Container Grown Plant Production

Derald Harp

Section Editor

Effect of Irrigation Frequency on Sedum Grown in Alternative Substrates

Travis R. Carmichael, Cheryl R. Boyer, Stuart L. Warren, Jason J. Griffin

Kansas State University, Department of Horticulture, Forestry, and Recreation Resources
Manhattan, KS 66506

trcarmic@ksu.edu

Index words: container media, eastern red cedar, nursery crops, pine bark, *Sedum spectabile* 'Autumn Fire'

Significance to Industry: Increasing shipping costs of pine bark (PB) and demand from other uses such as for fuel, has accelerated the need to find alternative substrates for nursery crop production. This need is particularly important in the Great Plains region where no native pine stands are available for bark harvest. Eastern red cedar (*Juniperus virginiana* RC), however, is abundant and finding uses for it will help recover prairie ecosystems currently being lost to red cedar invasion. Recent research has suggested that eastern red cedar can be used as an alternative substrate, but its physical properties (high air space, low container capacity) tend to limit its use as a full replacement for pine bark. The purpose of this study was to evaluate irrigation frequency as a method to improve and potentially overcome some of the physical properties of eastern red cedar as a substrate. The results of this study demonstrate that Sedum does not benefit from increased frequency and can be grown in PB/RC and red cedar mixes.

Nature of Work: Pine bark has been used for many years as a substrate for nursery production. Due to increases in demand for alternative uses of PB, such as fuel, PB is becoming more difficult to locate for use in the horticulture industry (2, 3). A previous study by Murphy et al. (2010) evaluated Clean Chip Residual and *WholeTree* substrates as alternatives to PB. In the study Murphy et al. (2010) reported that 'New Gold' lantana (*Lantana camara* L. 'New Gold'), 'Gold Mound' spirea (*Spiraea japonica* L.f. 'Gold Mound'), 'Amaghasa' azalea (*Rhododendron x* 'Amaghasa'), tea olive (*Osmanthus fragrans* Lour.), 'Roundifloia' ligustron (*Ligustrum japonicum* Thunb. 'Rotundifolia'), and Soft Touch' holly (*Ilex crenata* 'Soft Touch') grown in a greenhouse setting potted in PB amended with 75% alternative substrates were comparable to PB.

Eastern red cedar has been used as an alternative to PB in a nursery setting using Black-eyed Susan (*Rudbeckia fulgida* var *fulgida*) (4). In this study, RC was noted to have high container capacity and low air space (4), which may limit plant growth. Warren et al. (2002) reported that using Cotoneaster (*Cotoneaster dammeri* 'Skogholm') in a nursery setting and irrigating at 2-hour intervals in the afternoon before 18:00 HR had increased water utilization and thus grew better as they were less stressed.

The purpose of this study was to determine if adjusting irrigation frequencies would increase plant growth when using RC as an alternative substrate.

Materials and Methods: Eastern red cedar (Queal Enterprises. Pratt, KS) was processed through a hammer mill (C. S. Bell Co., Tiffin, OH, Model 30HMBL) with a 3/8-inch screen on 23 June 2011. On 22 July 2011, substrates consisting of 80% PB (SunGro, Bellevue, WA): 20% sand; 40% RC 40% PB: 20% sand (PB/RC); or 80% RC: 20% sand were mixed (by volume). Rooted liners of *Sedum spectabile* 'Autumn Fire' were obtained from Emerald Coast Growers (Pensacola, FL) and were transplanted into quart containers (Classic 200, Nursery Supply INC.) on 22 July 2011. Plants were placed in Throckmorton Plant Science Center greenhouse complex located in Manhattan, KS. Containers were top-dressed with 1 gram of Osmoform 18N-5P-13K 3 – 4 month slow release fertilizer (The Scotts Co. Maryville, OH) on 6 Aug 2011. Plants were watered by hand for 15 days after planting (DAP) to allow plugs to begin rooting into the new substrates and to make sure that the entire substrate profile was moist.

An irrigation system with five zones was designed to irrigate plants at four frequencies. A Rain Bird STP9PL (Tucson, AZ) irrigation controller was used to control the irrigation zones. All plants received 208 ml per day. Zones were broken into different times of watering with all times equaling a total of 208 ml total per day. Plants were watered 1, 2, 3, and 6 times per day using drip stakes (Angle Arrow Dripper 5/3, Netafim, Tel Aviv, Israel). Sedum irrigated 1x were irrigated at 0800 HR; 2x irrigated at 1100 and 1500 HR; 3x irrigated at 0900, 1200 and 1500 HR; and 6x irrigated at 0800, 1000, 1200, 1400, 1600, and 1800 HR. To help control the amount of water applied daily 0.5 gallons per hour (gph) pressure compensating drip emitters (0.5 gph Woodpecker Pressure Compensating Junior Drip Emitter, Netafim, Tel Aviv, Israel) were attached to the main line for each treatment. After 15 DAP the irrigation treatments were initiated. Electrical conductivity (EC) and pH were measured at 42, 62, and 81 DAP using the Pour-Through method (7). At the conclusion of the study, shoot and root dry weights were measured. Growth index (GI) was measured at 25 and 80 DAP and substrate shrinkage was measured at 42 DAP. Shoots were harvested at substrate level and roots were then washed of all substrate. Shoots and roots were placed into paper bags and placed in an oven (Grieve SC-350 Electric Shelf Oven. Round Lake, Il) at 71°C (160°F) until dry weight stabilized (13 days). The experiment was arranged in a randomized complete block factorial substrate by irrigation frequency. Data was analyzed using SAS 9.1 using Waller-Duncan's means separation.

Results and Discussion: Substrates at 42 DAP were significantly affected by pH with PB/RC having the highest pH (Table 1). However 62 and 81 DAP pH was similar between RC and PB/RC which were both higher than PB. Irrigation frequencies were unaffected by pH at any of the DAP measured (data not shown). EC levels were unaffected by substrates until 81 DAP where a difference was seen between PB and PB/RC. RC showed similarities between PB and PB/RC, which were only slight differences (Table 1). Throughout the entire study pH levels were higher then the recommended range of 4.5 to 6.5 according to Yeager et al. (2007). EC levels were low compared to recommendations by Yeager et al. (2007) which are 0.8 to 1.5 dS/m. EC readings were below the recommended levels reading 0.46 to 0.52.

At 25 DAP, PB growth index (GI) of Sedum grown in PB was significantly greater than RC whereas, PB/RC showed similarities to PB and RC, then by 80 DAP RC was significantly lower than the other two substrates (Table 2). During the duration of the study, irrigation frequencies did not have an impact on GI. Shoot dry weight was affected by substrate with PB being greater than RC and PB/RC. In contrast, shoot dry weight was unaffected by irrigation frequency (Table 2). Sedum grown in PB had root dry weight greater than Sedum grown in PB/RC; PB and RC were similar as well as RC was comparable with PB/RC. Root dry weight was significantly affected by irrigation frequencies with 1x being greater than 3x and 6x. This shows that for Sedum better root growth was obtained when watered once per day, but also could tolerate irrigating twice.

In conclusion, this study showed that irrigation had an effect on root dry weight of Sedum, a plant that is able to withstand dry conditions and a high pH range 5.5 to 7.0 (1, 5), The greatest growth was obtained with Sedum planted in PB and irrigated once per day. These results demonstrate that eastern red cedar may be used as a partial replacement for PB when growing Sedum. This study will be replicated with species that are high water users and less tolerant to drought in order to determine if increasing irrigation frequencies can overcome undesirable physical properties for species that are more susceptible to environmental stresses.

Literature Cited:

1. Armitage, A. M. 2008. Herbaceous perennial plants: a treatise on their identification, culture, and garden attributes. Stipes Publishing.
2. Lu, W., J. L. Sibley, C. H. Gilliam, J. S. Bannon, and Y. Zhang. 2006. Estimation of U.S. bark generation and implications for horticultural industries. J. Environ. Hort. 24: 29-34.
3. Murphy, A. M., C. H. Gilliam, G. B. Fain, H. A. Torbert, T. V. Gallagher, J. L. Sibley, S. C. Marble, and A. L. Witcher. 2010. Extending pine bark supplies with wholetree and clean chip residual substrates. J. Environ. Hort. 28: 217-223.
4. Starr, Z., C. Boyer, J. Griffin. 2011. Cedar substrate particle size affects growth of container-grown Rudbekia. Proc. Southern Nurs. Assoc. Res. Conf. 56: 292-296.
5. Steambank Garden. 2011. Sedum (Stonecrop). 8 Nov. 2011. <http://streambankgardens.com/sedum_stonecrop.html>
6. Warren, S. L., T. E. Bilderback. 2002. Timing of low pressure irrigation affects plant growth and water utilization efficiency. J. Environ. Hort. 20: 184-188.
7. Wright, R. D. 1986. The pour-though nutrient extraction procedure. HortScience. 21: 227-229.
8. Yeager, T., T. Bilderback, D. Fare, C. Gilliam, J. Lea-Cox, A. Niemiera, J. Ruter, K. Tilt, S. Warren, T. Whitwell, R. Wright. 2007. Best management practices: guide for production nursery crops. 2nd ed. Southern Nursery Association, Atlanta, GA.

Table 1. Solution pH and electrical conductivity (EC) of substrates[z].

Substrate	42 DAP[y] pH	42 DAP[y] EC (dS/m)	62 DAP pH	62 DAP EC (dS/m)	81 DAP pH	81 DAP EC (dS/m)	42 DAP Shrinkage[w]
Pine Bark	7.19 c[x]	0.46 a	7.20 b	0.47 a	7.38 b	0.44 b	1.24 b
Red Cedar	7.78 a	0.45 a	7.54 a	0.49 a	7.62 a	0.49 ab	1.93 a
PB/RC	7.48 b	0.52 a	7.52 a	0.49 a	7.66 a	0.50 a	1.34 b

[z]pH and EC of solution obtained by the pour-through method.
[y]Days after planting.
[x]Mean separation within column by Waller-Duncan Multiple Range test (α = 0.05, n = 16)
[w]Measurement taken from top of container to surface of substrate.

Table 2. Effect of substrate and irrigation frequency on the growth of *Sedum s.* 'Autumn Fire'

Substrate	25 DAP GI[z]	80 DAP GI	Shoot Dry Weight (g)[y]	Root Dry Weight (g)[x]
Pine Bark	12.8 a[w]	19.4 a	7.3 a	10.2 a
Red Cedar	9.4 b	14.8 c	4.4 c	8.6 ab
PB/RC	11.0 ab	17.8 b	5.8 b	7.8 b
Irrigation Frequency				
1x per day	12.0 a	17.7 a	6.0 a	10.6 a
2x per day	12.0 a	17.1 a	6.0a	9.7 ab
3x per day	10.5 a	17.5 a	6.1 a	7.2 c
6x per day	9.6 a	17.1 a	5.3 a	8.0 bc

[z]Growth Index = (height + width + perpendicular width) / 3 (1cm = 0.397 in.).
[y]Shoots harvested at container surface and oven dried at 71°C for 13 days (1 g = 0.0035 oz).
[x]Roots barerooted and oven dried at 71°C for 13 days (1 g = 0.0035 oz).
[w]Mean separation within column by Waller-Duncan Multiple Range test (α = 0.05, n = 18).

Long Residual Controlled Release Fertilizer Pour-through Results from Two Plant Species and a No-Plant Control

Winston Dunwell, Carey Grable, and Dwight Wolfe

University of Kentucky Research and Education Center
1205 Hopkinsville St, Princeton, KY 42445

wdunwell@uky.edu

Index Words: Pour-through, *Nyssa sylvatica* 'Fire Master'**,** *Cotoneaster* x 'Hessei'

Significance to Industry: This research was performed to determine if using controlled-release fertilizer (CRF) of high longevity, 12-14 month, would overcome mid-season low pour-through (PT) soluble salt readings that occur when 5-6 month CRF no longer provides adequate levels of fertilizer after 13 weeks in western Kentucky (2). The data show that the soluble salt level of the leachate from the No-plant container followed the same pattern as the leachate from containers with plants. The 12-14 month CRF provided adequate levels of fertilizer from the June application to October as indicated by PT soluble salt levels.

Nature of Work: Utilizing the pour-through (PT) method (3) to evaluate soluble salt levels that indicate fertilizer availability, has typically revealed that soluble salt levels in mid-summer following a spring CRF application were less than recommended (2). Previous work attempting to retrieve all fertilizer prills to test for fertilizer remaining in mid-summer when the low soluble salts PT results occurred has not been successful. Including a container with no plant might give us an indication of whether there was still fertilizer being released to the soil solution but not depleted by the plant.

April 20, 2011, fifteen plants each of *Nyssa sylvatica* 'Fire Master' and *Cotoneaster* x 'Hessei' were transplanted from RootTrapper® II RTII 8 bags and 3 gallon containers (Nursery Supplies, C300) respectively to 7-gallon containers (WhiteRidge, LLC, 2358 l). The substrate was aged pine bark with no amendments. Fifteen 7-gallon containers filled with media without a plant were used as the No-plant control. Containers were set in TopHat™ Container Stabilizers to avoid blow over and fertilizer loss. Irrigation was provided via a single Agridor 4463 sprayer per container. Water was applied at three cycles of 12 minutes each (250ml/min) at 1020, 1400, 1700. Osmocote Plus 15-9-12, 12-14 month formulation, was applied June 28, 2011 at the medium rate of 7.5 oz for a 7-gallon container. The three treatments were allocated to the 45 containers in a generalized randomized block design with three treatments per row and three rows (blocks).

Soluble salts and pH were recorded approximately every two weeks from June 6, 2011 to October 24, 2011 by the pour-through extraction method (3,7). The PT was performed 30 minutes following irrigation except on September 26, 2011 when the pour-through was done without irrigation following a 1.88 inch (5) overnight rain. The leachate soluble salts and pH were read with a Hanna HI9811 pH/EC/TDS meter.

Results and Discussion: Leachate salts showed a stable release rate (Figure 1.) averaging 294 µS/m for the no-plant control, 316 µS/m for the *Nyssa sylvatica* 'Fire Master' and 272 µS/m for the *Cotoneaster* x 'Hessei' over the duration of experiment and were not significantly different from each other (Table 1.). The soluble salts in the leachate for the September 26, 2011 non-irrigated PT spiked for the *N. sylvatica* 'Fire Master' and the *C.* x 'Hessei' while the No-plant container PT was significantly different from the *N. sylvatica* 'Fire Master' and the *C.* x 'Hessei' and was not significantly different from the September 12, 2011 No-plant PT. The salt level was in the 200 to 500 µS/m range considered adequate for growth (2,7,8) and was maintained from the June application date to the last PT in October. The levels of fertility in October are high enough for growth and may result in reduced cold hardiness leading to potential winter injury (4,6). A no-plant treatment did not contribute information for evaluating nutrient availability that is not gained by performing PT on containers with plants.

The spike in leachate soluble salts for *Nyssa sylvatica* 'Fire Master' and *Cotoneaster* x 'Hessei' on September 26, 2011 was due a lack of pre-PT leaching of soluble salts. The evening rainfall triggered elimination of the irrigation event prior to the PT. It is speculated that the lack of a significant soluble salts spike in the no-plant container reflects the lack of plant depletion of water leading to a concentration of soluble salts.

The average leachate pH readings over the course of the experiment for *Cotoneaster* x 'Hessei' were significantly different from the No-plant and *Nyssa sylvatica* 'Fire Master' Leachate pH (Table 2), but the readings were not consistently different from date to date. The pH of pour-through leachate declined over time (Figure 2).

Literature Cited

1. Ariana P. Torres, Michael V. Mickelbart, and Roberto G. Lopez. 2010. Leachate Volume Effects on pH and Electrical Conductivity Measurements in Containers Obtained Using the Pour-through Method.
2. Bilderback, Ted. 2001. Using The PourThru Procedure For Checking EC and pH For Nursery Crops . 03 Nov 2011. http://www.ces.ncsu.edu/depts/hort/hil/hil-401.html
3. Dunwell, Winston, Carey Grable, Dwight Wolfe, and Dewayne Ingram. 2011. Differences in Pour-through Results from Two Plant Species and a No-plant Control. Proc. SNA Res. Conf. 56: 246-249, http://www.sna.org/Resources/Documents/11resprocsec09.pdf
4. Dunwell, Win and Amy Fulcher. 2005. PourThru Extraction. 03 Nov. 2011 http://www.ca.uky.edu/HLA/Dunwell/PourThruExtract.html
5. Fuchigami, L.H., CJ. Weiser, and D.R. Even. 1971. Induction of cold acclimation in Comus sloionifera Michx. Plant Physiol. 47:98-103.
6. Kentucky Mesonet 2011. Monthly Climatological Summary: September 2011. December 22, 2011.

http://www.kymesonet.org/historical_data.php?site=PRNC&month=9&year=2011&GETOB=1
7. Pellett, H.M. and J.Y. Carter. 1981. Effect of nutritional factors on cold hardiness of plants. Hon. Rev. 3: 144-171.
8. Wright, Robert D. 1986. The Pour-through nutrient Extraction Procedure. HortScience 21(2):227-229.
9. Yeager, Tom, et.al. 2007. Best Management Practices: Guide for Producing Nursery Crops, 2nd ed. Southern Nursery Assoc., Atlanta, GA.

Table 1. Average soluble salt reading over the experiment

Treatment	**Soluble Salt**	**Number of Readings**
No-plant	294 a[1]	176
Nyssa sylvatica 'Fire Master'	316 a	176
Cotoneaster x 'Hessei'	272a	177
Lsd (0.05)	47	na
[1] Means with the same letter are not significantly different.		

Table 2. Average pH reading over the experiment

Treatment	**Soluble Salt**	**Number of Readings**
No-plant	6.91a[1]	176
Nyssa sylvatica 'Fire Master'	6.91a	176
Cotoneaster x 'Hessei'	6.85b	177
Lsd (0.05)	0.05	na
[1] Means with the same letter are not significantly different.		

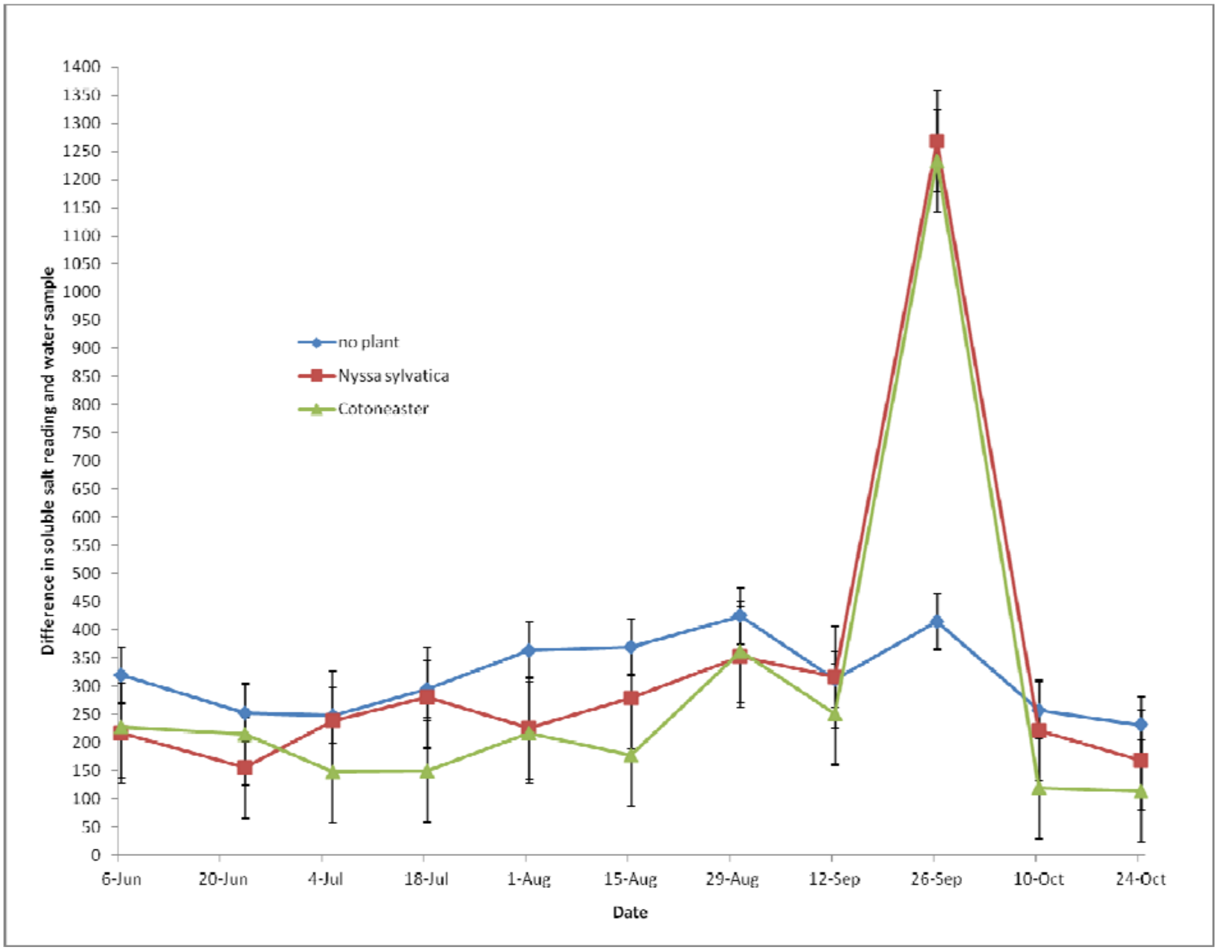


Figure 1. Soluble salts in PT leachate from *Nyssa sylvatica* 'Fire Master', *Cotoneaster* x 'Hessei' and No-plant containers for two-week sampling intervals. Mean intervals are + or – ½ the least significant difference at the 0.05 probability level.

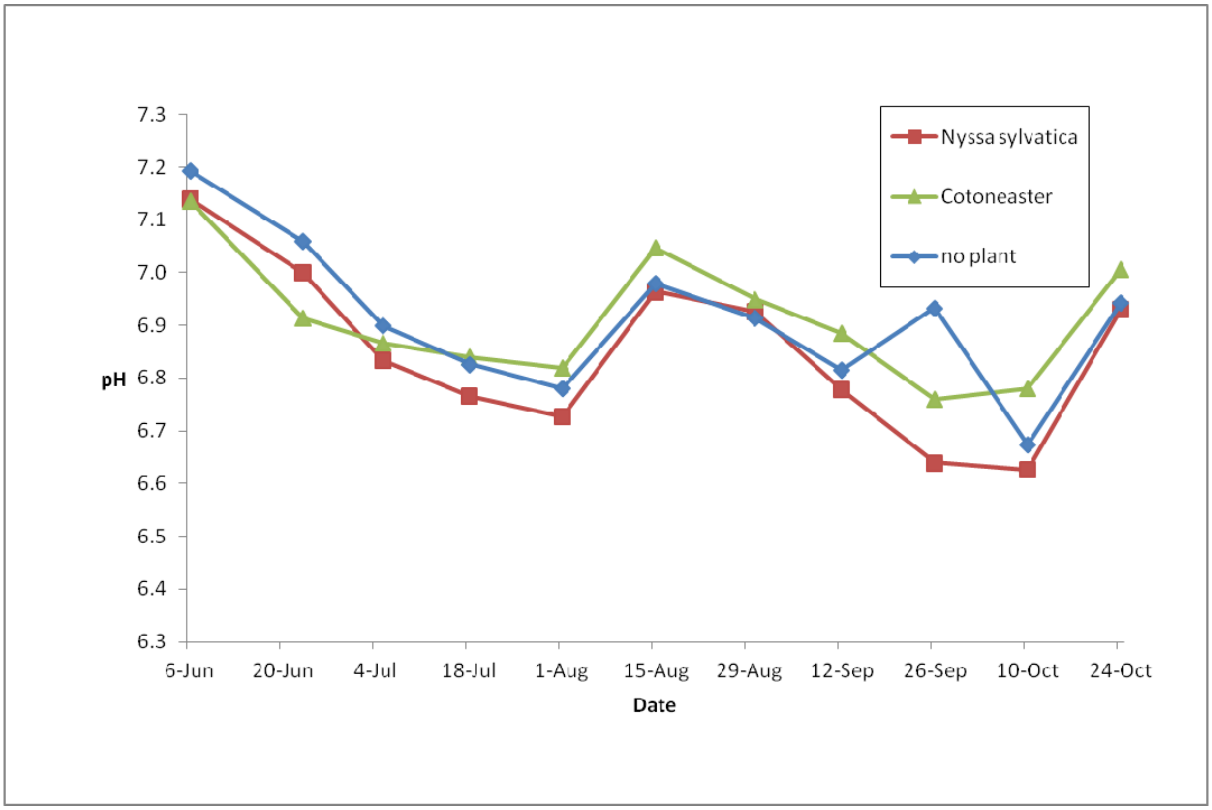


Figure 2. pH of the PT leachate from *Nyssa sylvatica* 'Fire Master'**,** *Cotoneaster* x 'Hessei' and No-plant containers for two week-sampling intervals.

Eastern Red Cedar as an Alternative Substrate in Nursery Production

Lucy Edwards, Charles H. Gilliam, Glenn B. Fain and Jeff L. Sibley

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

LEE0003@tigermail.auburn.edu

Index Words: alternative substrates, pine bark, eastern red cedar

Significance to the Industry: Recent decline in pine bark (PB) supplies has created concern for nursery growers about future availability and has created a need to evaluate alternative components for their standard growing substrate. In many areas they are looking for plants that are available locally in sustainable quantities. Eastern red cedar (*Juniperus virginiana)* has become a "weed species" throughout many parts of the Great Plains and Midwest. This study demonstrated that most woody nursery crops grown in varying ratios of PB: Cedar had similar growth to plants grown in a current nursery standard of 100% PB.

Nature of Work: Increasing energy cost has resulted in the use of bark as an alternative resource of clean fuels (7). Increasing demand for bark coincides with the slowly declining timber industry (4). Without a decrease of energy cost in sight and the horticulture industry's expected expansion bark shortages could occur. With energy cost preference over the horticultural industry, the need for an alternative substrate increases (1, 5, 6).

Thus far, eastern red cedar has been identified as a viable amendment incorporated, at different percentages, into a PB:sand substrate mixture evaluating seedling growth of Chinese pistache (*Pistacia chinensis*) and Indian-cherry (*Frangula caroliniana*) (3). Results from evaluation of *Acer saccharinum* seed propagation in varying eastern red cedar:sand:PB percentages concluded cedar could be a potential replacement for pine bark with further development of substrate physical properties (8). When *Taxodium distichum* was evaluated in PB:sand substrates amended with percentages of eastern red cedar, data concluded that there was little significant difference in plant height between the treatments (9). So far, limited research has been done with woody nursery crop production. The objective of this study was to evaluate Eastern Red Cedar as an alternative substrate to pine bark in the nursery production of woody nursery crops.

This study was initiated on May 16, 2011 at the Paterson Greenhouse Complex, Auburn University, Auburn, AL. Seven substrate treatments were evaluated: 100% PB, 5:95 cedar:PB, 10:90 cedar:PB, 20:80 cedar:PB, 40:60 cedar:PB, 80:20 cedar:PB, and 100% cedar. Cedar used for the study was harvested on April 7, 2011 at the Auburn Piedmont Research Station, Camp Hill, Alabama. Cedar was chipped through a Vermeer BC1400XL (Vermeer Co., Pella, IA) on April 12, 2011, then stored until processing through a hammer-mill on May 10, 2011. All substrates were pre-incorporated with a 6:1

(v: v) ratio of sand, and amended with 9.5 kg/m^{-3} (15.9 lbs/yd^{-3}) 15N-2.6P-9.9K (15-6-12) Polyon (Harrell's Fertilizer, Inc.,Lakeland, FL) control release fertilizer (8-9 months), 3.0 kg/m^{-3} (5 lbs/yd^{-3}) dolomitic limestone, and 0.9 kg/m^{-3} (1.5 lb/yd^{-3}) Micromax (The Scotts Company, Marysville, OH).

Liners of Knockout Rose (Rosa x 'Knockout') (32 cell pack), Reeves spirea (*Spiraea cantoniensis*) (72 cell pack), Wintergreen boxwood (*Buxus microphylla japonica* 'Wintergreen') (32 cell pack), Sergeants juniper (*Juniperus chinensis* 'Sargentii') (32 cell pack), and Formosa azalea (*Rhododendron x indica* 'Formosa') (72 cell pack) were transplanted from cell pack trays into a #1 containers, except for Premier blueberry and Wintergreen boxwood which were planted in trade gallons. All plants were watered with overhead irrigation (1.27 cm/day) (0.5 in/day). Formosa azalea and Premier blueberry were kept under a 30% shade structure; all other species were placed in direct sun.

The experimental design was a complete randomized block design with 8 single pot replications per treatment. Each species was treated as its own separate experiment. Data collected from the study includes physical properties (air space, water holding capacity, and total porosity), bulk density and particle-size distribution (2). Leachates were collected from the Formosa azalea using the Virginia Tech PourThru Method (11). pH and EC (mS•cm^{-1}) was measured at 7, 15, 30, 60, 90, and 180 days after potting (DAP). Leaf chlorophyll content was quantified using a SPAD-502 chlorophyll meter (Minolta Camera Co., Ramsey, NJ) at 90 and 180 DAP. Growth indices were measured at 90 and 180 DAP. Root growth ratings were taken at 180 DAP on a scale from 1-5, where 1- less than 20% root ball coverage, and 5 - between 80-100% root ball coverage. Substrate shrinkage was recorded at 180 DAP. Marketability was also determined at 180 DAP on a scale from 1-5, where 1 - dead and 5 - highly marketable.

All data were subject to analysis of variance using the general linear models procedure and multiple comparison of means, conducted using Tukey's honest significant test at α= 0.05 (Version 9.1.3; SAS Institute, Inc., Cary, NC).

Results: Substrate treatments containing 80 (25.0) and 100% (29.5) cedar had higher air space than PB (15.3), while all other treatments were statistically similar (Table 1). The recommend range of physical properties (10) for a standard growing media is between 10-30% air space, 45-65% water holding capacity, and 50-85% total porosity percent per volume. Substrate water holding capacity was similar among all treatments, except for 10% (42.0) cedar and 100% (48.5) cedar. Total porosity varied throughout the treatments, but was greatest for treatments containing 80 and 100% cedar. Bulk density varied between the recommend ranges of 0.19-0.70 g·cm^{-3} for all treatments.

Substrate pH levels ranged from 6.2-7.0 (Table 2). EC levels were generally similar throughout the study except at 30 DAP, when 5:95 cedar:PB had the highest EC level (0.72 mS·cm^{3}). EC levels generally declined over the study.

In general, growth was similar among all treatments across all species (Table 3). There were no statistical differences among Spirea or Juniper at 90 and 180 DAP.

Minor differences were observed between Knockout Rose and Boxwood. Knockout Rose grown in 80:20 PB:cedar substrate were smaller than those grown in 100% PB. Boxwood grown in 100% cedar were slightly smaller. Formosa azalea growth generally declined with increasing cedar levels. At 180 DAP, azaleas were statistically smaller when cedar levels were 40% or greater.

These data show that pine bark amended with cedar provides a suitable substrate for woody nursery crops, except with acid loving plants.

Literature Cited

1. Broussard, C., E. Bush, and A. Owings. 1999. Effects of hardwood and pine bark on growth response of woody ornamentals. Proc. Southern Nurs. Assoc. Res. Conf. 44:57-60.
2. Fonteno, W. C., C.T. Hardin, and J.P. Brewster. 1995. Procedures for determining physical properties of horticultural substrates using the NCSU Porometer. Horticultural Substrates Laboratory, North Carolina State University, Raleigh, NC.
3. Griffin, J. 2009. Eastern red-cedar (*Juniperus virginiana*) as a substrate component for container production of woody plants. HortScience 44:1131 (Abstr.)
4. Haynes, R. W. 2003. An analysis of the timber situation in the United States: 1952-2050. Gen. Tech. Rept. PNW-GTR-560. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Portland, OR.
5. Ingram, D.L., R.W. Henley, and T.H. Yeager. 1991. Growth media for container grown ornamental plants. Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida.
6. Laiche, A.J. and V.E. Nash. 1986. Evaluation of pine bark, pine bark with wood, and pine tree chips as components of a container plant growing media. J. Environ. Hort. 4:22-25.
7. Lu, W. J. L. Sibley. C. H. Gilliam, J. S. Bannon, and Y. Zhang. 2006. Estimation of U.S. Bark Generation and Implications for Horticultural Industries J. Environ. Hort. 24:29–34.
8. Starr, Z.W., C.R. Boyer, and J.J. Griffin. 2010. Growth of containerized Acer saccharinum from seed in a cedar-amended substrate. HortScience 45:S234. (Abstr.)
9. Starr, Z., C. R. Boyer, and J.J.Griffin. 2011. Growth of Containerized Taxodium distichum in a Cedar-Amended Substrate. Proc. Southern Nurs. Assoc. Res. Conf. 55:344-346.
10. Yeager,T., T. Bilderback, D. Fare, C. H. Gilliam, J. Lea-Cox, A. Niemiera, J. Ruter, K. Tilt, S. Warren, T. Whitwell, and R. Wright. 2007. Best management practices: Guide for producing nursery crops. 2nd ed. Southern Nursery Assn., Atlanta, GA.
11. Wright, R. D. and J. F. Browder. 1986. The pour-through nutrient extraction procedure. HortScience 21:227-229.

Table 1. Physical properties of five substrates containing pine bark and cedar[z].

Substrate[y]	Air Space[x] (% vol)	Substrate water holding capacity[w] (% vol)	Total Porosity[v] (% vol)	Bulk Density[u] (g·cm-3)
100% PB	15.3 b[t]	46.3 ab	62.7 c	45.3 a
5:95 Cedar: PB	22.3 ab	45.0 ab	67.3 bc	36.3 de
10: 90 Cedar: PB	21.3 ab	42.0 b	63.3 c	39.0 bcd
20:80 Cedar:PB	20.3 ab	44.0 ab	64.3 bc	40.3 bc
40:60 Cedar: PB	22.7 ab	46.3 ab	69.0 bc	37.0 cde
80:20 Cedar PB	25.0 a	46.0 ab	71.3 ab	41.0 b
100% Cedar	29.5 a	48.5 a	78.0 a	35.0 e
Recommended Range[s]	10-30%	45-65%	50-85%	0.19-0.70

[z]Analysis performed using the North Carolina State University porometer (http://www.ncsu.edu/project/hortsublab/diagnostic/porometer/).

[y]PB = pine bark.

[x]Air space is volume of water drained from the sample / volume of the sample.

[w]Substrate water holding capacity is (wet weight - oven dry weight) / volume of the sample.

[v]Total porosity is substrate water holding capacity + air space.

[u]Bulk density after forced-air drying at 105C (221.0F) for 48 hrs; 1 g·cm^{-3} = 62.4274 lb·ft^{-3}.

[t]Means within column followed by the same letter are not significantly different based on Tukey's Studentized Range Test at α = 0.05 (n=3).

[s]Recommended ranges as reported by Yeager, et al., 2007. Best Management Practices Guide for Producing Container-Grown Plants.

Table 2. Solution pH and substrate electrical conductivity (EC) for seven substrates containing pine bark and cedar[z].

	7 DAP[x]		30 DAP		60 DAP		180 DAP	
Substrate[y]	pH	EC (mS·cm^{-1})[w]	pH	EC (mS·cm^{-1})	pH	EC (mS·cm^{-1})	pH	EC (mS·cm^{-1})
100% PB	6.3 ab[v]	0.35 [ns]	6.7 ab	0.55 ab	6.3 ab	0.40 [ns]	6.4 abc	0.24 [ns]
5:95 Cedar: PB	6.3 b	0.42	6.2 b	0.72 a	5.7 b	0.57	6.2 bc	0.27
10: 90 Cedar: PB	6.3 ab	0.40	6.2 b	0.50 ab	6.2 ab	0.35	6.2 c	0.25
20:80 Cedar:PB	6.6 ab	0.38	6.6 ab	0.55 ab	6.3 a	0.36	6.5 abc	0.24
40:60 Cedar: PB	6.6 ab	0.37	6.7 ab	0.46 b	6.5 a	0.37	6.5 abc	0.26
80:20 Cedar PB	6.5 ab	0.37	7.0 a	0.66 ab	6.7 a	0.42	6.7 ab	0.27
100% Cedar	6.7 a	0.34	6.9 a	0.47 ab	6.7 a	0.37	6.8 a	0.27

[z]pH and EC of solution determined using pour-through method on 'Formosa' Azalea.

[y]PB = pine bark.

[x]DAP = days after potting.

[w]1 mS·cm^{-1} = 1 mmho·cm^{-1}.

[v]Means within column followed by the same letter are not significantly different based on Tukey's Studentized Range (HSD) Test at α = 0.05 (n=4).

[ns]Means not significantly different.

Table 3. Effect of seven substrates containing pine bark and cedar on growth indices[z] of five woody plant species.

Substrate[y]	*Juniperus chinensis 'Sargentii'* 90 DAP[x]	*Juniperus chinensis 'Sargentii'* 180 DAP	*Spiraea cantoniensis* 90 DAP	*Spiraea cantoniensis* 180 DAP	*Rhododendron x 'Formosa'* 90 DAP	*Rhododendron x 'Formosa'* 180 DAP
100% PB	28.4 [w, ns]	37.4 [ns]	64.5 [ns]	61.6 [ns]	31.3 a	42.2 a
5:95 Cedar: PB	29.4	34.6	48.8	64.9	33.2 a	44.3 a
10: 90 Cedar: PB	30.3	36.4	58.8	58.7	29.0 abc	40.6 a
20:80 Cedar:PB	32.7	40.4	63.9	65.2	30.3 ab	41.1 a
40:60 Cedar: PB	29.8	36.8	51.3	59.2	29.4 ab	32.7 b
80:20 Cedar PB	27.8	32.4	50.5	59.4	22.9 c	27.4 b
100% Cedar	26.9	33.3	49.2	56.5	24.7 bc	26.9 b

Substrate	*Buxus microphylla japonica 'Wintergreen'* 90 DAP	*Buxus microphylla japonica 'Wintergreen'* 180 DAP	*Rosa x 'Knockout'* 90 DAP	*Rosa x 'Knockout'* 180 DAP
100% PB	18.3 ab	18.5 ab	43.7 [ns]	59.0 ab
5:95 Cedar: PB	16.5 ab	17.2 ab	41.7	53.2 ab
10: 90 Cedar: PB	18.5 ab	18.4 ab	41.8	55.4 ab
20:80 Cedar:PB	18.6 ab	19.0 ab	43.3	60.3 a
40:60 Cedar: PB	18.9 a	19.7 a	39.7	54.6 ab
80:20 Cedar PB	17.0 ab	17.7 ab	39.7	50.3 b
100% Cedar	15.0 b	15.63 b	42.7	50.9 ab

[z]Growth Indices= ((height+width$_1$+width$_2$)/3) in cm.

[y]PB = pine bark.

[x]DAP = days after potting.

[w]Means within column followed by the same letter are not significantly different based on Tukey's Studentized Range Test at $\alpha = 0.05$ (n = 8).

[ns]Means not significantly different.

The Feather Pot: A Keratin-based Nursery Container

Donna C. Fare

US National Arboretum, USDA-ARS
McMinnville, TN

donna.fare@ars.usda.gov

Index Words: biocontainers, biopots, nursery production, woody ornamentals

Significance to Industry: The nursery industry produces over 500 million containers each year in the production of ornamental plants. Traditional nursery containers are made from petroleum based plastic; however, using new technology with keratin, a renewable natural plastic from poultry feathers, can provide a strong and stable nursery container that can be used in single or multi-year production. Though not biodegradable, the use of keratin can reduce the use of petroleum based plastic by about 40%. Also, utilizing feather waste is an effective and potentially profitable way of reducing a waste stream from another agricultural entity. The keratin based prototype nursery containers in this research had neither a positive nor negative effect on the growth of the plants evaluated, suggesting the potential of this polymer technology for use in container production.

Nature of Work: About 500 million nursery plants are produced annually in plastic nursery containers and up to 1.8 trillion plastic containers including greenhouse produced plants. This equates to about 350 million pounds of plastic used annually in the horticulture industry. Most of the containers are made with petroleum based plastic. Reusing and recycling nursery containers have several undesirable caveats such as potential weed seed and disease contaminations as well as finding recycling stations to accept nursery containers. Several research projects evaluating bio containers or biopots for short term crops such as vegetables, herbs and seasonal flowering plants have been successful (2, 3); however, growing and selling a one year crop as well as a multi-year crop as is with many woody ornamentals is difficult.

Recent research using polymers or plastics derived from renewable resources such as poultry feathers have proven successful to make bioplastic (4). Nearly four billion pounds of waste poultry feathers are produced each year in the United States and are processed into cheap animal feed, buried, or incinerated. Poultry feathers have about 91% keratin, which is a tough, strong and lightweight protein (1,4). Keratin blended with polyethylene traditionally used to make nursery containers resulted in the prototype containers used in this study (1). The objective of this research was to compare plant response and leachate chemistry from two prototype nursery containers made from keratin-derived polymer/polyethylene blends with a standard solid-wall black polyethylene nursery container.

On 2 June, *Spiraea japonica* 'Little Princess', spirea, *Camellia japonica* 'Boyd', Boyd camellia, and *Coreopsis x* 'Presto', coreopsis, liners were potted into #1 standard nursery container (TSW) (Nursery Supplies, Chambersburg, PA, USA) or a #1 solid wall keratin-based container (KSW). On 15 June, a second group of plants, *Camellia japonica* 'Spring's Promise', camellia, *Catharanthus roseus* 'Rosea', vinca, and *Acer x* 'Gingerbread', Girard maple, were potted into #1 STD nursery containers or a keratin-based ARPACC™ container (Air-Root-Pruning, Anti-Circling Containers) (Tri-Tech Molded Products Inc, McMinnville, TN, USA) (KAP). Containers were filled with a pine bark amended substrate with 4.5 lbs Osmocote Pro 19-5-9 (The Scotts Co., Marysville, OH), 1.0 lb Micromax (The Scotts Co., Marysville, OH), and 1.0 lb Aqua-Gro per cubic yard. Plants were placed on a gravel pad in full sun and watered daily with overhead irrigation. Three plants from each container style and species were selected to collect container leachate weekly. About 30 minutes after morning irrigation, 250 ml of irrigation water was surface applied and resulting leachate was collected. Within 30 minutes, pH and EC were measured using an AG6/pH meter (Myron L Co., Carlsbad, CA, USA) (pH data not shown). Leachate was analyzed for nitrate, ammonia and phosphate levels. Weekly leachate collections ceased on 30 August for spirea, coreopsis and vinca and 26 October for Boyd camellia, Spring's Promise camellia and Girard maple (only spirea and maple data shown). Spirea, coreopsis and vinca were harvested for dry weights by severing the shoots at the soil line; tissue was dried at 55C then weighed. Root systems were qualitatively rated on a scale of 1-5, with 5 indicating the most vigorous root system as seen on the perimeter of the root ball. Spirea roots were separated from the substrate by using compressed air, placed in brown paper bags and dried at 55C. Vinca and coreopsis roots were too fine to adequately separate from the media. Growth indices, [(plant height + width1 at widest point + width2 perpendicular to width1)/3], was measured at the onset and at termination with all species except Girard maple which height and soil-line caliper measurements were made. Plants were randomized by species with eighteen ('Boyd' camellia and spirea), sixteen ('Spring's Promise camellia and Girard maple) or fifteen (coreopsis and vinca) single plant replications. Differences in growth indices, shoot weight, root ratings and container leachate by pot type for each species were assessed using t-tests in GraphPad Prism 5.03 (La Jolla, CA, USA).

Results and Discussion: *Plant response*. Growth, as determine by growth indices, was similar with 'Boyd' camellia, spirea and coreopsis grown in KSW compared to plants in TSW containers (Fig. 1). Vinca and 'Spring's Promise' camellia both grew equally in the TSW and the KAP. There were no differences in height or caliper growth of 'Gingerbread' maple when grown in KAP and TSW containers (Fig. 2). The TSW and KSW containers used in these tests were similar in volume, 2490 mls and 2750 mls, respectively. The KAP container was slightly larger than the TSW with a volume of 3300 mls.

Visible root growth on the perimeter of the root balls was assessed on 31 August for spirea, coreopsis and vinca (Fig. 3). Root growth on the perimeter of the root ball was visually different with coreopsis grown in the KSW compared to the root system in the TSW. Roots had very little branching in the KSW and had the appearance of 'combed spaghetti' as the roots grew straight down the perimeter of the root ball. The altered root system did not affect shoot growth and shoot dry weight was greater in the KSW container compared to TSW.

Spirea and vinca had lower root ratings when grown in the KSW (spirea) or the KAP (vinca) containers compared to the TSW (Fig. 3). The roots appeared healthy, but had not grown to the point of encompassing the entire root ball which resulted in a lower root rating. However, the root dry weight of spirea showed an increase in root mass with plants grown in the KSW compared to plants grown in the TSW (Fig. 3). Shoot dry weight was greater in the KSW container with spirea compared to plants in the TSW. Shoot dry weight was similar with red vinca grown in KAP and TSW.

The roots of 'Spring's Promise' camellia in the KSW container and maple and 'Boyd' camellia in the KAP were rated and compared to plants in the TSW in Dec 2011 (data not shown). Plant roots systems in both the KSW and TSW had similar root growth and were typical of roots in standard solid wall containers. 'Boyd' camellia and maple in KAP had no root growth around the perimeter at the container-substrate interface of the root ball compared to plants in the TSW containers. This was expected as the KAP container is a root air pruning container.

Container leachate analysis. The electrical conductivity (EC) from leachate showed a consistent release of the controlled release fertilizer within days after potting (Fig. 4). Though an initial spike around 2.0 at the first collection date, the EC levels were similar throughout the sampling weeks and stayed with acceptable ranges (<1.0) for about 10 weeks. The rate of fertilizer used with both groups is about half the rate traditionally used for woody ornamentals; however, since both woody and herbaceous plant material was evaluated in the experiment a lower rate was used. The fertilizer rate and unusually hot temperatures attributed to the short duration of fertilizer release. There was no difference with EC readings between container prototypes.

Phosphorus, nitrate-N and ammonium-N levels were detected in weekly container leachates for all plants, but only data for spirea and maple are shown (Fig. 5). There was less nutrient leachate with spirea compared to maple throughout the test period. 'Little Princess' spirea is considered a heavy fertilizer user compared to the slow growing Girard maple. Thus, it was not unexpected to see nutrient levels higher in the container leachate from the maple compared to spirea.

At most sampling dates, phosphorus, nitrate and ammonia levels were similar between TSW and KSW and between TSW and KAP with all species, with the exception of nitrate levels in leachate from maple. The KAP prototype had considerably less nitrate in container leachate for most sampling dates. Though a similar trend was detected in the early weeks of the test with spirea grown in KSW, by the middle of July, the nitrogen fertilizer (nitrate and ammonia) was basically spent from the container substrate.

From this research, the growth and leachate chemistry was similar between the keratin based containers KSW and KAP compared to the industry standard container TSW.

This assessment is critical to determine the structural longevity of the keratin based containers. If during the research period, the nitrogen levels increased in the leachate, it could be an indication that the keratin protein was breaking down and the structural soundness of the container was compromised. The keratin based prototypes had neither a positive nor negative effect on the growth of the plants evaluated suggesting the potential of this polymer technology for use in container production.

Literature Cited

1. Barone, J.R. and W.A.Schmidt. 2005. Polyethylene reinforced with keratin fibers obtained from chicken feathers. Composites Science and Technology 65:173–181.
2. Camberato, D.M. and R.G. Lopez. 2010. Biocontainers for long-term crops. Greenhouse Grower. http://www.greenhousegrower.com/. Accessed 22 March 2011.
3. Evans, M.R. and D.L. Hensley. 2004. Plant growth in plastic, peat and processed poultry feather fiber growing containers. HortScience 39(5):1012-1014.
4. Halford, B. and C.E. Washington. 2008. Going beyond feather dusters. Science and Technology 82(36):36-39.

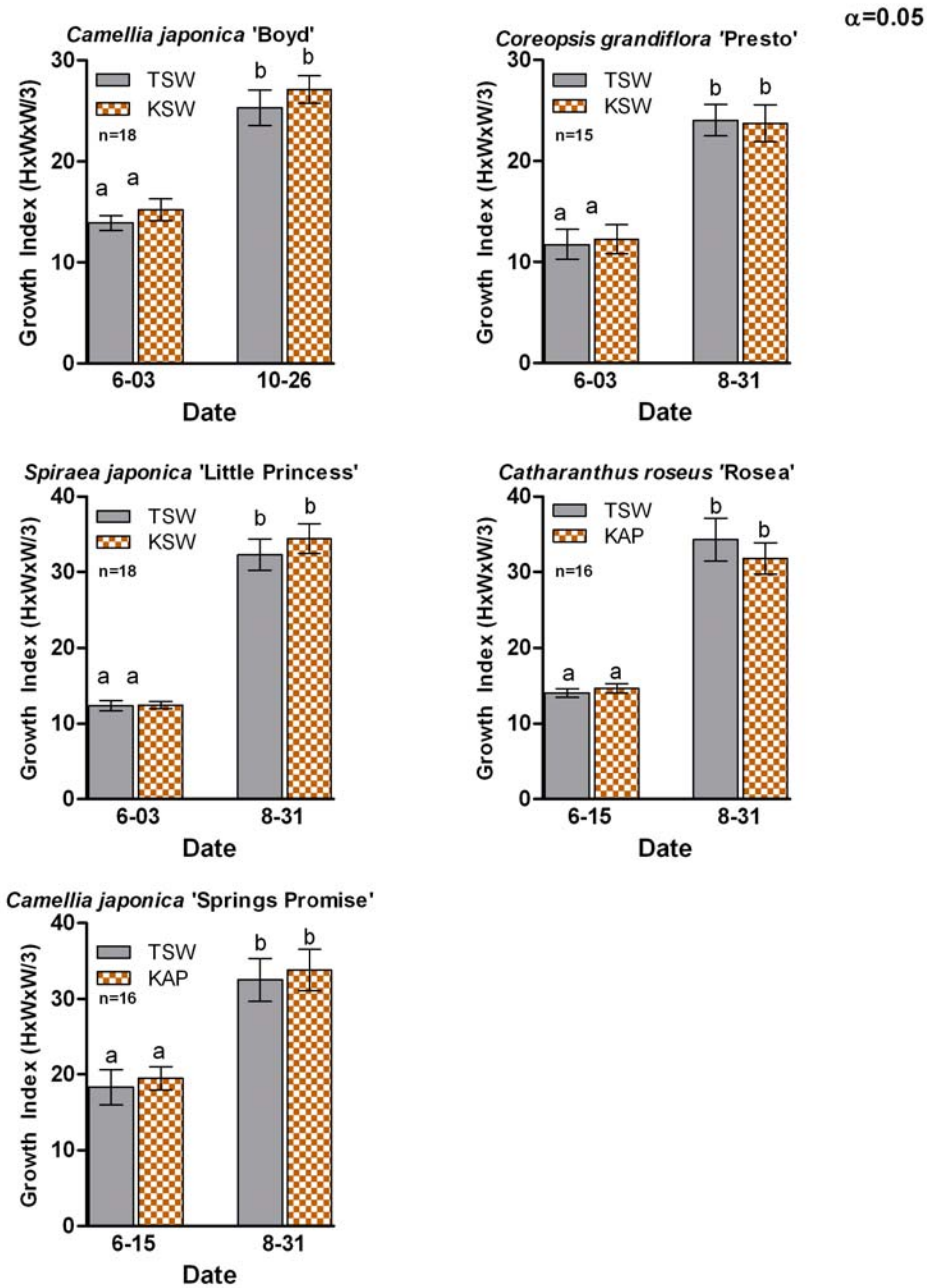


Figure 1. Growth response of ‘Boyd’ camellia, ‘Little Princess’ spirea, ‘Presto’ coreopsis, ‘Spring’s Promise’ camellia and ‘Rosea’ vinca grown in KSW, TSW or KAP containers.

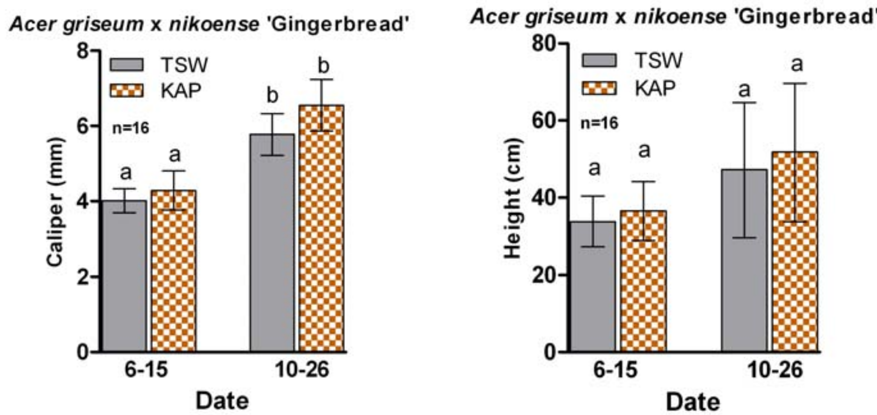


Figure 2. Height and caliper growth of ‘Gingerbread’ maple grown in KAP or TSW containers.

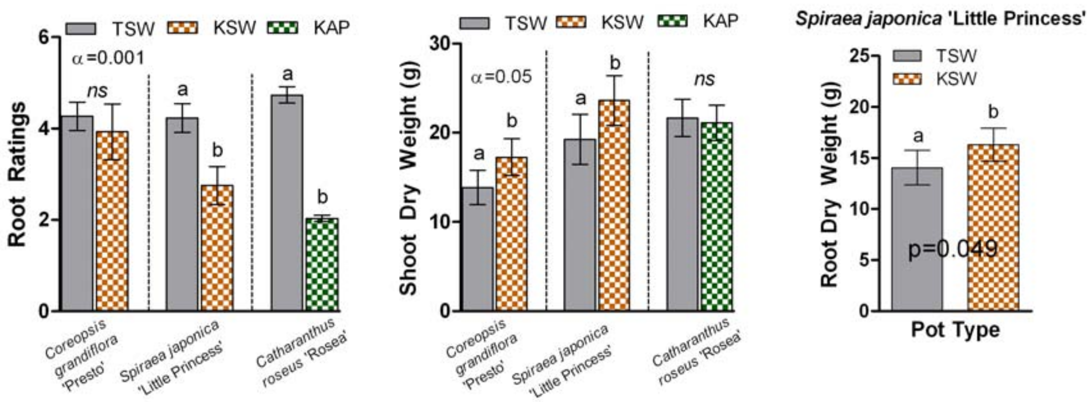


Figure 3. Root ratings and shoot dry weight of ‘Little Princess’ spirea, ‘Presto’ coreopsis and ‘Rosea’ vinca taken 31 Aug 2010 from plants grown in TSW, KSW and KAP containers and root dry weight of ‘Little Princess’ spirea.

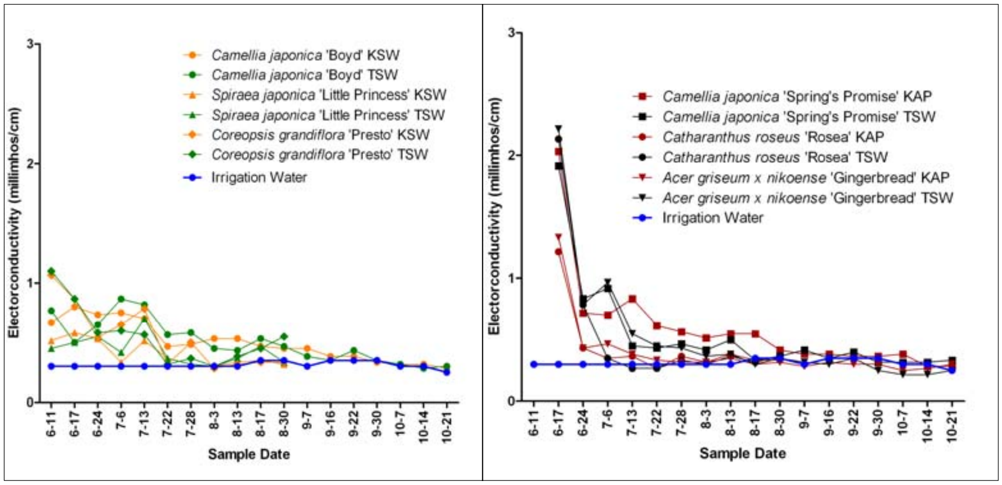


Figure 4. Electrical conductivity of container leachate from plants potted 2 and 15 June in TSW, KSW and KAP nursery containers.

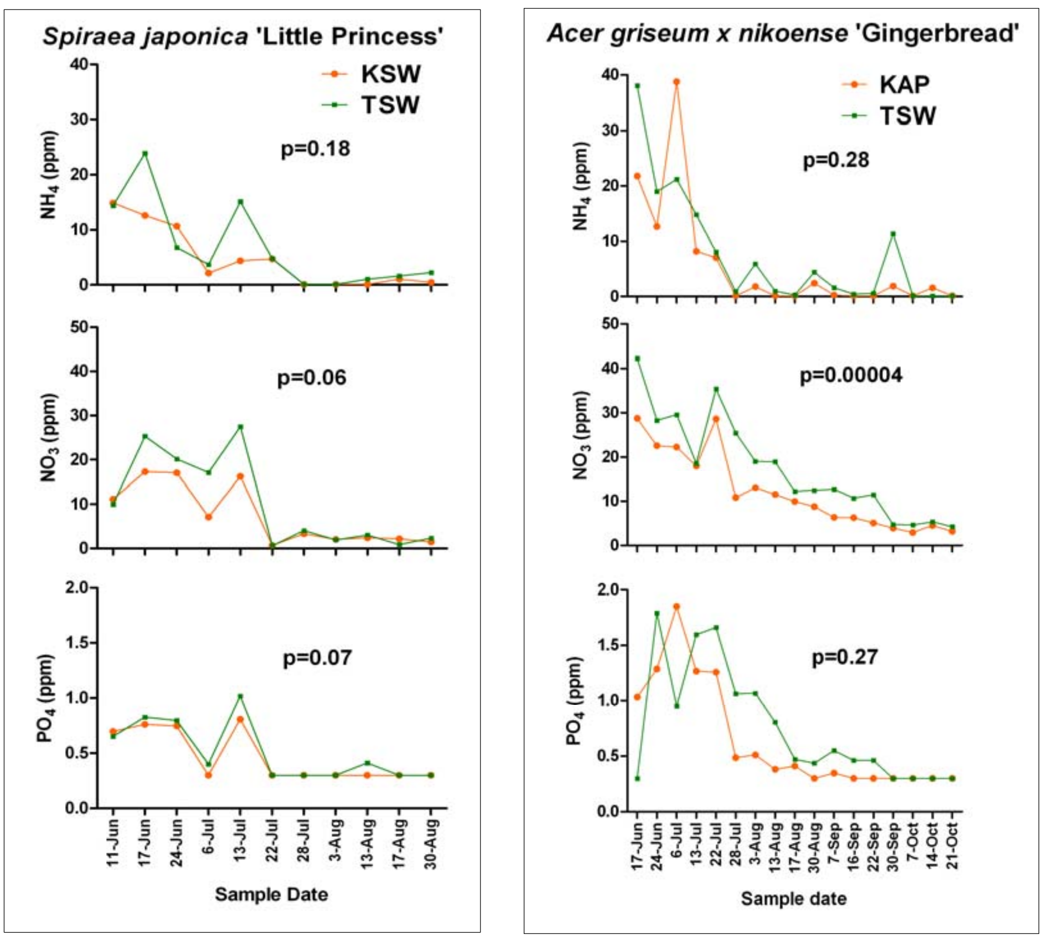


Figure 5. Phosphorus, nitrate-N and ammonium-N levels detected in weekly container leachates for 'Little Princess' spirea and 'Gingerbread' maple.

Plant Growth Promoting Rhizobacteria Positively Affect Root Growth and Nutrient Status of the Mexican Fan Palm (*Washingtonia robusta* Wendland: Arecaceae) Plants

Andrés Adolfo Estrada-Luna[1]; Esteban Camarena Olague[1];
José Carlos Romero González[1]; Victor Olalde-Portugal[2].

[1]Escuela de Agronomía. Universidad De La Salle Bajío. Av. Universidad 602, Col. Lomas del Campestre. León, Gto., México. C.P. 37150
[2]CINVESTAV-IPN. Km. 12.5. Libramiento Norte, Carretera Irapuato-León. Irapuato, Gto., México. C.P. 36821

aestradaluna@yahoo.com

Index Words: palms, plant growth promoting rhizobacteria, PGPRs, Mexican Washington palm, Mexican Washingtonia, Arecaceae.

Significance to Industry: The nursery industry can be benefited from the activity of naturally occurring microorganisms including soil rhizobacteria, which may be helpful in reducing pesticide and chemical fertilization inputs during production, promote plant growth, and increase product quality. Our data provide insights about the effects of selected PGPRs on young Mexican fan palm plants. This study demonstrated that PGPR enhance nutrient status and root growth and development, which may be of interest and application in sustainable agricultural commercial exploitations including woody and herbaceous plant species at the nursery industry.

Nature of Work: Plants growing under natural conditions are not isolated and intimately interact with harmful and beneficial macro and microorganisms above and underground. Beneficial microorganisms, which are those that fix atmospheric N, decompose organic wastes and residues, detoxify pesticides, suppress plant diseases and soil-borne pathogens, enhance nutrient cycling and produce bioactive compounds such as vitamins, hormones and enzymes that stimulate plant growth (1) includes different genus of fungi and bacteria. In particular, beneficial bacteria interact with plant roots by forming symbiotic associations (rhizobia) during biological nitrogen fixation; however, free living or non symbiotic bacteria referred as plant growth promoting rhizobacteria (PGPR) including *Acetobacter*, *Azospirillum*, *Azotobacter*, *Bacillus*, *Burkholderia, Pseudomonas*, etc. (2) enhance plant growth through several mechanisms including the synthesis of siderophores to facilitate nutrient uptake, hormones, low molecular mass compounds, enzymes or by reducing and preventing the deleterious effects of one or more pathogens (2, 3, 4, 5).

The Mexican fan palm (*Washingtonia robusta* Wendland) is a multipurpose plant cultivated as indoor and outdoor ornamental, to reforest degraded areas, as natural barrier or to recover eroded soils (6, 7, 8). Data on the biology (6, 7, 8), seed germination (9), and culture (7, 10) have recently been published; however, no information exists on the effects of the interaction PGPR - Mexican fan palm roots.

Because of this, any knowledge to understand this relationship may be applied on an ecological context or to enhance plant health and growth in sustainable commercial-oriented systems where chemical, water and nutrient inputs need to be reduced, and pathogen stresses are common production constrains. In this study we evaluated the effects of selected PGPRs on nutrient uptake and plant growth and assess PGPR root colonization.

A glasshouse study was conducted to evaluate three selected plant growth promoting rhizobacteria (PGPR) [*Bacillus subtilis* BEB-b13, *B. subtilis* BEB-Mz, *Azospirillum brasiliensis* BEB-Az] and their combinations. PGPR was inoculated by pipetting 30 mL of liquid inoculum directly on the roots, which corresponded to 5X10-6 cells (exponential phase of bacterial growth). At the end of the study, several growth measurements including leaf number, total shoot length (cm), root, shoot, total plant fresh (FM) and dry mass (DM) (g) were determined in all treatments. Root:shoot and Shoot:root ratio was calculated with the root and shoot DM data. Mineral nutrient analysis was performed from the aerial part of the plants (four mature and expanded leaves) to determine total concentration of all macronutrients and some micronutrients (Fe, Mn, Cu, Na, Zn). Samples were digested with a 2:1 $HNO_3/HClO_4$ solution. Nutrient uptake was calculated by multiplying the concentration (g Kg-1 or µg g-1) of a specific nutrient by the shoot DM (g). Root colonization by PGPRs was also determined.

Results and Discussion: After thirteen months of culture the *Washingtonia robusta* W. plants interacted with all PGPR tested and developed dense populations on the rhizosphere zone, which varied according to the bacteria or combination colonizing the roots. Our results provide the first data showing that PGPR can enhance nutrient status (Table 1, 2) and increase overall plant growth as compared to the control (Table 3, 4). Generally speaking, bacilli produced better results when compared to *Azospirillum*. The best treatment including a single inoculum was *B. subtilis* BEB-b13. The better dual combinations were *B. subtilis* BEB-Mz plus *B. subtilis* BEB-b13 and *Bacillus subtilis* BEB-b13 plus *Azospirillum brasiliensis* BEB-Az. Inoculation with PGPR increased total uptake of K, Fe, and Zn; however, the control enhanced Mn and S in leaf tissue concentration (Table 1, 2). This improvement in nutrient concentration resulted in better nutritional status in inoculated plants and enhanced plant growth and development. Greater carbon partitioning occurred in the root system of inoculated plants with *Bacillus subtilis* BEB-b13, which increased cumulative fresh and dry mass. The higher root:shoot ratio obtained from PGPR (>1.0) compared to control plants was an indication of changes in carbon partitioning and more effective root function (Table 3, 4).

Acknowledgements: Authors want to thank for the economical support provided by the Universidad De La Salle Bajío through the Office of the Research Council.

Literature Cited:

1. Singh JD, VC Pandey, DP Singh. 2011. Efficient soil microorganisms: A new dimension for sustainable agriculture and environment development. Agriculture, Ecosystems and Environment 140: 339-353.
2. Dimkpa C, T Weinand, F Asch. 2009. Plant-rhizobacteria interactions alleviate abiotic stress conditions. Plant, Cell & Environment 32: 1682-1694.
3. Glick BR. 1995. The enhancement of plant growth by free-living bacteria. Can. J. Microbiol. 41: 109-117.
4. Pérez-García A, D Romero, A de Vicente. 2011. Plant protection and growth stimulation by microorganisms: biotechnological applications of Bacilli in agriculture. Current Opinion in Biotechnology 22: 187-193.
5. Wipat, A., Harwood, C.R., 1999. The *Bacillus subtilis* genome sequence: the molecular blueprint of a soil bacterium. FEMS Microbiology Ecology 28: 1-9.
6. Bullock, S.H. and Heath D. 2006. Growth rates and age of native palms in the Baja California desert. Journal of Arid Environments 67: 391–402.
7. Gilman, E.F and Watson D.G. 1994. *Washingtonia robusta* Washington Palm. Fact Sheet ST-670, a series of the Environmental Horticulture Department, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida. 1-4pp.
8. Ishihata K. And Murata H. Morphological Studies in the Genus *Washingtonia*: On the Intermediate Form between *Washingtonia filifera* (L. Linden) H. Wendland and *Washingtonia robusta* H. Wendland. Ibusuki Experimental Botanic Garden. 331-354pp.
9. Estrada-Luna AA, A Rojas García. 2010. Improving Germination of seeds of Mexican Fan Palm (*Washingtonia robusta* H. Wendland) through physical and chemical treatments. 2010 SNA Research Conference 56: 314-318.
10. Estrada-Luna AA, HC Morales Torres, V Olalde-Portugal, E Camarena Olague, JC Romero Gonzalez. 2011. Effect of Cell Size on Growth and Physiology of Mexican Fan Palm (*Washingtonia robusta* H. Wendland: Arecaceae) Seedlings. 2011 SNA Research Conference 56: 389-392.

Table 1. Effects of selected Plant Growth Promoter Rhizobacteria on leaf mineral content (macronutrients) of Mexican Fan Palm (*Washingtonia robusta* H. Wendland) plants after 13 months of culture.

PGPR⁺ Treatment	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	S (ppm)
Control	1.25 a	0.11 a	3.75 ab	1.32 a	0.05 a	3712.50 ab
Mz•	1.34 a	0.14 a	4.11 ab	0.99 a	0.07 a	2272.28 c
Dn⊕	1.22 a	0.12 a	3.95 ab	1.05 a	0.05 a	2833.07 bc
Azº	1.20 a	0.12 a	3.81 ab	1.03 a	0.05 a	3059.03 bc
Mz X Dn	1.27 a	0.14 a	4.30 a	1.05 a	0.05 a	3675.35 ab
Mz X Az	0.88 a	0.13 a	3.69 ab	1.10 a	0.04 a	3147.87 bc
Az X Dn	1.32 a	0.12 a	4.21 a	1.27 a	0.06 a	4166.57 a
Mz X Az X Dn	1.30 a	0.13 a	3.19 b	1.00 a	0.05 a	3629.33 ab

⁺PGPR: Plant Growth Promoter Rhizobacteria, •Mz= *Bacillus subtilis* BEB-Mz, ⊕Dn= *Bacillus subtillis* BEB-Dn, ºAz= *Azosporillum brasiliensis* BEB-Az

Table 2. Effects of selected Plant Growth Promoter Rhizobacteria on leaf mineral content (micronutrients) of Mexican Fan Palm (*Washingtonia robusta* H. Wendland) plants after 13 months of culture.

PGPR⁺ Treatment	Fe (ppm)	Cu(ppm)	Zn (ppm)	Mn (ppm)
Control	178.06 c	16.00 a	15.56 d	170.11 a
Mz•	370.83 ab	22.06 a	17.14 bcd	114.75 b
Dn⊕	283.89 bc	16.56 a	16.22 cd	136.00 ab
Azº	203.17 c	19.33 a	20.60 abc	114.31 b
Mz X Dn	521.67 a	19.94 a	23.51 a	129.86 ab
Mz X Az	281.83 bc	17.22 a	20.19 abc	134.39 ab
Az X Dn	165.56 c	17.67 a	20.84 ab	137.08 ab
Mz X Az X Dn	245.00 bc	18.50 a	24.09 a	120.78 ab

⁺PGPR: Plant Growth Promoter Rhizobacteria, •Mz= *Bacillus subtilis* BEB-Mz, ⊕Dn= *Bacillus subtillis* BEB-Dn, ºAz= *Azosporillum brasiliensis* BEB-Az

Table 3. Effects of selected PGPRs on growth and development (Fresh Weight) of Mexican Fan Palm (*Washingtonia robusta* H. Wendland) plants after 13 months of culture.

PGPR+ Treatment	Root (g)	Stem (g)	Leaf (g)	Shoot (g)	Plant (g)	Height (cm)	Leaf Number
Control	243.50 ab	84.88 a	64.38 a	149.25 c	392.75 ab	63.50 a	12.00 a
Mz•	298.88 a	98.50 a	76.38 a	174.88 a	473.75 a	64.00 a	12.13 a
Dn⊕	283.25 a	95.88 a	70.05 a	166.38 ab	449.63 a	63.63 a	12.38 a
Azº	244.88 ab	101.00 a	76.00 a	177.00 a	421.88 ab	63.75 a	12.38 a
Mz X Dn	241.38 ab	91.63 a	67.50 a	159.13 ab	400.50 ab	62.88 a	12.00 a
Mz X Az	273.88 ab	89.75 a	71.00 a	160.75 ab	434,63 ab	62.75 a	12.13 a
Az X Dn	267.13 ab	96.88 a	68.13 a	165.00 ab	432.63 ab	64.13 a	12.25 a
Mz X Az X Dn	218.75 b	77.88 a	63.88 a	141.75 c	360.50 b	61.00 a	11.75 a

+PGPR: Plant Growth Promoter Rhizobacteria, •Mz= *Bacillus subtilis* BEB-Mz, ⊕Dn= *Bacillus subtillis* BEB-Dn, ºAz= *Azosporillum brasiliensis* BEB-Az

Table 4. Effects of selected PGPRs on growth and development (Dry Weight) of Mexican Fan Palm (*Washingtonia robusta* H. Wendland) plants after 13 months of culture.

PGPR+ Treatment	Root (g)	Stem (g)	Leaf (g)	Shoot (g)	Plant (g)	Root to Shoot ratio ($g\ g^{-1}$)	Shoot to Root ratio ($g\ g^{-1}$)
Control	48.38 a	26.75 a	24.00 a	50.75 a	99.13 a	0.96 a	1.06 a
Mz•	55.25 a	29.00 a	26.38 a	55.38 a	110.63 a	1.01 a	1.02 a
Dn⊕	54.63 a	29.50 a	25.63 a	55.13 a	109.75 a	1.00 a	1.02 a
Azº	46.63 a	30.00 a	27.38 a	57.38 a	104.00 a	0.85 a	1.26 a
Mz X Dn	48.25 a	27.63 a	23.75 a	51.38 a	99.63 a	0.97 a	1.12 a
Mz X Az	53.50 a	27.25 a	26.38 a	53.63 a	107.13 a	1.01 a	1.05 a
Az X Dn	48.25 a	28.63 a	24.50 a	53.13 a	101.38 a	0.90 a	1.33 a
Mz X Az X Dn	42.25 a	30.13 a	23.00 a	53.13 a	95.38 a	0.87 a	1.25 a

+PGPR: Plant Growth Promoter Rhizobacteria, •Mz= *Bacillus subtilis* BEB-Mz, ⊕Dn= *Bacillus subtillis* BEB-Dn, ºAz= *Azosporillum brasiliensis* BEB-Az

Interaction Between Selected Endomycorrhizas and Roots of the Mexican Fan Palm (*Washingtonia robusta* Wendland) Improve Overall Plant Growth and Nutrient Status

Andrés Adolfo Estrada-Luna[1]; José Carlos Romero González[1]; Esteban Camarena Olague[1]; Victor Olalde-Portugal[2]

[1]Escuela de Agronomía. Universidad De La Salle Bajío. Av. Universidad 602, Col. Lomas del Campestre. León, Gto., México. C.P. 37150
[2]CINVESTAV-IPN. Km. 12.5. Libramiento Norte, Carretera Irapuato-León. Irapuato, Gto., México. C.P. 36821

aestradaluna@yahoo.com

Index Words: endomycorrhizas, vesicular arbuscular mycorrhizas, palms, Mexican Washington palm, Mexican Washingtonia, Arecaceae

Significance to Industry: The nursery industry stands to benefit from naturally occurring soil microorganisms including mycorrhizal fungi symbionts that enhance plant health when properly interact with roots. The benefits of mycorrhizal symbiosis are of interest for a low input-sustainable agricultural system both at greenhouse, nursery production stage and field production stage. In this study, we demonstrated that inoculated *Washingtonia robusta* plants were extensively colonized with different endomycorrhizal fungi. Overall plant growth and nutrient status was significantly increased by mycorrhizas when compared to the control. However, a fungal consortium established a more efficient interaction that single pure isolates. There is great potential in using selected mycorrhizal isolates for improving growth of slow-growing plant species during field establishment of commercial orchards. This has application to other ornamental palms cultured under commercial nursery production systems in the US.

Nature of Work: Ubiquitous mycorrhizal fungi establish mutualistic and beneficial associations with most plant species including angiosperms and gymnosperms (1). Palms are woody perennial monocots, which are known to form mycorrhizas (2, 3, 4, 5, 6, 7) with several *Glomus* species (*G. aggregatum, G. deserticola, G. mossae, G. clarum, G. monosporus*). The mycorrhizal colonization on palms promotes better growth and enhances nutrient uptake on poor native soils (7) and is potentially significant in the ecology of wild palms and in the cultivation of ornamental palms. Although some studies have been published on the effects of mycorrhizas in palm species (2, 3, 6, 7), only limited and discrepant information on the Mexican fan palm has been published (8).

We ran a factorial experiment to study the effects of three endomycorrhizal fungi (EMF) isolates plus the control and two fertilization regimes (22 and 44 ppm of P) on growth, nutrient concentration and uptake of *Washingtonia robusta* H. Wendland young plants. The three experimental EMF included a consortium and two pure isolates: a) The Mexican consortium Selva (SE), which is composed by *Glomus constrictum*, *G. fasciculatum*, *G. tortuosum*, and *Acaulospora scrobiculata*, b). *G. clarum (*GC) pure isolate, c) *G. intraradices* (GI) pure isolate. During transplantation, the EMF, which corresponded to approximately 1,000 fungal spores, was applied by banding the inoculum just below the roots. The Mexican fan palm seedlings were obtained through seed germination (9) and cultured for 45 days before transplantation. Fertilization was provided with the Long Ashton nutrient solution modified according the experimental treatments. After thirteen months of culture under greenhouse conditions, several growth measurements including leaf number, total shoot length (cm), root, leaf, shoot, total plant fresh (FM) and dry mass (DM) (g) were determined in all treatments. Root:shoot and Shoot:root ratio was calculated with the root and shoot DM data. Mineral nutrient analysis was performed from the aerial part of the plants (four mature and expanded leaves) to determine total concentration of all macronutrients and some micronutrients (Fe, Mn, Cu, Na, Zn). Samples were digested with a 2:1 $HNO_3/HClO_4$ solution. Nutrient uptake was calculated by multiplying the concentration (g Kg-1 or µg g-1) of a specific nutrient by the shoot DM (g). Root colonization by EMF was also determined.

Results and Discussion: After thirteen months of greenhouse culture the roots of uninoculated plants remained free of EMF, while inoculated plants were extensively colonized and several internal hyphae, spores, vesicles, and arbuscules in root cortical cells were observed. Data on root colonization varied according the inoculum tested (45 to 84%). Out data showed that the Mexican fan palm is highly dependent mycorrhizal plant because the presence of EMF significantly increased overall plant growth when compared with the control treatment; however, no significant effect was recorded for P-level (Tables 1, 2). Significant differences were observed in plant height, leaf number, and stem, leaf, shoot, and plant fresh (Table 1) and dry (Table 2) mass accumulation between mycorrhizal and control treatments. In general, the consortium SE established the best beneficial interaction and it would be considered the best EMF for *Washingtonia robusta* plants since much better growth was observed as compared with the other isolates. Supplementary P did not show statistically significant differences in the two levels tested; however, the two pure isolates produced better responses when fertilized with 22 ppm of P. In contrast to this observation, 44 ppm of P enhaced the positive effects of the SE consortium. EMF and P levels affected foliar tissue elemental concentration of the Mexican fan palm young plants. Mycorrhizal associations had increased concentrations of P, Mg, Cu, and Zn in foliar tissue, but had lower Mn than NonEMF plants.

Acknowledgements: Authors want to thank for the economical support provided by the Universidad De La Salle Bajío through the Office of the Research Council.

Literature Cited:

1. Smith SE, I Jackobsen, M Gronlund, FA Smith. 2011. Roles of arbuscular mycorrhizas in plant phosphorus nutrition: Interactions between pathways of phosphorus uptake in arbuscular mycorrhizal roots have important implications for understanding and manipulating plant phosphorus acquisition. Plant Physiology 156: 1050-1057.

2. St. John TV. 1988. Prospects for application of vesicular-arbuscular mycorrhizae in the culture of tropical palms. Adv. Econ. Bot. 6: 50–55.
3. Al-Whaibi MH, AS Khaliel. 1994. The effect of Mg on Ca, K and P content of date palm seedlings under mycorrhizal and non-mycorrhizal conditions. Mycoscience 35: 213-217.3.
4. Clement CR, M Habte. 1995. Genotypic variation in vesicular-arbuscular mycorrhizal dependence of the pejibaye pal. Journal of Plant Nutrition 18: 1907-1916.
5. Dreyer B, A Morte, M Pérez-Gilabert, M Honrubia. 2006. Autoflorescence detection of arbuscular mycorrhizal fungal structures in palm rotos: an underestimated experimental method. Mycological Research 110: 887-897.
6. Fisher, JB, K Jayachandran. 1999. Root structure and arbuscular mycorrhizal colonization of the palm *Serenoa repens* under field conditions. Plant and Soil 217: 229-241.
7. Janos D.P. 1977. Vesicular-arbuscular mycorrhizae affect the growth of *Bactris gasipaes*. Principes 21: 12–18.
8. Broschat TK, ML Elliot. 2010. Effects of fertilization and microbial inoculants applied at transplanting on the growth of Mexican fan palm and queen palm. HortTechnology 19: 324-330.
9. Estrada-Luna AA, HC Morales Torres, V Olalde-Portugal, E Camarena Olague, JC Romero Gonzalez. 2011. Effect of Cell Size on Growth and Physiology of Mexican Fan Palm (*Washingtonia robusta* H. Wendland: Arecaceae) Seedlings. 2011 SNA Research Conference 56: 389-392.

Table 1. Effects of selected vesicular arbuscular mycorrhizas and phosphorus levels on growth and development (Fresh Weight) of Mexican Fan Palm (*Washingtonia robusta* H. Wendland) plants after 13 months of culture.

EMF+ Treatment	P Level (mM)	Root (g)	Stem (g)	Leaf (g)	Shoot (g)	Plant (g)	Height (cm)	Leaf Number
Control	22	375.1 ± 33.2	138.1 ± 16.7	99.7 ± 14.8	237.9 ± 31.2	613.0 ± 56.9	71.9 ± 4.0	12.3 ± 0.4
Control	44	372.1 ± 31.9	141.4 ± 12.1	108.4 ± 15.4	249.9 ± 27.4	622.0 ± 55.9	70.9 ± 4.8	12.1 ± 0.3
GIº	22	346.1 ± 19.5	218.4 ± 10.3	141.6 ± 10.8	360.0 ± 19.9	706.1 ± 38.6	83.4 ± 1.4	13.9 ± 0.3
GIº	44	379.7 ± 32.1	226.7 ± 23.7	161.1 ± 23.7	387.9 ± 46.6	767.6 ± 77.3	81.9 ± 3.2	13.4 ± 0.4
SE‡	22	393.1 ± 40.7	226.7 ± 19.6	152.1 ± 16.0	378.9 ± 34.7	772.0 ± 72.5	79.3 ± 2.6	13.6 ± 0.6
SE‡	44	433.9 ± 22.3	267.9 ± 15.5	173.4 ± 9.7	441.3 ± 24.1	875.1 ± 41.1	84.3 ± 1.7	14.0 ± 0.2
GC«	22	398.3 ± 39.7	191.3 ± 13.8	139.6 ± 10.4	330.9 ± 23.6	729.1 ± 48.8	80.6 ± 2.4	13.6 ± 0.3
GC«	44	419.4 ± 30.3	196.7 ± 15.00	137.3 ± 8.9	23.6 ± 23.4	753.4 ± 40.0	80.1 ± 2.5	13.1 ± 0.3
Significance:								
EMF		NS⊕	***	***	***	**	***	***
P		NS	NS	NS	NS	NS	NS	NS
EMF X P		NS	NS	NS	NS	NS	NS	NS

+ EMF: Endomycorrhizal Fungi, • P= Phosphorus, ºGI= *Glomus intraradices*, ‡SE= Consortium Selva, «GC= *Glomus clarum*, ⊕ NS= Non-significant, ***= Significant (0.001)

Table 2. Effects of selected endomycorrhizas and phosphorus levels on growth and development (Dry Weight) of Mexican Fan Palm (*Washingtonia robusta* H. Wendland) plants after 13 months of culture.

VAM+ Treatment	P• Level (mM)	Root (g)	Stem (g)	Leaf (g)	Shoot (g)	Plant (g)	Root / Shoot ratio (g g^{-1})	Shoot / Root ratio (g g^{-1})
Control	22	93.3 ± 8.9	41.7 ± 4.3	37.4 ± 5.3	79.1 ± 9.5	172.4 ± 16.1	1.30 ± 0.1	0.90 ± 0.1
Control	44	90.3 ± 8.4	45.7 ± 3.1	41.6 ± 5.0	87.3 ± 7.6	177.6 ± 15.4	1.00 ± 0.1	1.00 ± 0.1
GIº	22	99.4 ± 6.9	58.4 ± 4.3	59.0 ± 3.2	117.4 ± 7.1	216.9 ± 13.2	0.80 ± 0.01	1.20 ± 0.01
GIº	44	100.9 ± 8.2	66.6 ± 7.3	63.6 ± 7.0	130.1 ± 13.4	231.0 ± 20.9	0.80 ± 0.1	1.30 ± 0.1
SE‡	22	112.0 ± 14.1	66.1 ± 5.9	64.1 ± 5.3	130.3 ± 10.9	242.3 ± 23.3	0.90 ± 0.1	1.20 ± 0.1
SE‡	44	108.7 ± 7.6	71.4 ± 4.3	71.1 ± 5.1	142.6 ± 7.6	251.3 ± 14.0	0.80 ± 0.01	1.30 ± 0.1
GC«	22	105.4 ± 10.1	51.7 ± 4.8	55.6 ± 4.9	107.3 ± 7.8	212.7 ± 16.7	1.00 ± 0.1	1.10 ± 0.1
GC«	44	110.7 ± 15.1	60.3 ± 5.0	54.7 ± 3.3	115.0 ± 8.3	225.7 ± 20.0	1.00 ± 0.1	1.10 ± 0.1
Significance:								
EMF		NS⊕	***	***	***	***	***	***
P		NS	NS	NS	NS	NS	NS	NS
EMF X P		NS	NS	NS	NS	NS	NS	NS

+ EMF: Endomycorrhizal Fungi, • P= Phosphorus, ºGI= *Glomus intraradices*, ‡SE= Consortium Selva, «GC= *Glomus clarum*, ⊕ NS= Non-significant, ***= Significant (0.001)

Table 3. Effects of selected VAM and phosphorus levels on leaf mineral content (macronutrients) of Mexican Fan Palm (*Washingtonia robusta* H. Wendland) plants after 13 months of culture.

EMF+ Treatment	P• Level (ppm)	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	S (ppm)
Control	22	1.35 ± 0.04	0.13 ± 0.01	3.63 ± 0.27	0.94 ± 0.01	0.04 ± 0.01	3060.53 ± 243.13
Control	44	1.30 ± 0.05	0.12 ± 0.00	3.68 ± 0.30	0.93 ± 0.06	0.04 ± 0.01	3390.13 ± 220.72
GIº	22	1.39 ± 0.03	0.16 ± 0.01	3.55 ± 0.26	0.85 ± 0.04	0.07 ± 0.01	3086.28 ± 66.01
GIº	44	1.40 ± 0.07	0.17 ± 0.02	3.29 ± 0.07	0.83 ± 0.05	0.05 ± 0.00	3325.53 ± 485.27
SE‡	22	1.38 ± 0.04	0.14 ± 0.01	4.10 ± 0.54	0.84 ± 0.11	0.06 ± 0.01	2900.00 ± 99.97
SE‡	44	1.39 ± 0.04	0.17 ± 0.01	3.90 ± 0.32	0.76 ± 0.04	0.04 ± 0.01	2926.86 ± 167.99
GC«	22	1.41 ± 0.02	0.21 ± 0.02	5.03 ± 0.73	0.81 ± 0.07	0.04 ± 0.01	2549.50 ± 93.40
GC«	44	1.38 ± 0.06	0.18 ± 0.01	3.11 ± 0.23	0.93 ± 0.08	0.04 ± 0.01	3011.55 ± 213.77
Significance:							
EMF		NS⊕	***	*	NS	*	NS
P		NS	NS	NS	NS	NS	NS
EMF X P		NS	NS	NS	NS	NS	NS

+ EMF: Endomycorrhizal Fungi, • P= Phosphorus, ºGI= *Glomus intraradices*, ‡SE= Consortium Selva, «GC= *Glomus clarum*, ⊕ NS= Non-significant, ***= Significant (0.001)

Table 4. Effects of selected VAM and different phosphorus levels on leaf mineral content (micronutrients) of Mexican Fan Palm (*Washingtonia robusta* H. Wendland) plants after 13 months of culture.

EMF+ Treatment	P• Level (ppm)	Fe (ppm)	Cu (ppm)	Zn (ppm)	Mn (ppm)
Control	22	228.33 ± 30.80	17.33 ± 1.62	16.49 ± 0.74	104.61 ± 2.96
Control	44	247.50 ± 31.26	15.33 ± 0.51	17.23 ± 1.22	95.72 ± 10.07
GIº	22	403.33 ± 86.80	24.72 ± 2.67	17.88 ± 0.17	72.28 ± 2.78
GIº	44	357.50 ± 74.19	23.17 ± 2.10	19.41 ± 1.11	73.06 ± 9.19
SE‡	22	288.89 ± 51.41	21.56 ± 1.39	17.13 ± 1.70	66.67 ± 3.49
SE‡	44	233.50 ± 22.90	22.06 ± 2.02	17.00 ± 0.62	71.36 ± 7.07
GC«	22	204.17 ± 67.64	30.39 ± 3.32	16.41 ± 0.32	69.42 ± 5.56
GC«	44	242.78 ± 44.14	27.72 ± 4.85	15.72 ± 0.33	80.75 ± 1.04
Significance:					
VAM		*	**	*	*** ⊗
P		NS⊕	NS	NS	NS
VAM X P		NS	NS	NS	NS

+ EMF: Endomycorrhizal Fungi, • P= Phosphorus, ºGI= *Glomus intraradices*, ‡SE= Consortium Selva, «GC= *Glomus clarum*, ⊕ NS= Non-significant, ***= Significant (0.001)

An In-Depth look at Fertilizer and Irrigation Practices in Maryland's Ornamental Nursery Industry

John Majsztrik[1*], Andrew Ristvey[2], and John Lea-Cox[1]

[1] 2102 Plant Science Building, University of Maryland, College Park, MD, 20742
[2] Wye Research & Education Center, P.O. Box 169, Queenstown, MD, 21658

jcmajsz@umd.edu

Index Words: Greenhouse, container nursery, field nursery, nutrient, water, application rates

Significance to the Industry: The nursery and greenhouse industry is under increased scrutiny and regulation with regard to irrigation, fertilizer, chemical applications and runoff. Researchers and extension agents have been making substantial progress in researching these areas and providing recommendations to growers. We have found however, there is minimal published information on what best management practices ornamental growers have implemented in their operations. We therefore developed a comprehensive water and nutrient management practice database, with the voluntary assistance of 47 nursery and greenhouse growers in Maryland. This information provides us with a baseline for determining cultural inputs in the ornamental industry in Maryland, and could be used as a template for gathering similar information in other states. As Maryland works towards reducing nutrient and sediment loads to the Chesapeake Bay, general BMP implementation information could be used to inform government leaders and educate them about the concerted efforts this industry has made during the past ten years, and the BMP's that the industry has in place. It appears that much of this information has not been communicated to regulators and legislators, at least in Maryland. As the industry further improves their practices, we hope to use this baseline data to quantify improvements in nutrient and water management by this industry and determine the economic and environmental benefits of those changes.

Nature of Work: The Nursery and greenhouse industry is ranked in the top 5 market values of agricultural products sold in 34 states [1]. Along with the financial benefits of the industry, there are a number of environmental issues associated with the production of ornamental plants. Ornamental production operations typically have high rates of nutrient and irrigation inputs, especially in greenhouse and container-nursery operations [2-6]. Frequent irrigation combined with high fertilizer and pesticide use can lead to significant losses of agricultural chemicals in runoff water, which transports chemicals to containment structures, groundwater or surface water [7-9]. Irrigation water management is the key to nutrient management in ornamental crop production and reducing the impact of runoff water on local water resources [10, 11].

The nursery and greenhouse industry faces additional difficulties compared to traditional agriculture, in that the nutrient requirement of many species being grown is not known, crop production times can vary from weeks to years, a variety of production systems exist which have differing impacts, and different nutrient and irrigation practices are used [5]. Due to these variables, writing water and nutrient management plans requires a risk assessment approach, which has the advantage of allowing the grower to design and implement site-specific best management practices for the entire operation [10]. There is also a major concern across the country about reduced irrigation allocations for the nursery and greenhouse industry, and increased regulation of nutrients, sediment, and pesticides and other chemicals in runoff water [5]. This is particularly true in Maryland, where federal regulation of the Chesapeake Bay is currently being implemented for total maximum daily load (TMDL) limits on the Bay's 94 watershed segments [12]. Although the nursery and greenhouse industry makes up a relatively small amount of the overall farmland in the state, many operations are intensively managed, especially greenhouse and container operations. This leads to the *potential* for high levels of nutrient and sediment runoff *if* proper nutrient application and abatement practices are not followed.

To understand the complexities of irrigation and application practices in nursery and greenhouse operations in Maryland, site visits were conducted around the state. A total of 47 container, field and greenhouse operations voluntarily agreed to participate in this project, out of approximately 350 operations in the state. Growers were interviewed for 2-3 hours, and provided detailed information about irrigation and nutrient application rates and timings, as well as various best management practices that were used. Data was collected on a management unit level, for each operation. A management unit can be defined as the same or similar species of plants that have similar container sizes and cultural conditions. There may be any number of management units at an operation, depending on its size and complexity, and how the various plants that are grown are managed.

These data were separated into three databases for greenhouse, container nursery and field nursery. Some data, such as pounds per acre per year of nutrient were derived from the information provided by growers (i.e. using fertigation ppm, frequency, volume applied etc). If the grower applied a range of rates to a particular management unit (for example fertigation was applied 3-5 times a week), the information presented in this paper is the maximum application rate. This was done to maintain uniformity in the data, and represents the maximum amount of nutrients that would be applied during a typical crop cycle. If different rates were applied during a typical crop cycle (for example lower rates for the first ⅓ of the cycle, and a higher rate thereafter), that information is reflected in the data presented here. In this paper, we focus specifically on our major findings for container- and field nursery operations.

Results and Discussion:

Container-nursery operations: Irrigation application rates for container nurseries in this study are reported in Table 1. Many operations were irrigated for different lengths of time during spring and summer; with irrigation rates in the fall often being similar to spring; spring and summer irrigation rates are therefore reported separately. Irrigation rates for container-nursery operations were much higher than for greenhouse, especially at the upper quartile rates of 34,810 and 38,075 gal/application for spring and summer respectively (Table 1) compared to greenhouse operations which had an upper quartile rate of 9,253 gal/application ([13] data not shown). Irrigation rates are likely higher in container-nursery operations, since plants are typically more widely spaced, container sizes are often larger, and overhead irrigation is widely used, which decreases interception efficiency compared to greenhouse operations.

The majority (86%) of container operations surveyed used slow-release fertilizer (SRF) as the main or only source of fertilizer ([13]; data not shown). The high percentage of SRF use represents a major reduction in risk, compared to using overhead soluble fertilizer [14]. Nevertheless, upper quartile rates that are being applied (Table 2) are likely in excess of plant needs, which increases the potential for nutrient runoff from container-nursery operations. Plants that were grown using the average and lower quartile rates had similar production times compared to the upper quartile rates, and were likely meeting plant nutrient requirements (data not shown). It should be noted that rates reported for Tables 2 and 3 were not adjusted for plant densities, although similar spacings were used for the same container size or type of tree grown. The upper rates in Table 2 are likely in excess of plant needs, and could be reduced to realize financial savings, and reduce nutrient runoff. It is likely that container-nursery growers could reduce application rates to many plant species to at least average rates (Table 2) without any reduced growth or increase in production time. This would save money, and would reduce nutrient runoff over higher application rates, as indicated by water and nutrient models that have been developed, as part of this study [10; data not shown].

We noted some interesting comparisons between greenhouse and container operations. For example, container-grown 1-2 gallon mums (using mainly SRF) from Table 2 had an upper quartile rate of 82 lb of N/ac/yr and 30 lb of P/ac/yr. Greenhouse grown mums (using mainly soluble fertilizer) had an upper quartile rate of 431 lb of N/ac/yr and 477 lb of P/ac/yr [10]. Plants are produced in similar container sizes in approximately the same amount of time, and are of similar quality. This is an example where switching to slow-release fertilizer over soluble or reducing soluble fertilizer rates could substantially reduce nutrient inputs, and most likely reduce direct nutrient runoff [14].

Field Operations: On a per acre per year basis, field operations, especially those using drip irrigation, typically have the lowest irrigation use in the ornamental industry. Drip or micoirrigation is a cost-effective method for irrigating field operations, with decreased evaporation compared to overhead irrigation, which greatly increases water and nutrient application and interception efficiency.

Field operations were found to apply relatively low rates of N, P_2O_5 and K_2O, with typical rates below 50 lb/acre (Table 3). These low rates reduce the potential for nutrient loss, although sediment loss is a concern if best management practices (grass strips within and between blocks) are not used for managing erosion loss. A rate of 25-50 lb N, 6-15 lb P_2O_5, and 20- 40 lb K_2O per acre per year is recommended for all in-ground field stock, based on information from Bilderback [15] and Table 3.

The biggest concern in field operations is what happens when plants are harvested and fields are renovated before replanting. If heavy rainfall events occur during the establishment period, there is a chance of sediment and nutrient loss, compared to after rows are established. However, given that field growth cycles are typically from 5-7 years, this represents a relatively low risk, especially if fields are reestablished in the spring, with a full year for cover strips to establish. This is the best management practice that is typically followed by growers. In row and end of row buffer strips are recommended BMPs, and were present in 100% of the operations that were visited as part of this study. Field growers interviewed as part of this study used a variety of N : P_2O_5 : K_2O ratios, with 1 or 2 different fertilizer ratios used at each operation ([13] data not shown). There did not appear to be a particular reason why growers choose a particular fertilizer ratio at their operation.

Summary: The greenhouse, container nursery and field nursery operations that were visited as part of this project reported a variety of irrigation and nutrient application rates. Overall irrigation rates were lowest in field operations, followed by greenhouse, with container operations often applying the highest amounts of water per irrigation. There were often a wide range of nutrient application rates within similar management units, leading to the potential for decreased application rates, since similar plants are being produced in similar amounts of time, with less nutrient inputs with management units at the lower range. In general, greenhouse and container operations could reduce nutrient inputs for a number of crops and management units. Greenhouse and container-operations typically had implemented a number of site-specific BMP's that reduced the potential for nutrient and water runoff at their operations. Field operations that were visited had very low nutrient and irrigation inputs, and again were using a number of recommended BMP's to reduce the potential for nutrient and sediment runoff.

Literature Cited

1. U. S. Department of Agriculture. 2009. 2007 Census of Agriculture. National Agricultural Statistics Serv., Washington, D.C. 739.
2. Bilderback, T.E. 2001. Environmentally compatible container plant production practices. *Acta Horticulturae*. 548: 311-318.
3. Blythe, E.K., J.L. Mayfield, B.C. Wilson, E.L. Vinson, and J.L. Sibley. 2002. Comparison of three controlled-release nitrogen fertilizers in greenhouse crop production. *Journal of Plant Nutrition*. 25(5): 1049-1061.
4. Latimer, J.G., R.B. Beverly, C.D. Robacker, O.M. Lindstrom, R.D. Oetting, D.L. Olson, S.K. Braman, P.A. Thomas, J.R. Allison, W. Florkowski, J.M. Ruter, J.T. Walker, M.P. Garber, and W.G. Hudson. 1996. Reducing the pollution potential of pesticides and fertilizers in the environmental horticulture industry: I. Greenhouse, nursery, and sod production. *HortTechnology*. 6(2): 115-124.

5. Majsztrik, J.C., A.G. Ristvey, and J.D. Lea-Cox. 2011. Water and nutrient management in the production of container-grown ornamentals. *Horticultural Reviews*. 38: 253-297.
6. Mangiafico, S., S., J. Newman, D.J. Merhaut, G. Jay, B. Faber, and L. Wu. 2009. Nutrients and pesticides in stormwater runoff and soil water in production nurseries and citrus and avocado groves in California. *HortTechnology*. 19(2): 360-367.
7. Briggs, J.A., M.B. Riley, and T. Whitwell. 1998. Quantification and remediation of pesticides in runoff water from containerized plant production. *Journal of Environmental Quality*. 27: 814-820.
8. Cabrera, R.I. 2005. Challenges and advances in water and nutrient management in nursery and greenhouse crops. *Agric. Mediterr.* 135: 147-160.
9. Camper, N.D., T. Whitwell, R.J. Keese, and M.B. Riley. 1994. Herbicide levels in nursery containment pond water and sediments. *Journal of Environmental Horticulture*. 12: 8-12.
10. Lea-Cox, J.D., D.S. Ross, and K.M. Teffeau. 2001. A water and nutrient management planning process for container nursery and greenhouse production systems in Maryland. *Journal of Environmental Horticulture*. 19(4): 230-236.
11. Tyler, H.H., S.L. Warren, and T.E. Bilderback. 1996. Reduced leaching fractions improve irrigation use efficiency and nutrient efficacy. *Journal of Environmental Horticulture*. 14(4): 199-204.
12. Early, W.C. 2009. United States environmental protection agency region III: Preliminary Nitrogen and Phosphorus TMDLs. L.P. Bryant, Jr. Richmond, VA. 5.
13. Majsztrik, J. 2011. Modeling Nitrogen, Phosphorus and Water Dynamics in Greenhouse and Nursery Production Systems. Plant Science and Landscape Architecture, University of Maryland.College Park. 403
14. Ristvey, A.G. 2004. Water and nutrient dynamics in container-nursery production systems. Ph.D. thesis. Natural Resource Sciences and Landscape Architecture, Univ. Maryland.College Park, MD. 254 pp
15. Bilderback, T. Conservation and nutrient management practices for field production of nursery stock. North Carolina State University. Raleigh, NC.

Table 1. Gallons of water per acre applied per irrigation event, based on information from site visits to 27 container nursery operations representing 155 management units, and 17 field operations representing 29 management units. Quartile values are the average of: the lowest 25% of values (lower), middle 50% of values (middle), and highest 25% of values (upper).

	Gallons per acre per application		
	Container spring	Container summer	Field
Minimum	784	784	600
Lower quartile	8,469	9,827	3,485
Middle quartile	14,210	24,444	11,244
Average	32,477	38,681	4,574
Upper quartile	34,810	38,075	13,721
Maximum	375,000	375,000	53,434

Table 2 Fertilizer rates reported by similar management units (MU's) based on information from 27 container operations in Maryland. The lower quartile is the average of the lowest 25% of the values reported, average is the average of all values, and upper quartile is the average of the top 25% of values reported. Plant density (which impacts lbs/acre) was not taken into account, although in general container sizes and spacings were similar.

Container size and plant type	MU's represented	Statistical value	lb N/ ac/yr	lb P_2O_5/ ac/yr	lb K_2O/ ac/yr
1-2 gal mums	3	Lower quartile	30	10	19
		Average	56	21	30
		Upper quartile	82	30	42
.25- 1 gal woody perennials	22	Lower quartile	195	84	116
		Average	609	269	363
		Upper quartile	816	346	529
2 gal woody perennials	12	Lower quartile	104	92	60
		Average	477	188	301
		Upper quartile	633	243	341
3 gal woody perennials	22	Lower quartile	196	85	130
		Average	607	224	359
		Upper quartile	870	335	444
5 gal woody perennials	21	Lower quartile	205	64	120
		Average	485	166	277
		Upper quartile	674	225	347
7 gal woody perennials	12	Lower quartile	172	56	100
		Average	412	131	221
		Upper quartile	485	163	246
10 gal woody perennials	6	Lower quartile	361	106	167
		Average	816	233	430
		Upper quartile	830	230	507
15 gal woody perennials	6	Lower quartile	443	132	213
		Average	725	217	400
		Upper quartile	1122	321	657

Table 3 Fertilizer application rates reported by 17 field growers during site visits, representing 92 management units. The lower quartile is the average of the lowest 25% of the values reported, average is the average of all values, and upper quartile is the average of the top 25% of values reported. Note that plant density (which will impact lbs/acre) was not taken into account, although similar spacings were reported by growers.

Plant type	MU's represented		Lb N/ acre/ yr	Lb P_2O_5/ acre/ yr	Lb K_2O/ acre/ yr
Deciduous	6	Lower quartile	18	0	0
		Average	37	10	23
		Upper quartile	31	19	19
Evergreen	13	Lower quartile	0	0	0
		Average	25	6	11
		Upper quartile	25	8	16
Mixed	73	Lower quartile	34	8	8
		Average	69	21	24
		Upper quartile	95	23	23

Trace Gas Flux from Container Production of Woody Landscape Plants

S. Christopher Marble[1], Stephen A. Prior[2], G. Brett Runion[2], H. Allen Torbert[2], Charles H. Gilliam[1], Glenn B. Fain[1], Jeff L. Sibley[1], and Patricia R. Knight[3]

[1]Department of Horticulture, Auburn University, AL 36849
[2]USDA-ARS National Soil Dynamics Laboratory
411 S. Donahue Dr., Auburn, AL 36832
[3]Mississippi State University Coastal Research and Extension Center, Biloxi, MS 39532

marblsc@auburn.edu

Index Words: trace gas flux, greenhouse gas, container production, woody landscape plants

Significance to Industry: The agriculture industry is a large source of greenhouse gas (GHG) emissions which are widely believed to be causing increased global temperatures. Reduction of these emissions has been heavily researched, with most of the work focusing on row crop and animal production sectors. Little attention has been given to the environmental impact of specialty crop industries such as horticulture. There is speculation that future legislation limiting CO_2 and other GHG emissions from agricultural production could occur. There is a need for all sectors of agriculture to take preemptive action to determine ways in which management practices could be altered to comply with possible new legislation and reduce GHG emissions. To determine methods of reducing GHG from nursery container production systems, baseline trace gas emissions (CO_2, N_2O, and CH_4) from common practices must be established. The objective of this research is to determine efflux patterns of CO_2, CH_4, and N_2O associated with different nursery container sizes under common production practices. Our data show a significant relationship between container size and CO_2 efflux, with flux increasing as container size increased. Nitrous oxide flux was also highest in the largest containers. Determining gas flux from different container sizes establishes both a baseline for common nursery container production practices and the relative importance of container size on GHG fluxes. If estimates on the number and size of container-grown plants are developed for each state, the relationship between potting media volume and gas emissions can be scaled to develop estimates of industry-wide emission levels.

Nature of Work: Many scientists believe that anthropogenic climate change is occurring and will have serious environmental consequences. While it is still debatable that man-made emissions are causing increases in global temperatures, it is known that atmospheric concentrations carbon dioxide (CO_2), methane, (CH_4), and nitrous oxide (N_2O) have increased dramatically since 1750 (5). Agricultural production is a large source of these emissions, trailing only energy production, and accounts for about 20% of the annual increase in GHG (7). The ability of agricultural production systems reduce or mitigate GHG by altering production practices has been heavily researched (2, 8); however, most of this work focuses on agronomic and animal production systems. Almost no research has focused on the impact (either positively or negatively) of specialty crop industries such as horticulture. Although horticultural production encompasses much less acreage than agronomic crops, in many cases it is much more intensive.

GRACEnet (Greenhouse Gas Reduction through Agricultural Carbon Enhancement network) is a program initiated by the Agricultural Research Service of the USDA to identify and develop strategies that will enhance soil carbon sequestration, reduce GHG emissions, and provide a scientific basis for possible carbon credit and trading programs (6). One of the goals of GRACEnet is to establish net GHG emissions of existing agricultural systems, which must be determined in order to begin exploring ways to reduce these emissions. GRACEnet's primary objectives focus on determining emissions from row crop and animal production systems; however, for horticulture producers to benefit from the same carbon trading or offset programs, net GHG emissions from horticulture production practices must also be established. The objective of this research is to determine efflux patterns of CO_2, CH_4, and N_2O associated with different nursery container sizes under common production practices.

Materials and Methods: This experiment was conducted at the Paterson Greenhouse Complex in Auburn, AL. On April 1, 2010, *Ilex vomitoria* 'Nana' (dwarf yaupon holly) liners [approximately 2.5 cm (1 in)] were transplanted into four different nursery container sizes: 3 L (trade gal; TG), 3.8 L(#1; 1 gal), 7.6 L (#2; 2 gal), and 11.4 L (#3; 3 gal). Containers were filled with a pinebark:sand (6:1 v:v) media which had been previously amended with 8.3 $kg \cdot m^{-3}$ (14 lbs yd^{-3}) of 17-5-11 Polyon control-release fertilizer (10-12 month), 3.0 $kg \cdot m^{-3}$(5 lb yd^{-3}) of lime, and 0.9 $kg \cdot m^{-3}$ (1.5 lb yd^{-3}) of Micromax. The study used seven replicates for each container size; there were no differences in plant size at study initiation. All containers were placed in full sun and received daily overhead irrigation [1.3 cm (0.5 in)] via impact sprinklers.

Trace gases emitted from the containers were sampled *in situ* weekly for 1 year (April 1, 2010 to March 31, 2011) using the static closed chamber method (3, 4). Custom-made gas flux chambers were designed and constructed based upon criteria described in the GRACEnet protocol (1, 11) to accommodate nursery containers. A structural base consisting of polyvinyl chloride (PVC) cylinders [25.4 cm (10 in) inside diameter by 38.4 cm (15.1 in) tall] was sealed at the bottom. During gas measurement, the entire plant-pot system was placed inside the base cylinder and a vented flux chamber [25.4 cm (10 in) diameter x 11.4 cm (4.5 in) height] was placed on top of the base cylinder. The top flux chambers were constructed of PVC, covered with reflective tape, and contained a center sampling port. Gas samples for CO_2, CH_4, and N_2O were taken at 0, 15, 30, and 45 min intervals following chamber closure. At each time interval, gas samples (10 mL) were collected with polypropylene syringes and injected into evacuated glass vials (6 mL) fitted with butyl rubber stoppers as described by Parkin and Kaspar (11). Gas samples were analyzed with a gas chromatograph (Shimadzu GC-2014, Columbia, MD) equipped with three detectors: thermal conductivity detector for CO_2, electrical conductivity detector for N_2O, and flame ionization detector for CH_4. Gas concentrations were determined by comparing to a standard curve using standards obtained from Air Liquide America Specialty Gases LLC (Plumsteadville, PA). Gas fluxes were calculated from the rate of change of the concentration of trace gas (CO_2, N_2O, or CH_4) in the chamber headspace during the time intervals while chambers were closed (0, 15, 30, and 45 minutes) as described by Parkin and Venterea (12). Calculations in this study were used to express data as mg (CO_2-C) and ug (CH_4 and N_2O) trace gas per pot (per day). Daily gas efflux from each sampling date, as well as yearly estimates of total trace gas efflux (made by extrapolating daily averages over the course of one year) from each pot size were subjected to Fisher's Least Significance Test (p = 0.05) using the Proc Mixed procedure in SAS (SAS® Institute version 9.1, Cary, NC).

Results and Discussion: Regardless of container size, CH_4 efflux was consistently around 0 for the duration of the study (data not shown). It is likely that these values were close to or below the detection limits of the gas chromatograph. Given the pinebark media was well drained, it is likely the anaerobic conditions needed for CH_4 production did not occur in this study. Based upon the results from this study, CH_4 efflux does not appear to significantly contribute to total trace gas emissions from container-grown nursery crops.

Average daily trace gas emissions indicate a significant relationship between container size and CO_2 efflux (mg d^{-1}), as flux increased as container size increased (Table 1). This trend continued when total CO_2 efflux was estimated over the course of one year (Table 2). Plants grew larger in #2 and #3 containers (data not shown) increasing autotrophic respiration, while decomposition of larger quantities of growth media resulted in a greater loss via heterotrophic respiration.

Average N_2O efflux (ug d^{-1}) was highest in #3 containers, followed by #2 containers, with no difference among #1 or TG containers (Table 1). Estimates of annual N_2O efflux also show that the highest loss N_2O-N occurred in #3 containers. Due to the fact that the fertilizer was incorporated on a volume basis, larger containers had more fertilizer than smaller containers, causing a higher N_2O efflux. In addition, all plants were uniform in size at the beginning of the study and less fertilizer could be utilized by plants in larger containers also leading to higher losses via N_2O efflux.

Our data show that loss of both CO_2 and N_2O were greatest in the largest containers, and there is a significant relationship between container size and trace gas emissions. Estimates are now available on the number of container-grown plants in various container sizes produced in Alabama (9). If other states develop estimates on numbers of container-grown plants in different pot sizes, this relationship between potting media volume and gas emissions could be then be scaled to estimate industry-wide trace gas emissions. However, further investigation is needed to determine the impact of different production variables such as growing media, fertilization and irrigation practices, and plant species on trace gas emissions. It should also be noted that container flux data not reflect net emissions as they do not account for carbon sequestered in growing biomass, or the carbon sequestered by placing large amounts of carbon rich media (pinebark, etc.) belowground when plants are planted into the landscape (10). There is still uncertainty regarding the overall impact of the nursery industry on climate change, however results from this study begin to provide baseline data of trace gas emissions from container nursery production.

Literature Cited:

1. Baker J., Doyle, G., McCarthy, G., Mosier, A., Parkin, T., Reicosky, D., Smith, J., and Venterea, R. 2003. GRACEnet chamber-based trace gas flux measurement protocol. Trace Gas protocol Development Committee, March 14, pp 1-18.
2. Cole, C.V., J. Duxbury, J. Freney, O. Heinemeyer, K. Minami, A. Mosier, K. Paustian, N. Rosenburg, N. Sampson, D. Sauerbeck, and Q. Zhao. 1997. Global estimates of potential mitigation of greenhouse gas emissions by agriculture. Nutr. Cycl. Agroecosyst. 49:221-228.
3. Hutchinson, G.L. and Mosier, A.R. 1981. Improved soil cover method for field measurements of nitrous oxide fluxes. Soil Sci. Soc. Am. J. 45:311-316.
4. Hutchinson, G.L. and Livingston, G.P. 1993. Use of chamber systems to measure trace gas fluxes. p 63-78. In L.A. Harper, A.R. Moiser, J.M. Duxbury, D.E. Rolston (eds.).Agricultural Ecosystem Effects on Trace Gas and Global Climate Change. ASA Spec Publ. 55 ASA, Madison WI.
5. IPCC. 2007. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson (eds.). Cambridge University Press, Cambridge, UK.
6. Jawson, M.D., S.R. Shafer, A.J. Franzluebbers, T.B. Parkin, and R.F. Follet. 2005. GRACEnet: Greenhouse gas reduction through agricultural carbon network. Soil Till. Res. 83:167-172.
7. Johnson, J.M., A.J. Franzleubbers, S.L. Weyers, and D.C. Reicosky. 2007. Agriculture opportunities to mitigate greenhouse gas emissions. Environ. Pollut. 150:107-124.
8. Lal, R., J.M. Kimble, R.F. Follett, and C.V. Cole. 1998. The potential of US cropland to sequester carbon and mitigate the greenhouse effect. Lewis Publishers, Boca Raton, FL.
9. Marble, S.C., S.A. Prior, G.B. Runion, H.A. Torbert, C.H. Gilliam, and G.B. Fain. 2011. The importance of determining carbon sequestration and greenhouse gas mitigation potential in ornamental horticulture. HortScience 46:240–244.
10. Marble, S.C., S.A. Prior, G.B. Runion, H.A. Torbert, C.H. Gilliam, G.B. Fain, J.L. Sibley, and P.R. Knight. 2010. Soil carbon levels as affected by growth media and plant species. Proc. Southern Nurs. Assn. Res. Conf. 56:345-350.
11. Parkin, T.B. and T.C. Kaspar. 2006. Nitrous oxide emissions from corn-soybean systems in the Midwest. J. Environ. Qual. 35:1496-1506.
12. Parkin, T.B. and R.T. Venterea. 2010. Sampling Protocols. Chapter 3. Chamber-based trace gas flux measurements, p. 3-1-3 to 39. In R.F. Follet (ed.). Sampling Protocols. 6 August 2011.<http://www.ars.usda.gov/SP2UserFiles/program/212/chapter%203.%20gracenet%20Trace%20Gas%20Sampling%20protocols.pdf>.

Table 1. Average daily CO_2 and N_2O efflux from container-grown woody landscape plants[z].

Container size	Volume (L)[y]	Mean Daily Efflux	
		CO_2-C (mg d^{-1})	N_2O-N (ug d^{-1})
Trade gal.	2.05	142.10 d[x]	83.76 c
1 gal.	3.15	174.87 c	121.56 c
2 gal.	5.15	218.06 b	279.68 b
3 gal.	10.10	278.02 a	767.13 a

[z]Containers measured contained dwarf yaupon hollies (*Ilex vomitoria* 'Nana') in each container size listed (n=7).
[y]Container volumes (in liters) show the amount of substrate [pinebark: sand (6:1 v:v)] in each container size.
[x]Means were separated using Fishers Least Significance Difference Test in the Proc Mixed Procedure (p=0.05).

Table 2. Estimation of yearly CO_2 and N_2O efflux from container-grown woody landscape plants[z].

Container size	Volume (L)[y]	Yearly Efflux	
		CO_2-C (g yr^{-1})	N_2O-N (mg yr^{-1})
Trade gal.	2.05	51.89 d[x]	30.66 c
1 gal.	3.15	63.82 c	44.41 bc
2 gal.	5.15	79.59 b	102.08 b
3 gal.	10.10	101.48 a	280.00 a

[z]Containers measured contained dwarf yaupon hollies (*Ilex vomitoria* 'Nana') in each container size listed (n=7).
Estimates were made by extrapolating daily averages over the course of one year.
[y]Container volumes (in liters) show the amount of substrate [pinebark: sand (6:1 v:v)] in each container size.
[x]Means were separated using Fishers Least Significance Difference Test in the Proc Mixed Procedure (p=0.05).

BMPToolbox.org - Interactive Simulation Tools for Managing Water and Nutrients in Container Nurseries

Jeff Million and Tom Yeager

Dept. of Environmental Horticulture, Univ. of Florida, IFAS, Gainesville, FL

jmillion@ufl.edu

Index words irrigation, model, nitrogen, runoff, woody ornamental

Significance to the Industry Interactive, web-based simulation tools are available to help growers and grower-advisors evaluate and quantify effects that management practices might have on water and nutrient use efficiency when producing ornamental plants in containers. Production simulations are based on historical weather data so that outcomes can be evaluated over a number of years. In addition to tools which help make strategic decisions regarding best management practices, a real-time tool offers day-to-day irrigation recommendations based upon estimated plant demand.

Nature of Work A team of researchers developed a plant growth model for simulating production of woody ornamental plants in small (trade #1-3) containers with sprinkler irrigation (1). CCROP (Container Crop Resource Optimization Program) mathematically describes critical biophysical processes (e.g. plant growth and development, evapotranspiration, nutrient release from controlled-release fertilizers, plant nutrient uptake, leaching, etc.) and how these processes interact with environmental conditions imposed by weather and management practices. Web-based tools (www.bmptoolbox.org) were developed to 1) provide a user-friendly means for selecting input management practices, 2) run CCROP simulations, and 3) view outcomes both graphically and in tabular form. Historical weather data is obtained from the Florida Automated Weather Network (FAWN; http://fawn.ifas.ufl.edu). Use of the BMPtoolbox.org website is free-of-charge but users must login to an account. Simulations can be stored under the account, which we have found useful for extension educational programs. In the following section we will briefly describe the four tools currently available (Table 1) and provide examples of how they might be used in management practice decision-making.

Grower Tool This tool is designed to evaluate a single set of management practices. Unlike the other tools, graphical output includes daily time-plots which can be useful for evaluating changes that occur during the season (e.g. spacing, irrigation, plant growth, fertilizer release). For example, the Grower Tool could be used by a grower in Quincy, FL who wants to make some general plans for scheduling labor associated with pruning, spacing, irrigation demand, and fertility for a March 1 planting of a fast-growing woody ornamental in trade #3 containers. Liner transplants are started container-to-container in a triangular arrangement and then spaced one container diameter apart when recommended by model. With this option, containers are spaced when leaf area index (LAI=leaf area/ground area) reaches three at which time light becomes limiting. We select model-recommended irrigation which is based upon resupplying water lost through evapotranspiration (ET-based) and apply a 12-14 month CRF fertilizer (18% N; 15% controlled-release N) at 3 lb N/ yd^3 (99 g/container). A finish plant height of 30 inches is selected.

After submitting these Grower Tool inputs, daily time-plots can be viewed to get some insight into scheduling questions. The user can view the mean response to multiple years of weather data or select individual years to see how responses might change year-to-year (Fig 1). Selecting plant height from the plant response drop down menu shows that plants would typically be pruned 9-10 weeks after planting. Selecting leaf area index from same menu shows that plants might need spacing approximately 16 weeks after planting. Selecting mean irrigation from water-response menu shows how irrigation requirement changes during production from 0.1-0.2 inches at the beginning of the season to a maximum of 0.5-0.7 in the summer followed by a gradual decrease during the fall. From the same menu you might be interested to see patterns of drainage, N leaching, and runoff that were projected to occur during each year's simulation and how rain is closely linked to significant leaching events. For total irrigation demand, select summary to see that an average of 57 inches of water was required. To see if N or water was limiting, select N sufficiency or water sufficiency from plant-response menu in daily time-plots. For this example, N and water sufficiency (0 = severe deficiency; 1 = no deficiency, optimal growth) were 1 throughout the season indicating that the 3 lb N/yd^3 rate and ET-based irrigation met plant requirements. Repeating the example but changing fertilizer rate to 1.5 lb N/yd^3 and irrigation rate to 0.5 inch/day results in N and water deficiencies developing in the second half of the growing period.

<u>Comparison Tools</u> These tools help conduct virtual experiments by comparing several levels of a given factor (e.g. plant date, location, fertilizer rate, irrigation) keeping all other selected management practices the same. As an example, a company wanting to compare production at two of their nursery locations, one in Marianna (North Florida) and one in Homestead (South Florida) could run the Location Comparison Tool. If you select the two locations and submit the same input management practices as the Grower Tool example above, expected outcomes can be viewed graphically (Fig. 2). Simulated crop time was 1 month shorter for Homestead than for Marianna when planted in March and 3 months shorter in October. Simulated differences in crop time had implications relative to estimated irrigation pumping costs and N leaching. Interestingly, high runoff N was projected for the March planting in Homestead. Rainfall results reveal that this was likely due to summer rains in Homestead (40 inches for March planting but only 15 inches for October planting). Based solely on this information, the nursery might opt to plant a fall crop in Homestead location and a spring crop in Marianna to improve crop production efficiency.

<u>Real-time Irrigation Tool</u> This tool provides a daily irrigation recommendation based upon applying enough water to bring the simulated water deficit back to container

capacity. Weather is updated from FAWN weather stations at 2 a.m. each morning so that the tool can use the past day's weather to estimate the substrate water deficit that needs to be replenished with irrigation. The tool allows the user to adjust (calibrate) simulated plant growth if different from actual as well as enter important events such spacing and pruning. An example of a real-time irrigation output is given in Fig. 3 for a trade #3 woody ornamental planted 60 days earlier. The irrigation recommendation is based on 100% irrigation uniformity so growers will need to adjust irrigation rates according to actual irrigation uniformity measured in the field.

Technical Tool Geared for a more technical user, this tool allows a wider range of inputs to be changed. For example, a user wanting to evaluate the effect of a substrate's volumetric water-holding capacity (default value of 25% is used for other tools) may vary this input parameter incrementally and observe simulated effects on irrigation and runoff.

In summary, we described how CCROP provides growers and grower advisers with an interactive means to quantify effects of management practices on many aspects of container crop production. Comparative values may be just as important as absolute values as was demonstrated in the Location Comparison Tool example. While additional tools will be added and current tools likely modified, we hope the use of simulation tools will provide a fresh perspective on how management practices and the environment might interact in container nurseries.

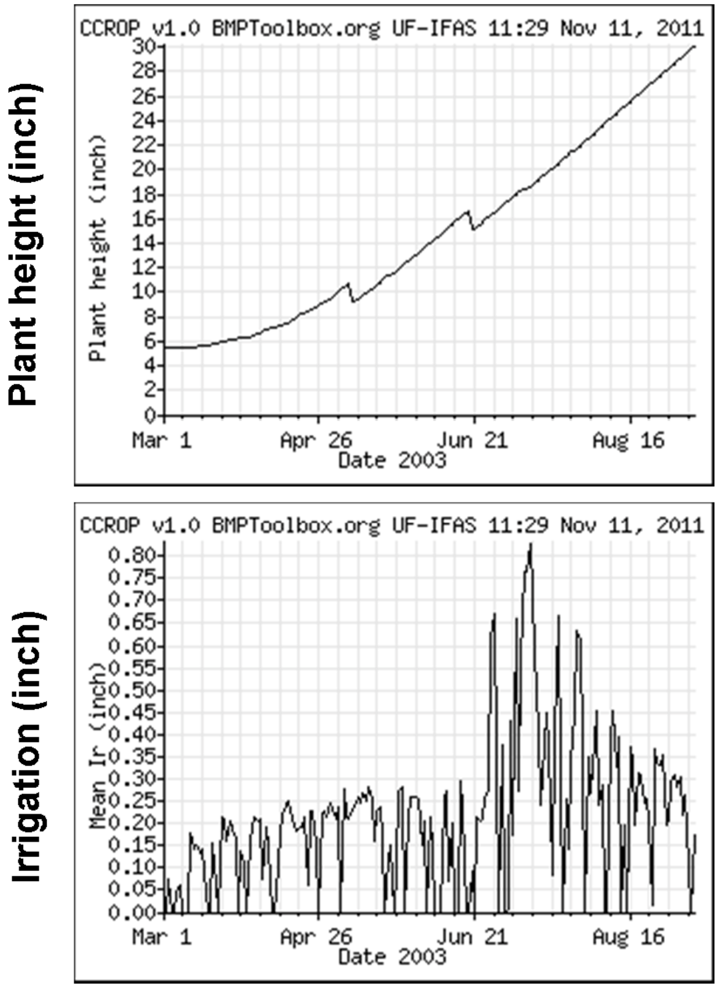
Literature Cited

1. Million, J.B., J.T. Ritchie, T.H. Yeager, C.A. Larsen, C.D. Warner and J.P. Albano. 2011. CCROP - Simulation model for container-grown nursery plant production. Scientia Horticulturae 130(4):874-886.

Acknowledgements This project was made possible through grant support from the USDA-ARS Floral and Nursery Research Initiative.

Table 1. Description of currently available tools for running CCROP simulations (www.bmptoolbox.org) to evaluate effects of management practices on plant growth and water and nutrient use during production of ornamental plants in trade #1 and #3 containers.

BMPToolbox	Purpose	Output
Grower Tool	Detailed simulation of one set of management practices	Daily time-plots and season totals
Comparison Tools	Run virtual experiments by comparing several levels of a factor (e.g. fertilizer, irrigation, location, planting date)	Season totals
Real-time Irrigation Tool	Tracks day-to-day progress of a crop in real-time providing a daily irrigation recommendation	Daily irrigation recommendation and daily time-plots
Technical Tool	For technical user, allows user to change all input variables	Daily time-plots including cumulative curves (metric units)



Daily time-plot for 2003 (Mar 1 planting)

Fig. 1. Example outcomes from using Grower Tool to simulate production of a woody, ornamental plant planted in trade #3 containers and grown in Quincy, Florida. Results from only one year (2003) out the nine years of simulated plantings (2003-2011) are shown.

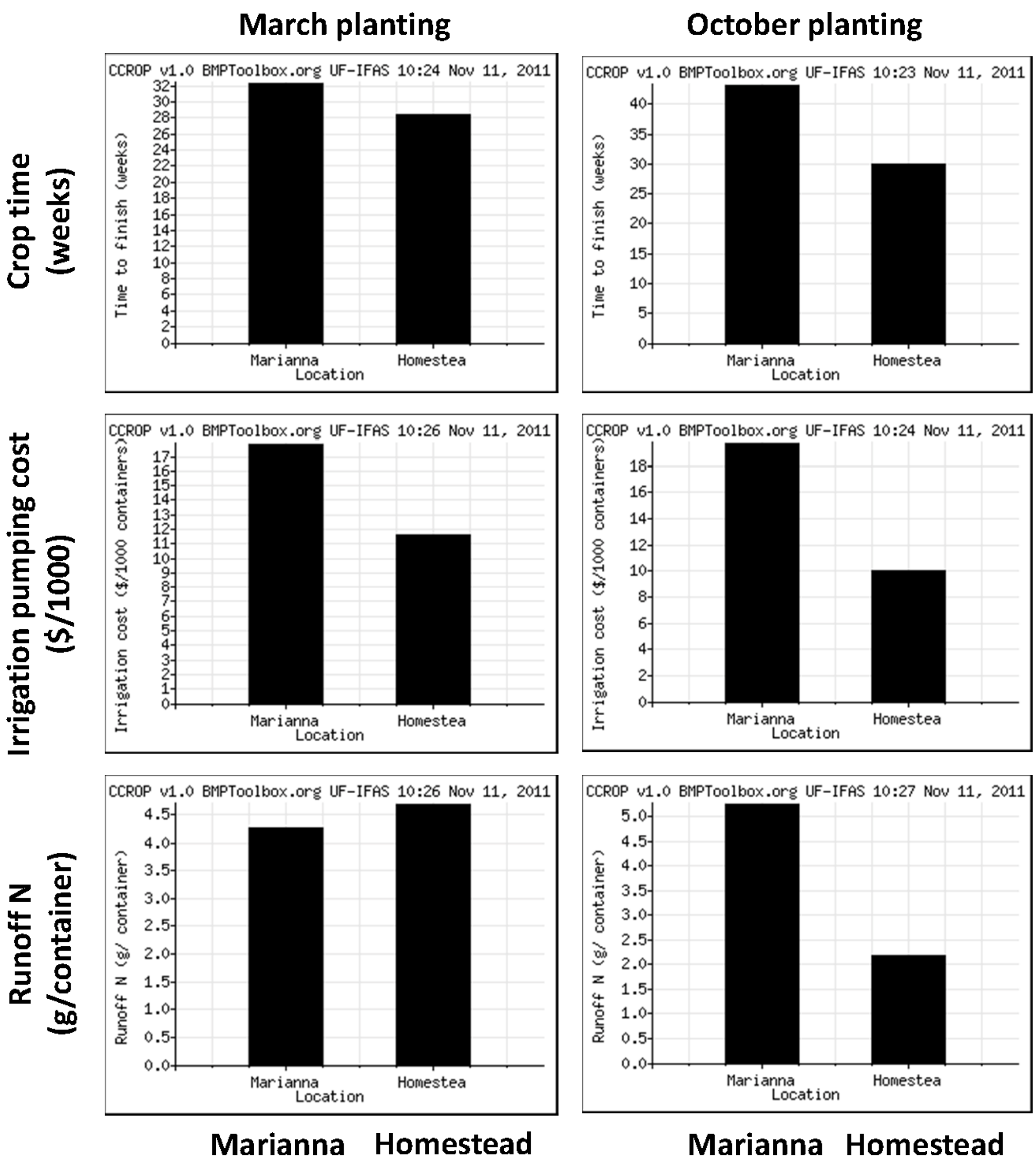


Fig. 2. Outcomes from using the Location Comparison Tool to simulate production of a fast-growing, woody ornamental plant in trade #3 containers at two locations, Marianna (North Florida) and Homestead (South Florida) and for two planting dates (March and October).

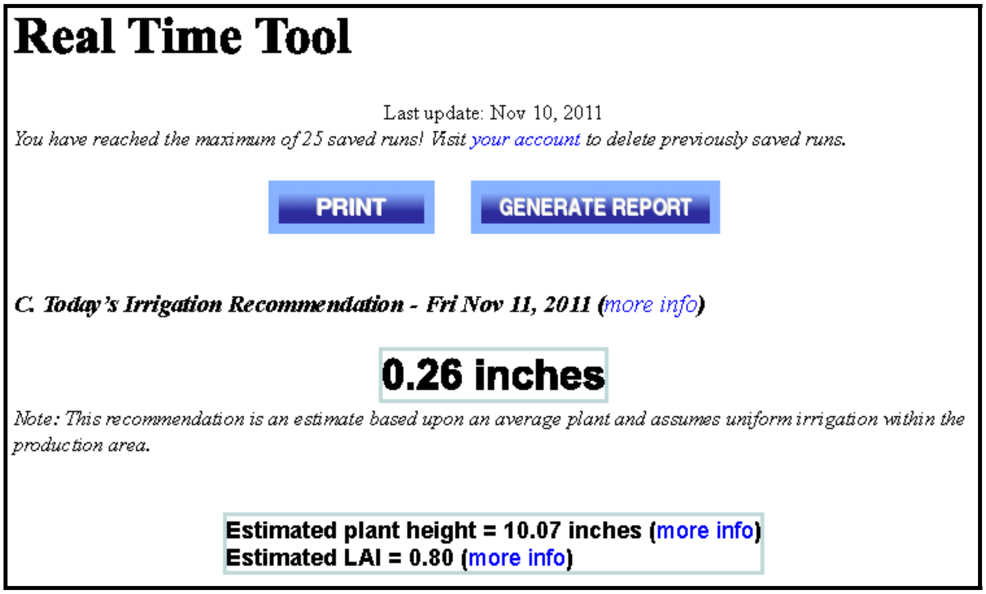


Fig. 3. The Real-Time Irrigation Tool provides a daily irrigation recommendation based on the amount of water required to replenish simulated water deficit in container substrate from the past day's evapotranspiration.

Alternative Substrates in Production of Trees in 25-Gallon Containers

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

murphan@auburn.edu

Index Words: container-grown, WholeTree, clean chip residual, pine bark

Significance to Industry: With a recent threat of diminishing available pine bark (PB) supplies, nursery growers need information about possible amendments or alternatives for their standard substrate mixes. Clean chip residual (CCR) and WholeTree (WT) substrates have been identified as two possible pine-based high wood content alternatives to PB for the production of annuals, perennials and woody ornamentals. This study shows the possibility of using 100% CCR or WT in the production of large container-grown trees (in 25-gal containers). The data suggests that while there are differences in the physical properties of these two alternatives compared to PB, the growth of three tree species (*Magnolia grandiflora* 'D.D. Blanchard', *Quercus shumardii*, and *Acer rubrum* 'Summer Red') was acceptable and generally similar to a PB standard.

Nature of Work: Pine bark (PB) supplies have wavered in availability over the past couple of years due to a downturn in the economy, a shift to in-field harvesting where bark is no longer brought to mills, and an increase in using PB as a biofuel material. Research in alternative potting substrates has continued across the country in an attempt to identify inexpensive, and locally available, substrate options that could offset any lapses in pine bark availability. Two high wood content, pine-based, substrates have been identified as potential amendments or replacements to pine bark in soilless media. WT consists of the entire pine tree harvested from pine plantations, generally at the thinning stage. It contains about 80% wood particles, 15% bark, and 5% needles. Several studies have shown WT to be a viable substrate alternative to peat (4,5,6,7) in the production of greenhouse-grown crops. CCR (approx. 50% wood, 40% bark, and 10% needles) was also evaluated as an alternative to peat in greenhouse substrates (2), as well as an alternative to PB in the production of perennial and woody nursery crops (1,3). CCR and WT were also evaluated together as potential amendments or alternatives to PB in the nursery production of six woody ornamental species in full gallon containers including 'New Gold' lantana (*Lantana camara* 'New Gold' L.), 'Gold Mound' spirea (*Spiraea japonica* 'Gold Mound' L.f.), 'Amaghasa' azalea (*Rhododendron* x 'Amaghasa' L.), tea olive (*Osmanthus fragrans* Lour.), 'Rotundifolia' ligustrum (*Ligustrum japonicum* 'Rotundifolia' Thunb.), and 'Soft Touch' holly (*Ilex crenata* 'Soft Touch' Thunb.) (8). Treatments consisted of 100% PB, WT, and CCR, and then treatments with either 25, 50, or 75% CCR or WT mixed with PB. Data from the study showed that after 365 days, five of the six species tested showed no difference in growth indices of any treatment compared to the PB standard.

Most of the previous research has evaluated production in 1-gal containers, and for only one growing season. In continuing the search for alternative substrates, this study was developed to evaluate long-term production with two particle sizes each of CCR and WT in 25-gal container production of three common tree species. Container-grown 3-gal liners of 'D.D. Blanchard' magnolia (*Magnolia grandiflora* 'D.D. Blanchard' L.), shumard oaks (*Quercus shumardii* Buckland), and 'Summer Red' maples (*Acer rubrum* 'Summer Red' L.) were potted into 25-gallon containers on April 22 and 24, 2009. Five substrate treatments were evaluated, including two 100% WT treatments [0.64 and 0.95 cm (1/4 in and 3/8 in)], two 100% CCR treatments [1.91 and 2.54 cm (0.75 in and 1 in)] and a 100% PB control. Dolomitic limestone was incorporated into each substrate at 3.0 kg/m^3 (5 lb/yd^3). Fertilizer [17N-2.1P-9.1K (17-5-11) Polyon CRF (11-12 month release) with blended minors (Harrell's Fertilizer, Inc., Lakeland, FL)], at 5.0 kg/m^3 (10 lbs/yd^3), was applied using a modified dibble method, where 75% of the pot was filled with substrate, the plant was placed inside, and 590 grams of fertilizer was poured around the root ball. The rest of the substrate was then placed around the root ball until the pot was filled completely. Trees were watered with spray stakes (Netafilm PC Spray Stakes; Double Spray; 6.6GPH) for 12 minutes twice per day [3.17 cm (1.25 in) total per day] On March 8, 2010 (320 DAP), the trees were fertilized again (dibble method with two holes per pot) with 590 g 17N-2.1P-9.1K (17-5-11) Polyon CRF (11-12 month release) (Harrell's Fertilizer, Inc., Lakeland, FL); this time without any blended minors. Trees were grown for a total of 500 days. Physical properties [air space (AS), container capacity (CC), total porosity (TP), and bulk density (BD)] were determined prior to planting on base substrates (without incorporated lime). Substrate pH and electrical conductivity (EC) were measured throughout the study at 30, 180, 365 and 500 DAP using the pour-through method. Height and caliper were both measured at 14 and 180 DAP, as well as at study termination (500 DAP). Height (cm) was measured from the substrate surface to the apical bud on each plant, while caliper (cm) was measured 15.2 cm (6 in) above the substrate surface. The experiment was a randomized complete block design with 8 replicates for each species tested. Data were analyzed using Tukey's Honestly Significant Difference Test ($p \leq 0.05$) in SAS (SAS® Institute version 9.2, Cary, NC).

Results and Discussion: While all container substrate AS and CC percentages were within the respective recommended ranges (10-30% for AS; 45-65% for CC), there were differences among treatments (Table 1). The 100% PB treatment had significantly less AS (11.6%) than all other treatments, while the 3/8" WT treatment had higher AS (32.1%) than the ¼" WT and both CCR treatments. With only one exception at 86.3% (3/4" CCR), all container substrate TP percentages were also within the recommended range (50-85%).

Except for the 100% PB treatment at 500 DAP (4.4), all pH values were within the BMP recommended range for nursery crops (4.5-6.5) (Table 2) (9). As expected, pH values generally decreased over time, and were similar at all but one testing date (270 DAP). At 270 DAP, all treatments were similar to the 100% PB standard (5.7) except for the 3/8" WT treatment (6.2). Values for EC followed the same general trend as pH, except that by 500 DAP, the EC of all treatments had increased from an average of 0.13 mS/cm at 270 DAP to an average of 1.3 mS/cm (Table 2). This can be attributed to the addition of dibbled fertilizer that occurred at 320 DAP. There were no differences among treatments at any testing date for EC.

For height and caliper of both 'D.D. Blanchard' magnolia and shumard oaks, there were no differences across any treatment at any testing date (14, 180, and 500 DAP) (data not presented). For 'Summer Red' maple, there were no differences for height or caliper across all treatments at 14 DAP, indicating that the plants were adequately blocked for height at the beginning of the study (Table 3). At 180 DAP, the only treatment that was different in height from the 100% PB control (248.8 cm) was the ¼" WT treatment (201.1 cm). However, by 500 DAP, there were no differences for height across any treatment. Differences in caliper occurred at both 180 and 500 DAP. Both WT treatments (2.8 cm for both ¼" and 3/8" WT) were different from the 100% PB control (3.3 cm) at 180 DAP, but by 500 DAP, the only treatment different from the 100% PB control (3.8 cm) was the ¼" WT treatment (3.4 cm).

While there were differences in physical properties between substrates, there were few differences in growth parameters (height and caliper). This data suggests that WT and CCR may be viable alternatives to PB in the production of large container-grown trees.

Literature Cited:

1. Boyer, C.R., G.B. Fain, C.H. Gilliam, T.V. Gallagher, H.A. Torbert and J.L. Sibley. 2008a. Clean chip residual as a substrate for perennial nursery crop production. J. Environ. Hort. 26:239-246.
2. Boyer, C.R., G.B. Fain, C.H. Gilliam, T.V. Gallagher, H.A. Torbert, and J.L. Sibley. 2008b. Clean Chip Residual: A substrate component for growing annuals. HortTechnology 18:423-432.
3. Boyer, C.R., C.H. Gilliam, G.B. Fain, T.V. Gallagher, H.A. Torbert and J.L. Sibley. 2009. Production of woody nursery crops in clean chip residual substrate. J. Environ. Hort. 27:56-62.
4. Fain, G.B. and C.H. Gilliam. 2006. Physical properties of media composed of ground whole pine trees and their effects on vinca (*Catharanthus roseus*) growth. HortScience 40:510 Abstr.
5. Fain, G.B., C.H. Gilliam, J.L. Sibley, and C.R. Boyer. 2006. Evaluation of an alternative, sustainable substrate for use in greenhouse crops. Proc. Southern Nurs. Assoc. Res. Conf. 51:651-654.
6. Fain, G.B., C.H. Gilliam, J.L. Sibley and C.R. Boyer. 2008a. *WholeTree* substrates derived from three species of pine in production of annual vinca. HortTechnology 18:13-17.

7. Fain, G.B., C.H. Gilliam, J.L. Sibley, C.R. Boyer, and A.L. Witcher. 2008b. WholeTree substrate and fertilizer rate in production of greenhouse-grown petunia (*Petunia ×hybrida* Vilm.) and marigold (*Tagetes patula* L.). HortScience 43:700-705.
8. Murphy, A.M., C.H. Gilliam, G.B. Fain, J.L. Sibley, T.V. Gallagher, H.A. Torbert, S.C. Marble, and Anthony L. Witcher. 2010. Extending Pine Bark Supplies with WholeTree and Clean Chip Residual Substrates. J. Environ. Hort. 28:217-223.
9. Yeager, T., T. Bilderback, D. Fare, C.H. Gilliam, J. Lea-Cox, A. Niemiera, J. Ruter, K. Tilt, S. Warren, T. Whitwell, and R. Wright. 2007. Best management practices: Guide for producing nursery crops. 2nd ed. Southern Nursery Assn., Atlanta, GA

Table 1. Physical properties of five substrates containing pine bark, clean chip residual, and *WholeTree*[z].

Substrate[y]	Air Space[x] (% vol)	Substrate water holding capacity[w] (% vol)	Total Porosity[v] (% vol)	Bulk density ($g \cdot cm^{-3}$)[u]
PB	11.6 c[t]	55.6 bc	67.1 d	0.46 a
1/4" WT	20.6 b	58.5 ab	79.2 c	0.39 c
3/8" WT	32.1 a	51.6 c	83.7 b	0.34 d
3/4" CCR	24.2 b	62.2 a	86.3 a	0.32 e
1" CCR	22.0 b	59.8 ab	81.8 b	0.41 b
Recommended Range[s]	10-30%	45-65%	50-85%	0.19-0.70

[z]Analysis performed using the North Carolina State University porometer (http://www.ncsu.edu/project/hortsublab/diagnostic/porometer/).

[y]PB = pine bark, CCR = clean chip residual, WT = *WholeTree*.

[x]Air space is volume of water drained from the sample / volume of the sample.

[w]Substrate water holding capacity is (wet weight - oven dry weight) / volume of the sample.

[v]Total porosity is substrate water holding capacity + air space.

[u]Bulk density after forced-air drying at 105C (221.0F) for 48 hrs; 1 $g \cdot cm^{-3}$ = 62.4274 $lb \cdot ft^{-3}$.

[t]Means within column followed by the same letter are not significantly different based on Tukey's Studentized Range Test at $\alpha = 0.05$ (n=3).

[s]Recommended ranges as reported by Yeager, et al., 2007. Best Management Practices Guide for Producing Container-Grown Plants.

Table 2. Solution pH and substrate electrical conductivity (EC) for five substrates containing pine bark, clean chip residual, or *WholeTree*[z].

	30 DAP[x]		120 DAP		270 DAP		500 DAP	
Substrate[y]	**pH**	**EC ($mS \cdot cm^{-1}$)[w]**	**pH**	**EC ($mS \cdot cm^{-1}$)**	**pH**	**EC ($mS \cdot cm^{-1}$)**	**pH**	**EC ($mS \cdot cm^{-1}$)**
PB	6.2 [v,ns]	0.36 [ns]	5.9 [ns]	0.20 [ns]	5.7 b	0.14 [ns]	4.4 [ns]	1.25 [ns]
1/4" WT	6.4	0.41	6.2	0.18	6.1 ab	0.14	5.3	1.38
3/8" WT	6.4	0.34	6.2	0.15	6.2 a	0.12	4.6	1.58
3/4" CCR	6.3	0.30	6.3	0.15	6.1 ab	0.11	4.6	1.02
1" CCR	6.3	0.36	6.1	0.32	5.8 ab	0.12	4.7	1.43

[z]pH and EC of solution determined using pour-through method on 'D.D. Blanchard' magnolia.
[y]PB = pine bark, CCR = clean chip residual, WT = *WholeTree*.
[x]DAP = days after planting.
[w]$1\ mS \cdot cm^{-1} = 1\ mmho \cdot cm^{-1}$.
[v]Means within column followed by the same letter are not significantly different based on Tukey's Studentized Range (HSD) Test at $\alpha = 0.05$ (n=4).
[ns]Means not significantly different.

Table 3. Effect of five substrates containing pine bark, clean chip residual, or *WholeTree* on height and caliper[z] of 'Summer Red' maple.

	Height			*Caliper*		
Substrate[y]	**14 DAP**	**180 DAP**	**500 DAP**	**14 DAP**	**180 DAP**	**500 DAP**
PB	175.6 [ns, w]	248.8 a	274.6 [ns]	1.8 [ns]	3.3 a	3.8 a
1/4" WT	169.9	201.1 b	270.7	1.8	2.8 b	3.4 b
3/8" WT	173.0	214.8 ab	263.8	1.7	2.8 b	3.5 ab
3/4" CCR	167.0	217.3 ab	257.3	1.9	3.0 ab	3.6 ab
1" CCR	169.4	214.8 ab	276.9	1.7	3.0 ab	3.6 ab

[z]Height and caliper measured in cm.
[y]PB = pine bark, CCR = clean chip residual, WT = *WholeTree*.
[x]DAP = days after planting.
[w]Means within column followed by the same letter are not significantly different based on Tukey's Studentized Range Test at $\alpha = 0.05$ (n = 8).
[ns]Means not significantly different.

Substrate Heat Buildup And Evaporation Rate Differs Between Plastic and Alternative One Gallon Nursery Containers

S. Nambuthiri[1], R. Geneve[1], T. Fernandez[2], A. Fulcher[3], A. Koeser[4], G. Bi[5], M. Evans[6], G. Niu[7], N. Pershey[2], R. Stewart[8], S. Verlinden[9], and X. Wang[2]

[1]University of Kentucky, [2]Michigan State University, [3]University of Tennessee, Knoxville, TN, [4]University of Illinois, [5]Mississippi State University, [6]University of Arkansas, [7]Texas AgriLife Research, Texas A&M University System, El Paso, TX, [8]Brigham Young University, and [9]West Virginia University

ssnamb2@uky.edu

Index Words: temperature, fiber containers, substrate

Significance to the Industry: Supra optimal root zone temperature of container-grown plants limits plant growth and quality. High substrate temperature can cause water stress, reduce photosynthesis, and increase respiration resulting in impaired plant growth and development. Reducing absorption of solar radiation and increasing heat exchange in the production container can reduce supra optimal substrate temperature. The current study discusses the impact of container type on substrate temperature and drying rate. The results demonstrate that the fiber nursery containers showed reduced substrate heat buildup and had a higher evaporation rate compared to black plastic containers.

Nature of Work: The importance of keeping substrate temperature below 100°F (37.8°C) to avoid root injury is well documented (1). However, during warmer months in the south eastern states it is common for the substrate temperature in black walled plastic containers to exceed 107.5°F (42°C) for several hours (1). Although container color has a greater impact overall, porous containers (clay, paper, peat, etc.) showed a slower rise in root zone temperature than non-porous (plastic, glass, paraffin protected, etc.) containers due to high latent heat of vaporization of water (2,3). One way to deal with heat stress is to use alternative containers such as those with porous container walls to improve heat exchange between the substrate and environment. In addition, increased substrate evaporative cooling can occur in containers made from alternative materials compared to solid, polyethylene containers (4). The objective of this study was to evaluate the heat buildup and dry down rate of substrate in different alternative and plastic containers. The study was conducted at the University of Kentucky. Four types of one gallon nursery containers were evaluated with five replicates per container type. They included a conventional black plastic container (C400, Nursery Supplies® Inc.); a white plastic container (Proven Winners, LLC); and two pulp-based biocontainers: Kord® Fiber Grow (FNP 0707, ITML Horticultural Products) and 7X7RD (Western Pulp Products Co.). The containers were filled with equal quantities of an 85% pine park: 15% peat (vol/vol) substrate. The substrate was wetted to saturation and allowed to drain prior to filling each container. The containers were permitted to equilibrate to room temperature for 30 minutes prior to initiating the experiments.

Heat transfer from the side wall to the substrate

The experiment was conducted under standard laboratory conditions with an ambient air temperature of 68°F (20°C). Two incandescent (100 watts each) bulbs, about one inch (2.5 cm) apart from each other in a tandem fixture was placed 6 inches (15.2 cm) away from the container sidewall to provide heating for 90 minutes. After 90 minutes, radiation flux density reflecting off the container wall was measured using a pyranometer (LI-200, LI-COR® Biosciences, Lincoln, NE) connected to a LICOR-1400 data logger. After turning the light off, the temperature of the container wall was measured using an InfraRed thermometer (Extech Instruments, Nashua, NH) aimed approximately 3 inches (7.4 cm) away from the wall. The wall temperature was measured at 2, 6 and 8 inches (5, 15.2 and 20 cm respectively) below the container rim. Temperature at one inch (2.54 cm) depth of the substrate was measured using a digital thermometer (Fisher scientific) at one inch (2.54 cm) away from the container wall, half the distance between the container wall and at the center of the container (about 3.5 inches away from the container wall).

Moisture evaporation from the container under a controlled environment

The experiment was conducted in a controlled environment chamber with temperature and humidity control (Parameter Generation and Control, Black Mountain, N.C.). A temperature of 89.6°F (32°C) and 45% relative humidity was maintained to provide a vapor pressure deficit (VPDair) of 2.6 k Pa inside the chamber. Weight measurements of the containers were taken hourly for eight hours until there was no significant weight change. There were five replicates for each nursery type container.

Results and Discussion

Flux density (W□m-2) reflected from container wall was 19.3, 171.0, 95.9 and 117.5 for the black, white, wood pulp, and Kord containers, respectively. The temperature of the side wall in the black plastic container heated to above 122°F (50°C) after 90 minutes. The substrate temperature (20□C at the start of the experiment), showed a 10.8°F (6°C) increase in black plastic containers compared to the white and fiber containers at one inch away from container side wall and a 5.9°F (3.3oC) increase 2 inches (5.1 cm) from the side wall (Figure 1).

The substrate drying rate under controlled environment showed an increased rate in the fiber containers compared to plastic containers. The moisture loss after 8 hours was 8.6, 8.8, 13.4, and 10.8% for the black, white, wood pulp, and Kord containers, respectively.

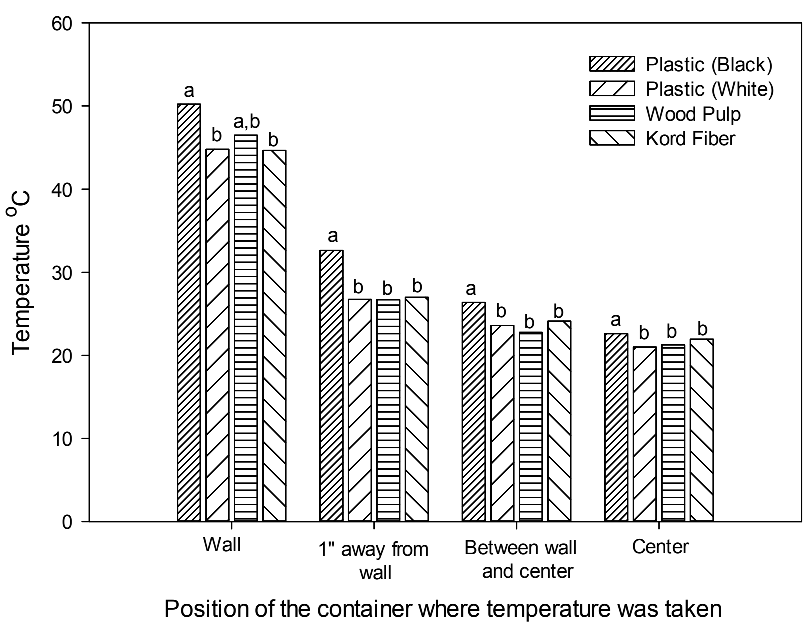
It was evident from the study that the heat buildup in a conventional black plastic container is significantly greater than fiber containers and that this was partially related to the ability to absorb or reflect short wave radiation. Therefore, fiber containers could improve plant production and quality by reducing the substrate temperature (4). The increased evaporation from fiber containers could result in increased water demand for plants grown in these containers compared to plastic containers. Future research will study the impact of temperature on water use in the field-grown plants in the plastic versus alternative containers.

Acknowledgements
The authors acknowledge USDA-SCRI for providing funding for this work, and Renewed Earth, Inc., MI for donating substrate; and Western Pulp Products Co. for donating containers.

Literature Cited

1. Ruter, J. M. and D. L. Ingram. 1990. ^{14}Carbon-labeled photosynthate partitioning in *Ilex crenata* 'Rotundifolia' at supraoptimal root-zone temperatures. J. Amer. Soc. Hort. Sci.115: 1008-1013.
2. Jones, L. H. 1931 Effect of the structure and moisture of plant containers on the temperature of the soil contents, *J. Agr. Res.,* 42, 375-378.
3. Krizek, D. T., Bailey, W. A., Klueter, H. H. 1971. Effects of relative humidity and type of container on the growth of F, hybrid annuals in controlled environments. Am. J. Bot. 58:544-51.
4. Ruter, J.M. 1999. Fiber pots improve survival of 'Otto Luyken' laurel. Proc. Southern Nurserymen's Assn. Res. Conf. 44:37-38.

Figure 1. Mean temperature build up on different parts of one gallon containers and their substrate after exposure to 200 W·m^{-2} flux density for 90 minutes. Pairs of means with the same letter are not significantly different from each other (Holm-Sidak method, P>0.05).



Cotton Waste: a New Spin on Southeastern Substrates

Elizabeth D. Riley, Helen T. Kraus, Ted E. Bilderback, and Brian E. Jackson

Department of Horticultural Science
North Carolina State University, Raleigh, NC 27695-7609

Helen_Kraus@ncsu.edu

Index Words: substrate alternative, cotton stalks, cotton gin trash, azalea, juniper

Significance to Industry: Any alternative substrate that is locally and readily available to a nursery grower is the answer to the alternative substrate dilemma. However, production management evaluations still need to be conducted. In our study, azalea shoot growth was larger with overhead irrigation and a black fabric ground cover (OH) for all substrates compared to low volume irrigation and a gravel ground cover (LV). With OH, azalea shoot growth was greatest in all of the pine bark (PB) based substrates that were amended with cotton wastes and 100% PB and was lowest in all of the whole pine tree (PT) based substrates. Shoot growth in azalea with LV was greatest in PB amended with cotton stalks composted with a nitrogen source and cotton gin trash. Juniper shoot growth with LV and OH was higher in PB alone and PB amended with cotton gin trash. Juniper root growth was also highest in LV with PB alone and PB amended with cotton gin trash; while, there were no differences between substrates with root growth with OH.

Nature of Work: Recent concerns that pine bark (PB) substrates could become less available and more expensive have fueled a stimulus for research on the use of alternative substrates (1). Nursery growers need accurate and timely advice about what alternative substrates should be used and the advantages and limitations of various alternative substrates. The best advice seems to be any alternative substrate that is locally, and readily available to them since the primary goal of the alternative substrate “movement” is to prevent losses in profit due to a rise in PB costs.

Throughout the southeast there is substantial cotton production. Best management practices for cotton production include the use of “no-till” methods after harvesting, cutting cotton stalks down, and leaving the debris in the field which can lead to a build-up of debris after several crop rotations (due to the woody nature of the cotton stalks) making it difficult for new crops to be planted, fertilized, etc. (1). However, cotton stalks can also be removed from the field, composted and used as a substrate amendment (2).

Cotton gin trash is another waste product of cotton production. Large supplies of these cotton wastes are locally available to the nursery industry and have been shown to be viable substrate components when looking at physical properties and growth (2,5). However, nursery management practices for containerized plant production with cotton waste amended substrates need to be further defined. Therefore an experiment was conducted to further evaluate the use of composted cotton stalks (CS) and cotton gin trash (CGT) for its use as an amendment to PB and PT based substrates for the production of two nursery crops [*Rhododendron obtusum* (Lindl.) Planch. 'Sunglow' (azalea) and *Juniperus conferta* Parl. 'Blue Pacific' (juniper)] in two commonly used growing environments [overhead sprinkler irrigation with black weed fabric covering the ground (OH) and low volume irrigation with gravel covering the ground (LV)].

Cotton stalks were composted for 5 months either without the addition of a nitrogen source (CS) or with a nitrogen source (CSN) [5 parts CS : 1 part Daddy Pete's Plant Pleaser (0.5-0.5-0.5), Stony Point, NC]. The PT-based substrates were produced from whole pine trees (*Pinus taeda*) which were harvested, delimbed, chipped, and hammer-milled with a cotton amendment through a 3/8" (9.5 mm) screen. There were seven different substrates evaluated in this experiment: 4:1 pine bark: cotton stalks (PB:CS), 4:1 pine bark: cotton stalks + nitrogen (PB:CSN), 9:1 pine bark: cotton gin trash (PB:CGT), 1:1 whole pine tree: cotton stalks (PT:CS), 1:1 whole pine tree: cotton stalks + nitrogen (PT:CSN), 4:1 whole pine tree: cotton gin trash (PT:CGT), and 100% pine bark (PB) was used as a control for comparisons. These substrates were blended at these ratios to achieve similar water holding capacities (5).

PB-based substrates were amended with 1 lb/9 ft^3 (1.4 kg/m^3) of lime incorporated at mixing. Based on previous work, no lime was added to PT-based substrates (4). Azaleas and junipers were potted into all of the different substrates on May 7, 2010. On May 17^{th}, PB-based substrates and the 100% PB control were top-dressed with 2.6 g N [15 g (0.52 oz) fertilizer] and PT-based substrates were top-dressed with 3.4 g N [20 g (0.71 oz) fertilizer] supplied by a polymer-coated, slow release fertilizer, 17-5-10 (17N-2.2P-0.83K) (Harrell's, Sylacauga, AL). OH was supplied using rotary spray nozzles (R13-18, Rainbird, Tucson, AZ) that delivered 1.6 gpm. LV was applied by a spray stake (PC Spray Stake, Netafim, Ltd., Tel Aviv, Israel) that delivered 3.2 gph. Irrigation volume was managed separately for LV and OH to maintain a 0.2 leaching fraction (volume of water leached ÷ volume of water applied) for each of the seven substrates. On August 26, plants were separated into shoots and roots. Only roots of juniper were harvested and washed to remove substrate. All plant parts were dried for five days at 62C (144F). To evaluate the effects of irrigation and ground covering on substrate temperatures, temperatures of the substrates at a depth of approximately 1" (2.5 cm) were measured on the south side of the container using a Hobo (U12 Outdoor/Industrial, Onset Hobo Data Loggers, Bourne, MA).

The study was conducted at the Horticulture Field Laboratories, Raleigh, NC (longitude: 35^o47'29.57"N; latitude: 78^o41'56.71"W; elevation:136 m). The factorial treatment arrangement of substrates was arranged in a RCBD. All variables were tested for differences using analysis of variance procedures and lsd means separation procedures (p > 0.05) where appropriate (6).

Results and Discussion: Azalea shoot growth was larger with OH irrigation for all substrates compared to LV ($p \geq 0.0001$). The increase in azalea shoot growth with OH was most likely due to the cooling effect of the water applied to the canopies as evidenced by the azalea substrate temperature data (data not shown). With OH, growth was greatest in azalea shoots in all the PB based substrates and 100% PB and was lowest in all the PT based substrates (Fig. 1). Shoot growth in azalea with LV irrigation was greatest in PB:CSN and PB:CGT and was lowest in PB:CS, PT:CS, and PT:CGT. The 100% PB control and PT:CSN resulted in growth that was not significantly different than any of the other substrates. Similarly, Jackson et al. found that pine bark amended with cotton gin compost resulted in growth of 'Winter Gem' boxwood, 'Firepower' dwarf nandina and 'Midnight Flare' azalea that was similar to or larger than the pine bark: sand control substrate (3).

Juniper shoot growth with LV and OH was higher in the PB:CGT and PB control (Fig. 2). Root growth was also highest in LV with the PB:CGT which coincided with the shoot growth. Juniper root growth was lowest in PB:CS and PB:CSN and all the PT based substrates, while the PB control was intermediate. With OH there were no significant differences in root growth. Previous work proved that PT based substrates have greater total porosity than the PB based substrates (5); but the PT based substrates did not improve juniper root growth. Additionally, PB:CGT had the lowest airspace over the growing season, but produced roots as large or larger than other substrates (Fig. 2).

Literature Cited:

1. Bilderback, Ted E., and Stuart L. Warren. 2010. Cotton and other low to no bark alternatives: getting past BCAP. Proc. of IPPS.
2. Bridges, E.D., H.T. Kraus, B.E. Jackson, and T.E. Bilderback. 2011. Cotton amended substrates: Wrinkle free? 56th Annual Southern Nurseryman's Association Research Conference. p. 6-10.
3. Jackson, B. E., et al. 2005. Cotton Gin Compost as a Substrate Component in Container Production of Nursery Crops. J. Environ. Hort. 23:118-22.
4. Jackson, B.E., R.D. Wright, N.Gruda. 2009. Container Medium pH in a Pine Tree Substrate Amended with Peatmoss and Dolomitic Limestone Affects Plant Growth. HortScience 44(7):1983–1987.
5. Lumpkin, E., B. Jackson, H. Kraus, B. Fonteno, and T. Bilderback. 2011 Pine Tree Substrate Properties: Before and After Production. 56th Annual Southern Nurseryman's Association Research Conference. p. 274-276.
6. SAS Institute, Inc. 2001. SAS/STAT User's Guide: Release 8.2 Edition, SAS Inst., Inc., Cary, NC.

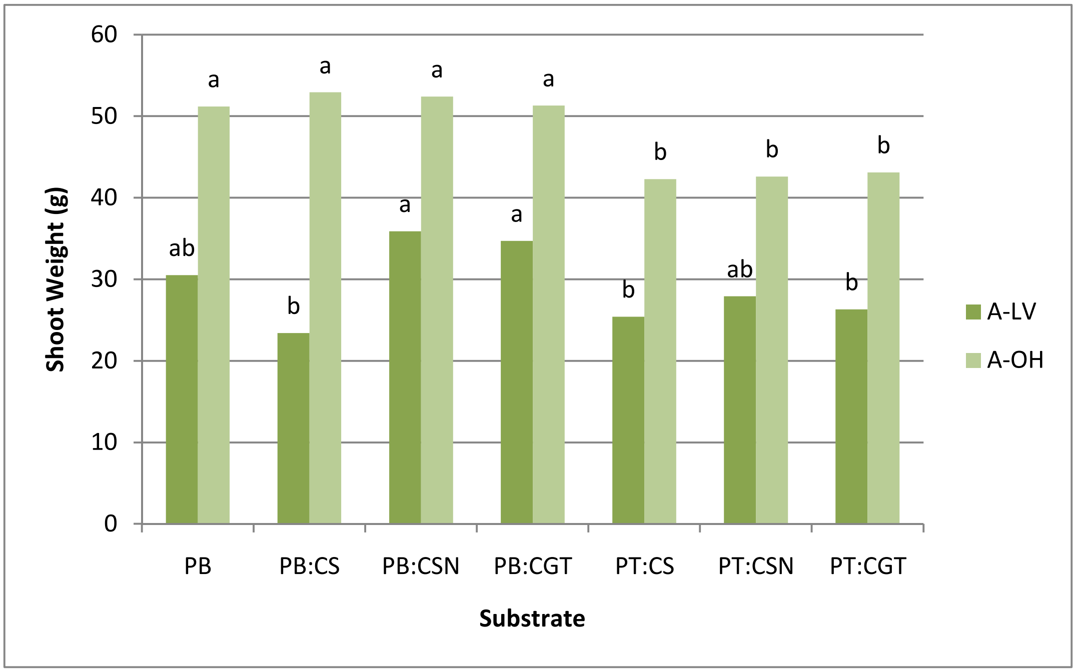


Figure 1. Effect of substrate on azalea shoot growth with two different production methods. Plants were grown with overhead, sprinkler irrigation and black weed fabric covering the ground (OH) or low volume, spray-stake irrigation system and gravel covering the ground (LV). Means between substrates with different letters are significantly different from each other based on lsd means separation procedures (p>0.05). The substrates consisted of 4:1 PB : CS (PB:CS), 4:1 PB : CS+N (PB:CSN), 9:1PB : CGT (PB:CGT), 1:1 PT : CS (PT:CS), 1:1 PT : CS+N (PT:CSN), and 4:1 PT : CGT (PT:CGT) where PB = pine bark, PT = whole pine tree, CS = composted cotton stalks, CS+N = composted cotton stalks with a nitrogen source added during composting, and CGT = aged cotton gin trash.

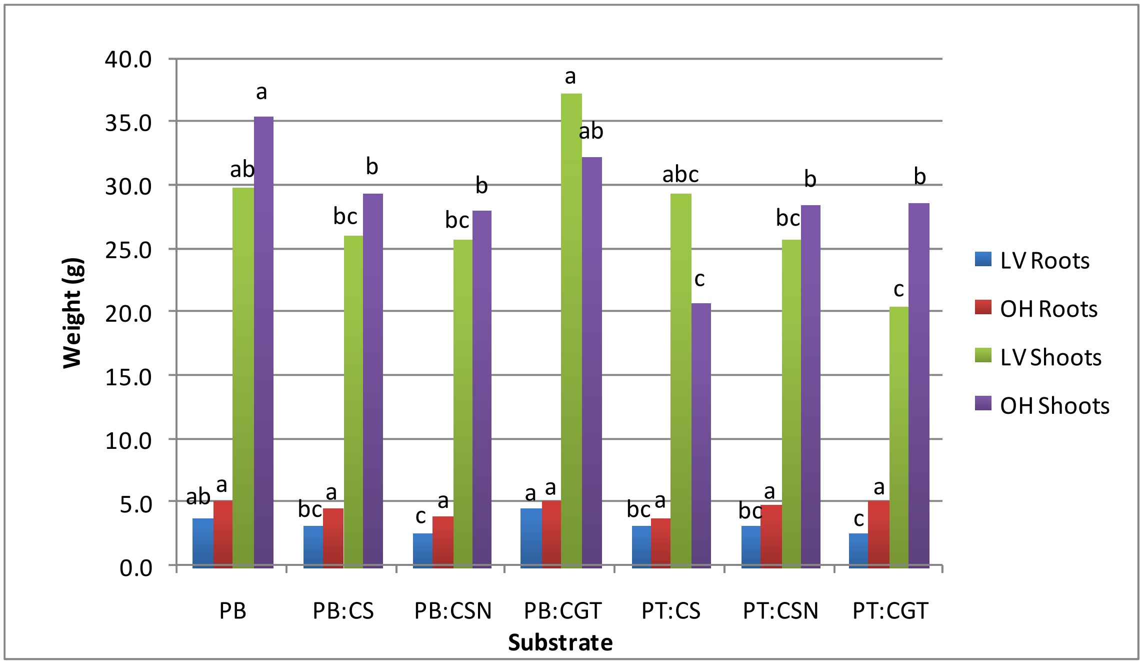


Figure 2. Effect of substrate on juniper root and shoot growth with two different production methods. Plants were grown with overhead, sprinkler irrigation with black weed fabric covering the ground (OH) or low volume, spray-stake irrigation system with gravel covering the ground (LV). Means between substrates with different letters are significantly different from each other based on lsd means separation procedures (*p*>0.05). The substrates consisted of: 4:1 PB : CS (PB:CS), 4:1 PB : CS+N (PB:CSN), 9:1PB : CGT (PB:CGT), 1:1 PT : CS (PT:CS), 1:1 PT : CS+N (PT:CSN), and 4:1 PT : CGT (PT:CGT) where PB = pine bark, PT = whole pine tree, CS = composted cotton stalks, CS+N = composted cotton stalks with a nitrogen source added during composting, and CGT = aged cotton gin trash.

Poultry Litter Ash as a Fertilizer Amendment in Greenhouse Crop Production

Daniel E. Wells and Edward W. Bush

Louisiana State University, School of Plant, Environmental, and Soil Sciences
Baton Rouge, LA 70803

dwell11@lsu.edu

Significance to Industry: 'New Gold' lantana, 'Homestead Purple' verbena, and 'Nirvana Red' vinca were grown in a greenhouse for five weeks in a substrate consisting of pine bark (PB) and peat moss (PM), and were fertilized with different sources of phosphorus and potassium. Results indicate that poultry litter ash can be utilized as a phosphorus (P) and potassium (K) source in greenhouse ornamental crop production.

Nature of Work: Global and domestic phosphate reserves are finite mineral resources. At current production rates, global phosphate reserves are expected to last approximately 50-100 years (3), while domestic reserves are projected to last less than 20 years (7). Global phosphate resources, on the other hand, are expected to last for an estimated 300 years. However, quality of phosphate rock is expected to decline while price is expected to increase, necessitating a search for alternative, sustainable sources of phosphorus for agricultural applications. Biomass ashes, from bioenergy production operations, have the potential to serve as nutrient sources for crop production (8). One biomass source that is abundant, high in plant essential nutrients, and is being utilized for energy production via combustion, is poultry litter. Poultry litter has been intensively and successfully applied as a nutrient source for crops in poultry producing areas, but transportation difficulties have severely limited land area available for such application, leading to an accumulation of P in soils (5). Combustion of poultry litter is one strategy that is being employed to concentrate nutrients contained in the litter, thereby lowering shipping costs, as well as, satisfying environmental concerns. The resultant poultry litter ash (PLA) contains essential plant nutrients including, but not limited to, phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), and sulfur (S) in relatively high concentrations and has been successfully used as a P source for agronomic crops (1, 2, 4). Since water solubility of PLA-P is very low (2), PLA could serve as a naturally slow-releasing P source. These factors, along with its high pH and calcium carbonate equivalence, make PLA a potentially ideal fertilizer amendment for greenhouse crop production.

Materials and Methods: Two plugs each, from 105-cell trays, of three species, (*Catharanthus roseus* (L.) G. Don 'Nirvana Red', *Lantana camara* L. 'New Gold', and *Viburnum canadensis* Britton 'Homestead Purple') were planted into 1.6 L containers filled with a substrate composed of PB and PM (4:1; v:v), placed on a raised bench in a greenhouse, and grown for five weeks. Eight fertilizer treatments, including a control, were applied to each species. The substrate amendments common to all treatments were 1.5 lbs yd^{-3} (0.89 kg m^{-3}) Micromax (Scotts Company, Marysville, OH) and 5 lbs yd^{-3} (2.97 kg m^{-3}) pulverized dolomitic limestone. Nitrogen (N) was supplied as NH_4NO_3 (aq.), with an initial concentration of 250 ppm N. P was supplied as superphosphate (SP) or PLA and was pre-plant incorporated at a rate of 0.8 lbs yd^{-3} P (282 g m^{-3}). Potassium (K) was supplied as KCl (aq.), at a concentration of 200 ppm K, or as PLA. The PLA (0-7-5) was a product of North American Fertilizers, LLC (Benson, MN) and SP (0-18-0) was a commercially available product (Hi Yield). The control group received no exogenous N, P, or K. Substrate pH and EC were monitored weekly using the Virginia Tech Extraction Method (9). At termination, flowers were quantified by counting flower buds showing color. Recently matured leaves were collected, oven-dried at 60 ˚C for 48 hours, and analyzed for nutrient content via ICP-AES. Plant tops were harvested at the substrate surface, oven-dried at 60 °C for 48 hours, and weighed to determine shoot dry weights (SDW). Root systems were assigned quality ratings based on root coverage and overall root health. The study was a completely randomized design (CRD) with five individual pot replicates. Data were analyzed using PROC MIXED in SAS. Means were separated using Tukey's Studentized Range Test ($\alpha = 0.05$).

Results and Discussion: Substrate leachate pH values ranged between 6.2 and 7 for all treatments and all species at study termination. The treatment containing PLA as the sole fertilizer amendment had the highest substrate leachate pH throughout the experiment while treatments containing SP as the sole fertilizer amendments had the lowest substrate leachate pH values throughout the experiment. Substrate leachate electrical conductivity values ranged between 0.5 and 2.5 mS cm^{-1} at study termination for all treatments and all species (data not shown).

'New Gold' lantanas fertilized with NH_4NO_3 + SP + KCl had the highest SDW while those grown in treatments receiving no exogenous P had the lowest (Table 1). Lantanas fertilized with NH_4NO_3 + PLA and with NH_4NO_3 + SP + PLA were significantly larger than those receiving no exogenous P. Bloom counts were highest for plants fertilized with SP. Lantanas fertilized with NH_4NO_3 + PLA were not different from those fertilized with NH_4NO_3 + SP + 0. Lantanas fertilized with SP had the highest root ratings, while those fertilized with NH_4NO_3 + PLA were not different from those fertilized with NH_4NO_3 + SP + 0.

'Homestead Purple' verbenas fertilized with SP had the highest SDW, while those fertilized with NH_4NO_3 + PLA were not different from those fertilized with NH_4NO_3 + SP + PLA (Table 1). Verbenas fertilized with SP and those fertilized with NH_4NO_3 + PLA had the highest number of blooms at study termination. Root system ratings were highest for verbenas fertilized with SP and with NH_4NO_3 + PLA, while those fertilized with NH_4NO_3 + PLA + KCl and NH_4NO_3 + 0 + 0 were not different from others fertilized with PLA.

'Nirvana Red' vincas fertilized with SP had the highest SDW, while those fertilized with NH_4NO_3 + PLA were not different from those fertilized with NH_4NO_3 + SP + KCl and those fertilized with NH_4NO_3 + SP + 0 (Table 1). Vincas fertilized with NH_4NO_3 + SP +

KCl, NH_4NO_3 + SP + PLA, or NH_4NO_3 + PLA had the highest number of blooms, while those receiving no exogenous P fertilization had lower numbers of blooms. Root system ratings were highest for vincas fertilized with SP or with NH_4NO_3 + PLA.

'Homestead Purple' verbenas fertilized with SP were the only plants that had foliar P concentrations within a reported sufficiency range (6) (Table 2). Plants fertilized with NH_4NO_3 + PLA + KCl were not significantly different from those fertilized with NH_4NO_3 + SP + PLA. All plants fertilized with PLA had higher foliar P concentrations than plants receiving no exogenous P. Verbenas receiving no exogenous K and those fertilized with NH_4NO_3 + 0 + KCl had foliar K concentrations below the reported sufficiency range. Plant growth, however, was not affected for plants fertilized with NH_4NO_3 + SP + 0, since this group had the highest SDW, bloom counts, and root system ratings.

Plants fertilized with PLA performed as well as those fertilized with SP is some cases. Foliar P concentrations were below the reported sufficiency range for plants fertilized with PLA alone. However, plant growth characteristics were not affected, in most cases. Plants fertilized with PLA had foliar K concentrations that were within the reported sufficiency range. Foliar K concentration, however, did not appear to affect plant growth and quality parameters. Reduced uptake of P by plants fertilized with PLA as the sole P source is believed to be the result of low water solubility of PLA-P. PLA has great potential as a naturally slow-releasing P fertilizer amendment for greenhouse crop production.

Literature Cited:

1. Codling, E.E., Chaney, R.L, and J. Sherwell. 2002. Poultry litter ash as a potential phosphorus source for agricultural crops. J. Environ. Qual. 31:954-961.
2. Codling, E.E. 2006. Laboratory characterization of extractable phosphorus in poultry litter and poultrylitter ash. Soil Science. 171 (11):858-864.
3. Cordell, D., Drangert, J., and S. White. 2009. The story of phosphorus: global food security and food for thought. Global Environmental Change 19:292-305.
4. Faridullah, M.I., Yamamoto, S., Eneji, A.E., Uchiyama, T., and T. Honna. 2009. Recycling of chicken and duck litter ash as a nutrient source for Japanese mustard spinach. J. Plant Nutr. 32:1082-1091.
5. Maguire, R.O., and G.L. Mullins. 2008. Evaluating long-term nitrogen- versus phosphorus-based nutrient management of poultry litter. J. Environ. Qual. 37(5):1810-1816.
6. Mills, H.A., and J.B. Jones, Jr. 1996. Plant analysis handbook II: a practical sampling,
   preparation, analysis, and interpretation guide. Micromacro Publishing, Inc.
7. Roberts, T.L. and W.M. Stewart. 2002. Inorganic phosphorus and potassium production and reserves. Better Crops. 86(2):6-7.
8. Schiemenz, K. and B. Eichler-Lobermann. 2010. Biomass ashes and their phosphorus fertilizing effect on different crops. Nutr. Cycl. Agroecosyst. 87:471-482.
9. Wright, R.D. 1986. The pour-thru nutrient extraction procedure. HortScience 21:227-229.

Table 1. Plant growth characteristics as affected by fertilizer amendments.

Treatment[Z]	'New Gold' lantana			'Homestead' verbena			'Nirvana Red' vinca		
	Shoot Dry Weight	Bloom Count[Y]	Root Rating[X]	Shoot Dry Weight	Bloom Count	Root Rating	Shoot Dry Weight	Bloom Count	Root Rating
NH_4NO_3 + SP + KCl	11.23a[W]	59.2a	4.0ab	13.07a	7.4a	4.8a	9.46ab	22.8ab	4.8a
NH_4NO_3 + PLA + KCl	3.34d	29.8c	1.0c	7.05c	4.0b	3.6b	5.39c	17.2c	2.2b
NH_4NO_3 + 0 + KCl	2.25de	5.8d	1.6c	2.69d	0.4c	1.4d	2.92d	11.6d	2.6b
NH_4NO_3 + SP + PLA	9.35b	54.4a	4.4a	12.59ab	10.4a	4.4ab	9.63a	26.6a	4.4a
NH_4NO_3 + PLA	6.65c	40.8bc	3.4b	10.65b	9.0a	4.2ab	8.04b	22.4abc	4.4a
NH_4NO_3 + 0 + 0	1.97de	2.8d	1.6c	2.95d	0.8c	3.6b	2.88d	6.8de	2.6b
NH_4NO_3 + SP + 0	9.16b	50.2ab	4.2ab	14.38a	8.4a	4.8a	9.12ab	20.6bc	4.4a
0 + 0 + 0	0.84e	0.0d	1.0c	1.54d	0.0c	1.0d	1.04e	5.4e	1.0c

[Z]Treatments were: SP = superphosphate (0-18-0); PLA = poultry litter ash (0-7-5).

[Y]Flower buds showing color at study termination.

[X]Rating scale was from 1 to 5 and was based on root system coverage, health, and overall quality.

[W]Means in columns followed by different letters are significantly different according to Tukey's Studentized Range Test (α = 0.05).

Table 2. Foliar macronutrient content of *Verbena canadensis* 'Homestead Purple'.

Treatment[Z]	Calcium	Magnesium	Nitrogen	Phosphorus	Potassium	Sulfur
	Percentage					
NH_4NO_3 + SP + KCl	1.22abc[Y]	0.52bc[X]	3.73bc	0.50a	2.87c	0.52a[W]
NH_4NO_3 + PLA + KCl	0.95cd[X]	0.42cd[X]	4.02b[W]	0.39bc[X]	4.40a	0.54a[W]
NH_4NO_3 + 0 + KCl	1.11abc[X]	0.55b	4.89a[W]	0.08d[X]	1.38d[X]	0.43b
NH_4NO_3 + SP + PLA	1.06bcd[X]	0.44cd[X]	3.81bc	0.47ab	3.65b	0.52a[W]
NH_4NO_3 + PLA	1.26ab	0.49bc[X]	3.60bc	0.36c[X]	3.06c	0.49ab
NH_4NO_3 + 0 + 0	1.37a[W]	0.58ab	5.10a[W]	0.07d[X]	1.05de[X]	0.46ab
NH_4NO_3 + SP + 0	1.39a[W]	0.66a	3.55c	0.51a	0.72e[X]	0.49ab
0 + 0 + 0	0.78d[X]	0.33d[X]	0.85d[X]	0.08d[X]	0.98de[X]	0.13c[X]

[Z]Treatments were: SP = superphosphate; PLA = poultry litter ash.
[Y]Values in column followed by different letters are significant according to Tukey's Studentized Range Test (α = 0.05).
[X]Indicates a value that is below the sufficient range reported by Mills and Jones (1996).
[W]Indicates a value that is above the sufficient range reported by Mills and Jones (1996).

Assessing Biocontainers and a Sustainable Irrigation Regime for the US Nursery Industry

A. Fulcher[1], G. Niu[2], G. Bi[3], M. Evans[4], T. Fernandez[5], R. Geneve[6], A. Koeser[7], S. Nambuthiri[6], N. Pershey[5] R. Stewart[8], S. Verlinden[9], and X. Wang[5]

[1]University of Tennessee, Knoxville, TN, [2]Texas AgriLife Research, Texas A&M University System, El Paso, TX, [3]Mississippi State University, [4]University of Arkansas, [5]Michigan State University, [6]University of Kentucky, [7]University of Illinois, [8]Brigham Young University, and [9]West Virginia University

afulcher@utk.edu

Index Words: plastic, nursery crop, renewable, biodegradable

Significance to the Industry: Current container nursery crop production consumes a substantial amount of plastic and water, raising environmental concerns. Decreasing consumption of plastic and reducing water use are practices that will assist the nursery industry in achieving greater sustainability and protecting natural resources. This research examined the use of biocontainers and a sustainable irrigation system to determine how nursery producers can most practically and profitably adopt sustainable practices. Preliminary results suggest there is no effect of container type on growth, however, in some locations container type may affect mortality.

Nature of Work: Above ground nursery production and pot-in-pot production rely almost exclusively on plastic containers. In 1993, approximately 240 million pounds of plastic (58.8% of total plastics consumed by the nursery and floriculture industries) were generated by the nursery industry in the manufacture of high-density polyethylene and polypropylene nursery containers (2). Just 1% of horticulture plastics are recycled in spite of the fact that plastic pots and trays are recyclable. Non-plastic containers are slowly being adopted by a select number of businesses, however concerns exist about durability during plant production and shipping, biodegradability in the landscape, and plant growth during and post production (4). Research shows that consumers may not only desire biodegradable containers but may be willing to pay more for them (7).

Water is essential to container nursery crop production. Because the nursery industry has shifted from primarily field-produced crops to container-produced crops, the need for irrigation water is increasing. Over 75% of nursery crops in 17 of the major nursery-producing states are currently grown in containers (5). A container nursery with 70% of the land in production under overhead irrigation could use between 14,000 to 19,000 gallons of water per acre per day during the peak-growing season. Scientists and industry leaders anticipate less water available for production in the future (1). U.S. municipalities in all or part of California, Florida, North Carolina, Texas and Oregon have already responded to competition for water and/or concerns regarding water quality and runoff with container nursery irrigation restrictions.

The objectives of this work were to 1) test pulp-based containers for water use, plant performance, and container strength in above ground production plots and pot-in-pot production and 2) examine a conservative irrigation regime based on water consumption for above ground container production.

Above Ground Container Experiment

In mid-May 2011, rooted *Euonymus fortunei* 'Roemertwo' Gold Splash® cuttings were potted with 85% pine park:15% peat (vol/vol) into one gallon conventional plastic pots (C400, Nursery Supplies® Inc.) or one of two pulp-based biocontainers: Kord® Fiber Grow (FNP 0707, ITML Horticultural Products) or 7X7RD (Western Pulp Products Co.). The pot sizes were 3.8 L for plastic and 3.9 L for both biocontainers. Plants were fertilized with 8 g of 19.0N–2.2P–7.5K per container (HFI Topdress Special, Harrell's Inc.) or comparable fertilization. Irrigation application volume replaced 100% of the water used since the previous substrate moisture measurement (6). Dielectric probes (Decagon Devices, Inc.) connected to a datalogger were used to measure volumetric water content (two probes per irrigation zone replicate). The datalogger program calculated evapotranspiration and then opened solenoid valves for the appropriate time to apply what was lost in evapotranspiration. Plants were irrigated twice daily.

Irrigation was applied through four overlapping Shrub Spray Sprinklers (570, The Toro Co.) per irrigation zone. Emitters were mounted on 1.3-cm diameter risers at a height of 66 cm. Irrigation zones were 10 square feet. A single Rain Bird 13DE04K solenoid valve (Rain Bird Corporation) provided irrigation for each treatment replicate. The experiment was a randomized complete block design. There were three replicate zones per treatment and 15 plants per zone. Sixteen border plants were included in each zone but not utilized for data collection.

Above ground production experiments were conducted in IL, KY, MI, MS, WV, and TX. Mortality, height, and growth index were recorded monthly from June through October. Mortality was reported as the cumulative mortality for the season.

Pot-in-Pot Production Experiment

Betula nigra bare root liners were potted with 85 pine bark:15 peat (vol/vol) into seven gallon containers in mid-June 2011. The containers were a conventional black plastic pot (GL2800, Nursery Supplies® Inc.), Kord® Fiber Grow (FNP1514, ITML Horticultural Products), and 15x13 RD (Western Pulp Products Co.). A GL6900 (15 gallon) container served as the socket pot. A gap existed between the production and socket pot for some container types. This gap was filled with bubble wrap and sealed. Copper treated fabric was placed between each production and socket pot to prevent roots from escaping the production pot and rooting into the soil. Container moisture content was determined with a theta probe (ML2, Dynamax Inc.). Irrigation was applied to replace 100% of daily water use. Irrigation was delivered with one Tornado RayJet emitter (Plastro Irrigation Systems Ltd.) per container. The study was conducted from July thru October 2011. The experiment was a completely randomized design with eight replications. Pot-in-pot experiments were conducted in KY, MI, MS, and TX.

Results and Discussion:

Above Ground Container Experiment

Preliminary results are presented from El Paso, Texas and East Lansing, Michigan.

In Texas, there were no differences in plant height or growth index. Plants gained approximately seven cm in height over the course of the experiment and the growth index increased from approximately 11 at the beginning of the experiment to 18 at the termination of the experiment. Plant mortality was significantly greater for the plastic pots than either biocontainer, 60% mortality versus 20% in each of the biocontainers (Figure 1). Plastic pots may have had substantially higher temperatures than biocontainers. Plastic container temperatures can exceed 135 °F in the Southern US during the growing season (3). Because fiber containers are porous, plants in them may have benefitted from evaporative cooling.

In Michigan, there also was no significant difference in plant height or growth index between pulp-based container and plastic container (control). The average height of plants had increased from 12 cm (June 30, 2011) to 20 cm (Oct 18, 2011). The growth index ((height + width1 +width2) / 3) had increased by five units during the experimental growing season. The plant mortality was 13% in plastic containers, which was higher than 2% in pulp-based containers. Plastic containers generally had greater temperature than pulp-based containers. The biomass (dry weight) of each treatment was measured on September 24, 2011. There was no significant difference in biomass between treatments (Figure 2).

Pot-in-Pot Experiment

Preliminary results are reported for Crystal Springs, Mississippi and East Lansing, MI.

In Mississippi, there was no effect of container type on plant biomass. Plants gained approximately 20 cm in height regardless of container type. Growth indices increased from 40, based on measurements taken near the beginning of the experiment (July 21, 2011) to 58 in October 3, 2011. Minimal plant mortality occurred in the pot-in-pot experiment and was independent of container type.

In Michigan, there was also no effect of container type on plant height and growth index. The plant growth index had increased from an average of 23 cm (June 30, 2011) to 67 cm (October 3, 2011). The plant height generally increased by 40 cm regardless of treatment. There was no plant mortality during the growing season.

In conclusion, these preliminary data suggest that pulp-based containers do not have negative consequences on plant growth in above ground or pot-in-pot production. In fact, plant stress may be reduced and survival may be greater in biocontainers compared to conventional black plastic containers when used in above ground container production. Future research will investigate water consumption and temperature differences between biocontainers and conventional black plastic containers, strength of biocontainers during and after production, and landscape plant performance.

Acknowledgements:
The authors wish to acknowledge support of Spring Meadow Nursery, Renewed Earth, and Western Pulp Products Co. for product donations, Dr. Daniel Warnock, and a USDA Specialty Crop Research Initiative grant, all of which made this work possible.

Literature Cited:

1. Beeson Jr., R.C., M.A. Arnold, T.E. Bilderback, B. Bolusky, S. Chandler, H.M. Gramling, J.D. Lea-Cox, J.R. Harris, P.J. Klinger, H.M. Mathers, J.M. Ruter and T.H. Yeager. 2004. Strategic vision of container nursery irrigation in the next ten years. J. of Env. Hort. 22:113-115.

2. Garthe, J.W. and P.D. Kowal. 1993. Recycling used agricultural plastics. Penn State Fact Sheet C-8. 26 Oct. 2009. <http://www.abe.psu.edu/extension/factsheets/c/C8.pdf>.

3. Martin, C.A. and D.L. Ingram. 1988. Temperature dynamics in black poly containers. Proc. Southern Nurseryman Assoc. Res. Conf. 33:71-74.

4. Taylor, M., M. Evans, and J. Kuehny. 2010. 'The Beef on Biocontainers: Strength, Water Use, Biodegradability, and Greenhouse Performance. OFA Bulletin. September/October Number 923. <http://www.ofa.org/pdf/bulletins/sample_bulletin.pdf >

5. U.S. Department of Agriculture. 2008. 2007 Census of Agriculture, Washington, DC.

6. Warsaw, A. L., R. T. Fernandez, and B.M. Cregg. 2009. Water conservation, growth, and water use efficiency of container-grown woody ornamentals irrigated based on daily water use. HortScience 44:1308–1318.

7. Yue, C., Hall, C.R., Behe, B,K., Campbell, B.L., Lopez, R.G., and Dennis, J.H. 2010. Investigating consumer preference for biodegradable containers. J. Environ. Hort. 28(4):239-243.

Figure 1. *Euonymus fortunei* Gold Splash® mortality grown above ground in three container types (El Paso, Texas).

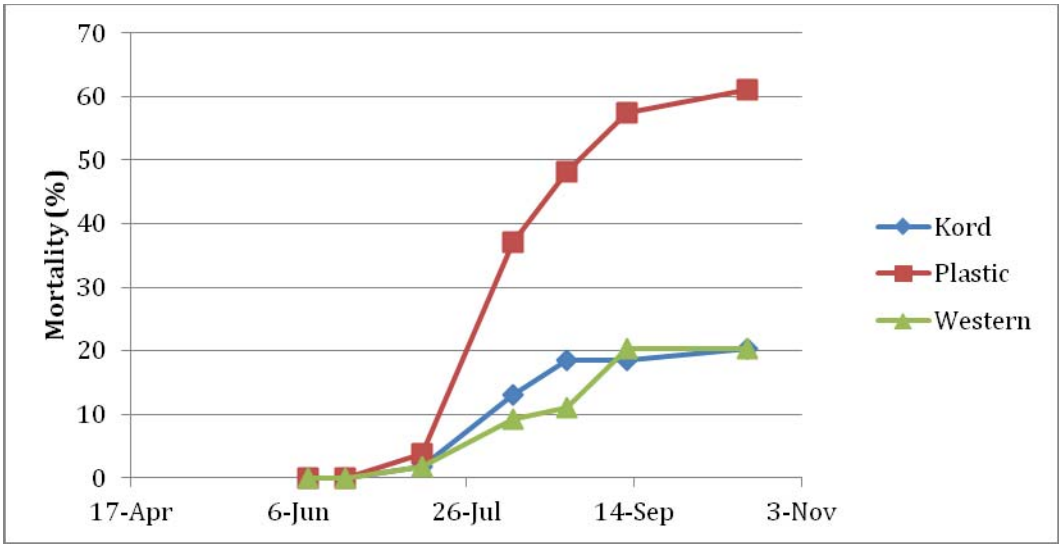


Figure 2. Dry weight of *Euonymus fortunei* Gold Splash® grown above ground in three container types (East Lansing, MI).