with calcium sulfate ($CaS0_4$) at 0.6 kg·m^3 (1 lb/yd^3) and dolomitic limestone at 5.3 kg·m^{-3} (9 lbs/yd^3). On 25 July, 2008, mum rooted cuttings (Yoder Brothers, Inc., Barberton, OH) were potted into round (l.25 L) plastic containers with the different substrates. Plants were glasshouse grown in Blacksburg, VA and fertilized at each watering with 300 mg·L^{-1} N from a Peters 20-10-20 (20N-4.4P-16.6K) Peat-Lite Special (The Scotts Co., Marysville, OH). On 3 September, 2008 shoots were severed at the substrate surface, oven dried, and weighed. On 5 August, 2008 marigold seedlings from 144 units plug trays were transplanted into 10-cm square (l L) plastic containers with the different substrates. Plants were glasshouse grown in Blacksburg, VA and fertilized at each watering as above. On 26 August, 2008 shoots were severed at the substrate surface, oven dried, and weighed.

To further explore the potential of eastern white pine as a desirable tree species for PTS spiraea was selected to evaluate the growth of woody plants produced in pine bark, loblolly pine-based PTS, and eastern white pine-based PTS. Pine tree substrates were prepared by further grinding coarse chips of *Pinus taeda* and *Pinus strobus* through a hammer mill fitted with a 1/4-inch screen. The PTS was then amended with calcium sulfate ($CaS0_4$) at 0.6 $kg \cdot m^3$ (1 lb/yd^3). A control treatment of pine bark was included; it was amended with calcium sulfate ($CaS0_4$) at 0.6 $kg \cdot m^3$ (1 lb/yd^3) and dolomitic limestone at 3.5 $kg \cdot m^{-3}$ (6 lbs/yd^3). All substrates were further amended with 7 $kg \cdot m^{-3}$ (12 lbs/yd^3) Osmocote 15-9-12 (15N-3.9K-10P) Northern (The Scotts Co., Marysville, OH). On 29 August, 2008 rooted cuttings from 18 cell liner tray were transplanted into 17.3-cm round (2.8L; 1 gal) plastic containers with the different substrates. Plants were glasshouse grown in Blacksburg, VA and were watered as needed. On 20 November, 2008 the plants were measured to determine growth index value.

Results and Discussion: Shoot dry weight for both marigold and mum increased incrementally with the addition of 25 and 50% peat moss to PTS produced from eastern white pine (Table 1). Plants for both species required the incorporation of at least 50% peatmoss in PTS to equal in size to plant grown in 100% PL. Shoot growth as indicated by a growth index was the same for spirea regardless of the substrate type (Table 2). These results demonstrate the potential of producing greenhouse and woody nursery crops in northern states where eastern white pine is readily accessible. This would offer considerable cost savings compared to producing plants in peat moss and pine bark, since peat moss is considerably more expensive than PTS and the cost of shipping southern pine bark to northern states would be saved.

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Table 1: Mean dry weights (g) of two species grown in peatlite (PL), a pine tree substrates (PTS), or a PTS amended with peat moss.

Species	PL [z]	PTS [y]	PTS w/25% peat	PTS w/50% peat
Tagetes erecta 'Inca Gold'	8.0a[x]	5.5c	7.0b	8.1a
Chrysanthemum ×morifolium 'Mary'	14.5a	6.9c	10.2b	15.7a

[z]PL: [80% peat moss / 20% perlite (v/v)].
[y] PTS: Pine tree substrate produced from 15-year-old *Pinus strobus* trees harvested at ground level, delimbed, chipped, and hammer milled to pass through a 4.76-mm screen.
[x] Mean separated within row by Duncan's multiple range test, $P \leq 0.05$

Table 2: Shoot growth index of Spiraea x bumalda 'Anthony Waterer' when grown in pine bark or pine tree substrates (PTS). [y]

	Substrate		
	Pine bark	Loblolly pine PTS	Eastern white pine PTS
Growth index[z] (cm)	40a	42a	42a

[z]Shoot growth index [(height + widest width + perpendicular width)÷3]
[y]Pine tree substrates produced from 12-year-old *Pinus taeda* and 15-year-old *Pinus strobus* trees harvested at ground level, delimbed, chipped, and hammer milled to pass through a 6.35-mm screen.
[x] Mean separated within row by Duncan's multiple range test, $P \leq 0.05$

Container Production of Native Purpletop (*Tridens flavus* (Lam.) Trin.), a New Ornamental Grass

Gary W. Knox, Jeffrey G. Norcini and James H. Aldrich

University of Florida/Institute of Food and Agricultural Sciences
North Florida Research and Education Center
155 Research Road, Quincy, FL 32351

gwknox@ufl.edu

Index Words: tall redtop, bunchgrass, liner production

Significance to Industry: The increasing popularity of native grasses for landscapes, restoration and mitigation prompted studies of container production protocols for purpletop. Month-old seedlings of a Florida ecotype of purpletop (*Tridens flavus* (Lam.) Trin.) were larger when seeds were sown on 22 May than when seeds were sown 19 June. However, the 19 June seedlings had a greater root to shoot ratio. Seeds sown in May and potted into #1 containers in a pine bark based substrate amended with Osmocote 15-9-12 (15N-4.0P-9.8K, 12-14 month Southern, Scotts Inc., Marysville, OH) at 15.2 lb/yd^3 (9.0 kg/m^3) produced plants with 24 flowering stems per plant when deemed shippable (date of first visible inflorescence) compared to 10 flowering stems per plant for plants grown from seed sown in June. However, the latter sowing date resulted in a plant closer to the desired shipping height of 18 inches and reduced production time by 3 weeks. Sowing date had little influence on the date when plants were shippable.

Nature of Work: Ornamental grasses are increasing in popularity in southern states as evidenced by evaluations in Florida (7, 8, 9), Georgia (6) and South Carolina (1). In the search for new ornamental grasses, native grasses that have been evaluated for landscape use include chalky bluestem (*Andropogon capillipes* Nash or *Andropogon glomeratus* var. *glaucopsis* (Elliot) C. Mohr), Indian woodoats (*Chasmanthium latifolium* (Michx.) Yates), bigtop lovegrass (*Eragrostis hirsuta* (Michx.) Nees), and switchgrass (*Panicum virgatum* L.) (3, 4, 5, 7).

Purpletop, tall redtop or purpletop tridens (*Tridens flavus*) is a native bunchgrass with showy purplish-red inflorescences that has excellent ornamental potential (4, 7). Purpletop occurs throughout much of the eastern U.S. and as far west as Nebraska and Texas (2). It is adapted to well-drained to droughty soils of any fertility level and tolerates road salt. It also seems resistant to deer browsing (4).

Under landscape conditions, even with minimal inputs, purpletop produces dense, daylily-like foliage with inflorescences held entirely above the foliage. Purpletop consistently performed well under north Florida landscape conditions in a 3-yr study at two sites (7) as well as in a demonstration planting (4). Since availability of

containerized purpletop is very limited, our objective was to develop liner/container production protocols appropriate for southern nurseries.

Seeds used in this study were from a selection of a north Florida ecotype of purpletop (Dixie County) that were harvested 10 October 2007 from a landscape planting of this selection that was growing at the UF/IFAS, North Florida Research and Education Center in Quincy. Seeds were stored at 30-35% relative humidity and 75°F (24 °C). Container production cycles commenced when seeds were sown on 22 May 2008 (Cycle 1) or 19 June 2008 (Cycle 2). Seeds were sown into 10 x 20-inch (25.4 x 50.8-cm) flats with #1201 inserts (Cassco, Montgomery, AL) filled with MetroMix 200 (MM200; Sun Gro Horticultural Products, Vancouver, B. C., Canada) and lightly covered with MM200. Flats were overhead irrigated each morning via a mist system. Starting about 10 days after sowing, flats were bottom fertilized with 100 ppm N of Miracle-Gro All Purpose Plant Food 15-30-15 (15N-13.2P-12.4K, Scotts Miracle-Gro Products, Inc., Marysville, OH). On 18 June (Cycle 1) and 17 July (Cycle 2), seedlings were transplanted into #1204 inserts (Cassco; one seedling per cell; 48 cells) filled with MM 200 in 10 x 20-inch (25.4 x 50.8-cm) flats.

On 17 July (Cycle 1) or 14 August (Cycle 2), seedling liners were transplanted into #1 containers ('Classic 400'-1.0 gal; Nursery Supplies, Inc. Fairless Hills, PA). The potting substrate was 60:20:20 (by volume) pine bark:sand:peat (Graco Fertilizer Company, Cairo, GA) amended with fertilizer (Osmocote 15-9-12, 15N-4.0P-10.0K, 12-14 month Southern; Scotts Inc., Marysville, OH) at 4.2, 9.7 or 15.2 lb/yd^3 (2.5, 5.8, or 9.0 kg/m^3). The potted liners were measured (height and two widths) and then placed on a full sun production bed; shoots and roots of 10 liners per cycle were harvested and dried for 3 days at 145°F (63 °C) for dry mass determination.

Plants were overhead irrigated twice per day with 0.28 inches (0.71 cm) water. Containers were hand weeded as needed. Plants were grown until the first flowers were visible, the stage at which plants would be shipped to retailers. Once flowers begin to open, the flowering stems rapidly elongate and within 1 to 2 weeks extend well above the foliage. Shipping date of each plant was recorded along with total plant height, two widths and number of flowering stems. There were 15 single container replications for each starting date by fertilizer rate treatment. The 90 plants (2 seeding dates x 3 fertilizer rates x 15 replications) were arranged in a completely randomized design on the production bed.

Results and Discussion: Liners. At the time liners were potted into #1 containers, heights of liners in Cycle 1 were about 8.5 to 10 inches (21.6 to 25.4 cm), while those in Cycle 2 were significantly smaller at about 7 to 7.5 inches (17.8 to 19.1 cm) tall. Liners in both cycles had well-developed root systems, but Cycle 2 liners had a better ratio of root dry mass to shoot dry mass (0.82 vs. 0.71), suggesting that Cycle 2 liners might be more tolerant of drought stress.

#1 Container Plants. In terms of flowering and overall appearance, the best plants resulted from seed sown on 22 May and subsequently potted into #1 containers in a

substrate amended with Osmocote 15-9-12 at 15.2 lb/yd^3 (9.0 kg/m^3). These plants averaged 24 flowering stems per plant (Table 1), which was over twice as many flowering stems for any plant started on 19 June. However, the production cycle for seeds sown in May was 3 weeks longer than for seeds sown on 19 June. A shorter plant resulted when seeds were sown on 19 June. Seeding date and fertilizer rate had little influence on date that plants were shippable.

Additional Observations. Regardless of sowing date, plants at the lowest fertilizer rate appeared to have more red leaves, which probably was due to phosphorus deficiency. Flowering of plants started on 22 May responded more to fertilizer than plants started on 19 June. Finally, plant responses to treatments were fairly uniform, which is unusual for seed-grown plants.

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Table 1. Effects of sowing date and fertilizer rate on production of purpletop in #1 containers.

					Vegetative growth	
Sowing date	Fert. rate (lb/yd^3)[z]	Ship date[y]	Length of prod. cycle (wk)	No. of flowering stems	Height (in)	Ave. width (in)[w]
22 May	4.2	22 Sept.	17.1 a[x]	9 c[x]	22.7 b[x]	24.6 b[x]
	9.7	22 Sept.	17.1 a	18 b	25.3 a	28.6 a
	15.3	22 Sept.	17.1 a	24 a	25.2 a	29.8 a
19 June	4.2	22 Sept. to 6 Oct.	14.6 b	5 d	19.4 c	14.8 e
	9.7	26 Sept.	14.1 c	6 d	22.4 b	18.6 d
	15.3	22 Sept. to 29 Sept.	14.1 c	10 c	21.5 bc	20.7 c

[z] Incorporated rate of Osmocote 15-9-12, 12-14 month Southern.
[y] Ship date was defined as the date when flowers first emerged; flower stems rarely extended above the top of the foliage at this point. When a single date is shown, flowers emerged on the same date.
[x] Means, within a column, followed by the same letter, are not statistically different at the 5% level.
[w] Average width is mean of the widest width and the width perpendicular to the widest point.

Foliar Thermotolerance of *Tsuga* spp.

Matthew S. Wilson, Jeff L. Sibley, D. Joseph Eakes, Gary J. Keever, and John M. Ruter

Auburn University Department of Horticulture
101 Funchess Hall Auburn University, AL 36849-5408

sibleje@auburn.edu

Index Words: Hemlock, electrolyte leakage, heat tolerance, direct heat injury, thermostability

Significance to Industry: Evaluation of plant response to environmental and biotic stresses benefits industry professionals by providing practical information useful in selecting species for production and landscape use under various conditions. Information concerning heat tolerance of species and cultivars provides valuable resources for plant production and use in areas pre-disposed to high temperatures. Until now, no research has been conducted to investigate the heat tolerance of *Tsuga* spp., commonly known as hemlock, for potential use in heat-disposed climates.

Nature of Work: Electrolyte leakage has been used as an accepted measure of cellular membrane damage in foliage, fruit, and root tissues (4, 6, 16, 17, 18). Electrolyte leakage measures thermal tolerance with respect to direct injury (7). Direct injury occurs when tissues are exposed to extreme temperatures for short periods of time, causing compartmentalization provided by cell membranes to fail and allow cell contents to flow out from the cell (1). The purpose of the following study was to examine the tolerance of six *Tsuga* species to direct heat injury determined by electrolyte leakage.

In January 2008, liners of six *Tsuga* species (*T. canadensis* (L.) Carr., *T. caroliniana* Engelm., *T. chinensis* (Franch.) Pritzel, *T. diversifolia* (Maxim) Mast., *T. heterophylla* (Raf.) Sarg., and *T. yunnanensis* (Franch.) Pritzel) were potted into #2 containers in a substrate of 6 pine bark: 1 builders' sand (by volume) and amended with 11.1, 5, and 1.5 lbs/yd^3 of 18-6-12 (18N-2.6P-9.9K) 8-9 month Osmocote® (Scotts Co., Marysville, OH), dolomitic limestone, and Micromax® (Scotts Co.) respectively. Plants were placed in a complete randomized block design blocked according to species. Plants were grown on a container pad in Auburn, AL (USDA cold hardiness zone 8a) and irrigated with approximately ½ inch water daily for nine months prior to foliar membrane thermostability determination in October 2008.

Electrolyte leakage procedures were modified from those described by Sullivan (17) and modified by Ahrens (2), Ingram and Buchanan (6), and Ruter (12). Recently matured needles from current-season growth were weighed to 0.0265 oz (.75 g) samples and treated within a thermostatically controlled water bath at 12 temperatures (77, 86, 95, 99.5, 104, 108.5, 113, 117.5, 122, 126.5, 131, and 140 °F). Each temperature treatment contained 5 replications for each species (temp n=30, total n=360). Initial and final

electrical conductivity measurements were collected after treatment and autoclaving. Electrolyte leakage was expressed as a ratio of the initial electrical conductivity post-treatment to the conductivity post-autoclave. Electrolyte leakage response to temperature was sigmoidal in arrangement as reported with different species (2, 6, 10, 12, 15). Critical midpoint temperatures (T_m) were determined by fitting electrolyte leakage data across temperature treatments (15) using Gauss-Newton method of non-linear regression approach and correlations with PROC CORR using SAS Version 9.1.3 (14). Critical midpoint temperatures and *k*-values of fitted response curves were determined for each species (Table 1).

Results and Discussion: Correlation procedures revealed a correlation between electrolyte leakage and temperature across all species (r= 0.77, p= <0.0001, n=360). Differences were found in T_m for *T. yunnanensis* and *T. canadensis* when compared to *T. caroliniana*, but not for *T. chinensis, T. diversifolia,* and *T. heterophylla*. Predicted T_m for needles of *T. yunnanensis* (126.9 ± 0.1°F) and *T. canadensis* (126.1 ± 0.3°F) were ≈ 4.8°F and ≈ 4°F greater than for needles of *T. caroliniana* (122.1 ± 1.2°F). *K*-values indicated narrower response curves for needles of *T. yunnanensis* and *T. canadensis* (1.39 ± 0.22 and 0.90 ± 0.16) compared to *T. caroliniana* (0.40 ± 0.09), indicating higher temperatures would be necessary to cause direct heat injury to foliage of *T. yunnanensis* and *T. canadensis* with smaller tolerance range for supraoptimal canopy temperatures around critical temperature midpoint (5, 8, 13). Further investigations of electrolyte leakage of hemlock foliage are necessary to verify aforementioned results as exposure duration, tissue age, season, and stage of acclimation may contribute to varied responses for thermostability (5, 7, 10).

Electrolyte leakage provides an indication of heat tolerance for cell membrane stability in response to extreme temperatures due to direct injury (7). However, it may not serve as a complete indicator of the plant's performance in adverse conditions as photosynthetic and metabolic pathways are often more sensitive to high temperatures than membranes (3, 7). Other measures in the form of indirect injury include chlorophyll fluorescence, respiration, and carbon partitioning (3, 12). Foliar and root heat tolerance determined by electrolyte leakage are acceptable measures of heat tolerance as temperatures have been shown to reach and exceed 122°F in plant canopies (11) and 145°F in container media (9). Exposure to these temperatures for brief periods may contribute to direct damage to cellular membranes and metabolic pathways as the result of direct heat injury. With further investigations into indirect heat injury, certain species of hemlock may prove more suitable for production and use in heat-disposed areas than others.

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Table 1. Summary of hemlock species response to elevated foliar temperatures[z]

Species	Zone[y]	T_m[x]	*k*-values
T. canadensis	*5*	126.1 ± 0.3	0.90 ± 0.16
T. caroliniana	*5*	122.1 ± 1.2	0.40 ± 0.09
T. chinensis	*8*	124.6 ± 1.5	0.33 ± 0.07
T. diversifolia	*8*	125.5 ± 0.8	0.64 ± 0.15
T. heterophylla	*5*	124.2 ± 0.7	0.66 ± 0.15
T. yunnanensis	*8*	126.9 ± 0.1	1.39 ± 0.22

[z]Data presented from electrolyte leakage study in 2008.

[y]USDA cold hardiness zone for location of nursery responsible for the supply of stocks or seedlings

[x]Means and standard errors for predicted critical temperature (Fahrenheit) parameters determined by least squares approach Gauss-Newton method of non-linear regression