Water Quality & Management

Samuel O. Dennis
Section Editor and Moderator

Soil pH and Organic Carbon Content Under Rain-fed Condition in Nursery Stock Quarantine Treatment of Japanese beetle

Sam O. Dennis, Jason Oliver,
Peter Nveawiah-Yoho and Bhargavi Sheshahala
Institute of Agricultural and Environmental Research,
Tennessee State University, 3500 John A. Merritt Blvd., Nashville, TN 37209
sdennis@tnstate.edu

Index Words: Sorption, Pesticides, Drench Treatment, Dip Treatment, Organic Matter, Grubs, Surface Water

Significance to Industry: Insecticides are used extensively in the nursery industry to control insect pests. A number of these nursery pests, like Japanese beetle, occur in the soil around the root zone of the crop. Soil-borne insect pests present unique challenges to nursery producers and regulatory agencies. One of these challenges is achieving pesticide longevity in the soil. It is important that pesticides be sorbed (adsorbed) to the soil around the root zone long enough to provide for a good pest control. Soil pH and organic carbon are important soil parameters in the sorption and degradation process of pesticides in soils. Carbon is the main element present in soil organic matter comprising about 58% of the total weight. Organic carbon values are often used as a basis for organic matter estimates. By multiplying the soil organic carbon value by 1.724, the corresponding result is approximately the soil organic matter content. Soil organic matter tends to enhance the adsorption of pesticides to soil. The enhanced pesticide adsorption facilitates pesticide availability to the targeted host and retards pesticide mobility to contaminate surface and ground water. Growers need to be aware that soil organic matter can be depleted because it also serves as a source of food for soil microorganisms. Therefore, growers need to replenish organic matter during soil management practices.

Nature of Work: Japanese beetle (*Popillia japonica* Newman) is a pest that does considerable damage to horticultural crops including nursery stock. Annual turf damage has been estimated at nearly $156 million and the estimated annual cost for controlling the adult and a larval (grub) stage is greater than $460 million (USDA-APHIS, 1998). Female Japanese beetles lay their eggs throughout the summer while the grubs remain in the soil until the following spring/summer. Thus, the risk of spreading the grubs with movement of soil-containing products like nursery stock is a threat to agricultural systems. As a result of the damaging nature of the Japanese beetle, the USDA quarantined the movement of products that are likely to contain Japanese beetle during the 1920s. In 1978, regulatory responsibility for the quarantine program was transferred from USDA to individual States. The U.S. Domestic Japanese Beetle Harmonization Plan was developed by the National Plant Board to standardize Japanese beetle quarantine treatments among States, because the elimination of the federal Japanese Beetle Quarantine resulted in considerable confusion regarding interstate treatments.

The nursery industry needs Japanese beetle quarantine treatments for in-field nursery stock that are effective, practical and environmental friendly. Current field nursery stock treatments for Japanese beetle include one in-field treatment and one post harvest (balled & burlap [B&B]) treatment option (U. S. Domestic Japanese Beetle Harmonization Plan, 2000). However the utilization of these treatments by the green industry producers has serious environmental and economic limitations. The in-field treatment option (i.e., Marathon 60WP or Discus [imidacloprid] for Japanese beetle is expensive, costing around $400 to $800 per acre). The post-harvest B&B treatment requires an insecticide dip in chlorpyrifos. Plant dips have a number of problems that include being hazardous to labor, very time consuming, disruptive of root balls, and the disposal of large volumes of insecticide solution.

Soil characterization for certain soil physical-chemical properties is important for understanding pesticide dynamics in soil or in soil constituents such as clay minerals and humic substances. For example, loss of soil organic matter (thus of soil organic carbon) can result in the breakdown of soil structure and subsequently greater vulnerability of the soil to erosion, pesticides and nutrient runoff, and reduced fertility.

This research was initiated in fall of 2003 as part of a major study that addresses alternative field nursery stock quarantine treatments for imported fire ants and Japanese beetle. The specific objective of this study was to characterize soil organic carbon (OC) content and soil pH in root balls harvested for Japanese beetle quarantine treatments, because both parameters (pH and OC) may be needed to explain the test pesticides' persistence in the root balls. Soil pH plays a major role in the fate of pesticides in soils (Sparks, 1989). Generally, addition of organic matter increases the adsorption of pesticides and decreases their subsequent mobility in the soil profile (Singh, 2003, Sluszny et al., 1999, Guo et al., 1993). Some growers use plant residues as part of their soil management practices to increase soil organic matter in their nursery crop production systems.

Two quarantine treatment methods were used in this study. One of the quarantine treatments consisted of a post-harvest B&B nursery stock drench treatment using three pesticides (insecticides): Dursban TNP (Chlorpyrifos), Talstar Lawn & Tree F (Bifenthrin), and Flagship 25WG (Thiamethoxam). The second treatment method was a post-harvest B&B nursery stock dip treatment using the same pesticides in the drench protocol. The balled and burlapped plants used in this study were purchased from local commercial nurseries. The B&B plants used for the dip and drench experiments had root ball diameters of about 37.5 and 60 cm (15 and 24 in), respectively. The root balls were artificially infested with Japanese beetle grubs and drenched or dipped in the three previously described pesticides (i.e., Dursban, Talstar, and Flagship). Root balls were left under field weather conditions to simulate open B&B yard storage. Soil samples were taken from the root balls at 0.5, 1.0, 2.0, and 4.0 months post pesticide treatment and analyzed for pH and organic carbon. The soil pH was determined with a soil to water ratio of 1:2, while the organic carbon content was performed with a solid total organic carbon (TOC) analyzer. A sub-sample of the soil was also taken for pesticide persistence study; the data is not being presented at this time.

Results and Discussion: The pre-harvest soil pH of the site where B&B plants were removed ranged from 5.23 to 5.45 and 6.23 to 6.76 for samples collected from the drench and dip study, respectively. The initial soil organic carbon content ranged from 1.36 to 1.74 percent for the drench treatments and 1.33 to 1.36 percent for the dip samples. The B&B plants used for the study were obtained from different nursery sites, which explains the variation in both the pH and organic carbon content of the drench and dip treatment soils. The pH and organic carbon values for the drench and dip treatments are shown in Table 1. Results from the 2 and 4 months post treatment soil sampling have not been analyzed and are not shown in the table. The pesticides used in the study had no effect on soil pH or soil organic carbon. Pesticides applications do not normally impact soil pH or organic carbon; instead these soil characteristics affect pesticide behavior in soils. Although not statistically different, organic carbon values, and subsequently the soil organic matter, seem to decrease slightly with time in dip and drench treatment samples that were studied. These results demonstrate that it is possible for soil organic matter to become depleted with time in a harvested root ball. The extent of the soil organic carbon depletion occurring in B&B root balls could have implications for the longevity and efficacy of pesticide quarantine treatments, especially if root balls are stored for extended periods of time. It is well documented that sorption of non-ionic organic compounds like the pesticides used in the study are controlled by the organic matter component of the soil. According to Brusseau (1995), there is a positive linear correlation between sorption of non-ionic organic chemicals and soil organic matter (OM) content, expressed in terms of organic carbon partition coefficients (K_{oc}). This relationship (chemical sorption and OM) may be valid in soils with organic carbon content as low as 0.1%. The organic carbon content in this study was greater than 0.1% (Table 1), indicating the tested pesticides have the potential to sorb to the soil, especially around the root zone where most soil-borne pests occur. If grub densities are greater in the root zone where pesticide adsorption is the highest, then the efficacy of the pesticides will be enhanced; which is the goal of the Japanese beetle quarantine program.

Literature Cited:

1. Brusseau M. L., 1995. Sorption and transport of organic chemicals. In vadose zone characterization & monitoring. Lewis Publishers pp. 93-104.
2. Guo L., T. J. Bicki, A.S. Felsot and T. D. Hinesly. 1993. Sorption and movement of alachlor in soils modified by carbon rich waste. J. Environ Qual. 22: 186-194.
3. Singh N., 2003. Organic manure and urea effect on metolachlor transport through packed soil columns. J. Environ Qual. 32: 1743-1749.
4. Sluszny C., E. R. Graber and Z. Gerstl. 1999. Sorption of s-triazine herbicides in organic matter amended soils: Fresh and incubated systems. Water Air Soil Pollut. 115:395-410.
5. Sparks D. L. 1989. Kinetics of pesticides and organic pollutant reactions. In kinetics of soil chemical processes. Academic Press Inc. pp. 128-145.

6. USDA-APHIS. 1998. Managing the Japanese beetle: a homeowner's handbook. Program Aid No 1599.
7. U. S. Domestic Beetle Harmonization Plan. 2000. http: //www.aphis.usda.gov/Npb/jbintro.html.

Table 1. Soil pH and soil organic carbon values of the dip and drench treatments.

Treatment	Chemical	MAT*	pH	% Organic Carbon
Drench	Dursban	0.5	5.44	1.53
Drench	Dursban	1.0	5.36	0.84
Drench	Flagship	0.5	5.40	1.61
Drench	Flagship	1.0	5.04	0.85
Drench	Talstar	0.5	5.52	1.56
Drench	Talstar	1.0	5.32	1.39
Dip	Dursban	0.5	6.65	1.39
Dip	Dursban	1.0	6.00	1.20
Dip	Flagship	0.5	6.25	1.40
Dip	Flagship	1.0	6.20	1.27
Dip	Talstar	0.5	6.32	1.46
Dip	Talstar	1.0	5.82	1.27

*MAT = Months after treatment.

Acknowledgements: The authors would like to thank the USDA Pest Management Alternatives Program (PMAP) for funding portions of this research project.

Establishment of Perennials in Hydrophilic Polymer-Amended Soil

Jyotsna Sharma
Department of Environmental Horticulture
University of Florida NFREC, Quincy, Florida 32351
jsharma@ifas.ufl.edu

Index words: Hydrogel, Polyacrylamide, Drought stress, Stomatal conductance, Leaf water potential

Significance to Industry: Newly transplanted plants often are susceptible to drought stress. Establishment of perennials may be improved if moisture holding capacity of the substrate is increased by adding substances, such as hydrogel, that retain water. Because water is held within the substrate, plants growing in the amended substrate may be watered less frequently. In this study, hydrogel amendment reduced drought stress in plants of *Asclepias incarnata* and *Gaillardia grandiflora*. Stomatal conductance and leaf water potential were higher in plants growing in amended soil than in plants growing in unamended soil. Time to wilting was longer for plants growing in amended soil, amended soil appeared less compacted than non-amended soil, and the root systems were larger on plants growing in amended soil.

Nature of Work: Improved retention of water in the substrate can benefit plants in the establishment phase. Anionic polyacrylamide (PAM) polymers or hydrogels are chains of acryl-amide monomer that can hold up to 1500 times their weight in pure water (Johnson, 1984; Nadler and Steinberger, 1993). Amending the substrate with hydrogel has been shown to: (1) reduce watering frequency; (2) increase pore space and water infiltration; (3) reduce erosion and runoff; and (4) improve soil aeration (Bowman et al., 1990). The objective of this study was to determine the effect of hydrogel amendment on shoot gas exchange, time to wilting, and root size among plants of *Asclepias incarnata* and *Gaillardia grandiflora*. Seedlings were transplanted into a silty clay loam (pH = 6.1) amended with HydroSource™ (Western Polyacrylamide Inc., Castle Rock, CO) to replace 0% (control), 7.5%, 15% (recommended rate), and 30% of the container (20 cm (8”) plastic pot) volume. Experimental units were replicated and arranged on a nursery bed in a completely randomized design. Stomatal conductance was measured each day during the 4-day drying cycle. Leaf water potential was measured on the first and the last day of the drying cycle. Wilting of plants was documented and roots also were compared visually at the end of the experiment.

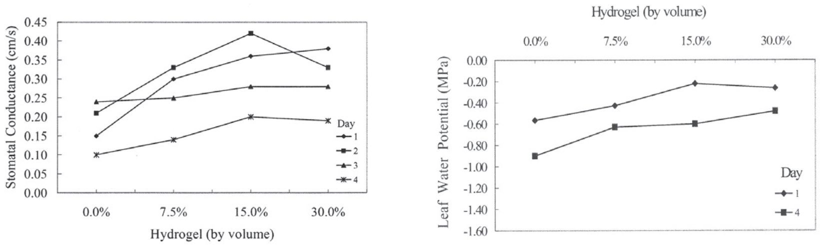
Results and Discussion: Stomatal conductance (a measure of available water) increased with increasing rate of hydrogel amendment. An interaction was observed between day of drying cycle and hydrogel amendment rate ($p<0.05$), whereby stomatal conductance decreased on each successive day of the drying cycle. Daily values were more similar through the drying cycle at higher hydrogel rates than at lower rates of hydrogel amendment (Figs. 1a and 2a). Plants growing in unamended soil had lower water potential as reflected in the leaf water potential measurements than plants growing in amended soil (Figs. 1b and 2b). Leaf water potential means were significantly lower ($p<0.0001$) on the last day of the drying cycle than on the first day (Figs. 1b and 2b). Plants growing in amended soil were larger and had more roots than the plants growing in unamended soil.

Results from this study show that amendment of substrate with hydrogel can increase the water available to plants because water is retained within the hydrated polymer. Frequency of watering consequently may be reduced. Plants growing in hydrogel amended soil had more water available (reflected in higher stomatal conductance and higher leaf water potential) for longer periods of time compared to control plants. Overall, plant growth and root development were improved with hydrogel amendment. Other researchers have reported similar results (Wang and Boogher, 1987). Increase in plant growth may also be due to increased nutrient retention in hydrogel-amended substrate (Bres and Weston, 1993). However, no fertilizer was applied to plants in this study. Tripepi, et al. (1991) showed that hydrogel retained moisture instead of releasing it to the surrounding medium and therefore did not increase water availability for plants. In this study roots grew through the hydrated polymer; this suggests that roots may be directly drawing water held within the hydrogel. Plant growth and root development of *Asclepias incarnata* and *Gaillardia grandiflora* were improved by amending the substrate with hydrogel. Growers may benefit from amending growing substrate with hydrogel to improve plant growth while reducing irrigation frequency.

Literature Cited:

1. Bowman, D.C., R.Y. Evans, and J.L. Paul. 1990. Fertilizer salts reduce hydration of polyacrylamide gels and affect physical properties of gel-amended container media. Journal of American Society of Horticultural Science 115:382-386.
2. Bres, W. and L. Weston. 1993. Influence of gel additives on nitrate, ammonium, and water retention and tomato growth in a soilless medium. HortScience 28:1005-1007.
3. Nadler, A. and Y. Steinberger. 1993. Trends in structure, plant growth, and microorganism interrelations in the soil. Soil Science 155:114-122.
4. Tripepi, R.R., M.W. George, R.K. Dumroese, and D.L. Wenny. 1991. Birch seedling response to irrigation frequency and a hydrophilic polymer amendment in a container medium. J. Environ. Hort. 9:119-123.
5. Wang, Yin-Tung, and C.A. Boogher. 1987. Effect of a medium-incorporated hydrogel on plant growth and water use of two foliage species. J. Environ. Hort. 5:125-127.

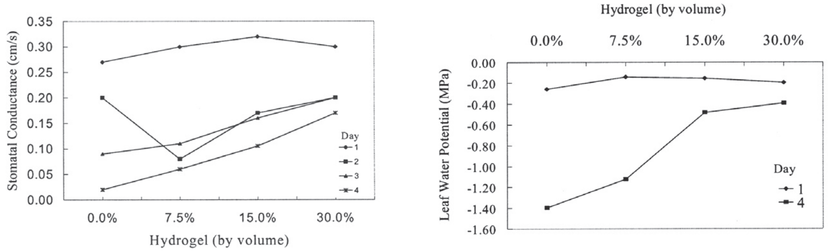
Figure 1. Stomatal conductance (1a) and Leaf water potential (1b) in *Asclepias incarnata* growing in soil amended with hydrogel. Because a significant interaction was observed between day of drying cycle and hydrogel amendment rate, means for each hydrogel treatment are plotted for each of the four days of the drying cycle. Pool standard errors: 0.02 for stomatal conductance means; 0.05 for leaf water potential means.



(1a)

(1b)

Figure 2. Stomatal conductance (2a); and Leaf water potential (2b) in *Gaillardia grandiflora* growing in soil amended with xhydrogel. Because a significant interaction was observed between day of drying cycle and hydrogel amendment rate, means for each hydrogel treatment are plotted for each of the four days of the drying cycle. Pool standard errors: 0.03 for stomatal conductance means; 0.06 for leaf water potential means.



(2a)

(2b)

N and P Discharge During Spring Regrowth from Constructed Wetlands in a Commercial Nursery

Milton D. Taylor[1], Stephen J. Klaine[1], and Ted Whitwell[2]
[1]Clemson Institute of Environmental Toxicology,
Clemson University, Pendleton, SC 29670
[2]Department of Horticulture, Clemson University, Clemson, SC 29632
taylor@clemson.edu

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

Significance to Industry: Farming has long been considered the ‘classic’ example of a non-point source discharger of pollutants and consequently has come under close scrutiny by regulatory agencies. However, nurserymen want to be good stewards of their land and the environment and so adopt fertilizer management practices designed to meet or exceed water quality standards set by State and Federal regulators. In this study, there was concern that a constructed wetland system used to meet water quality regulations may be exporting N and P during spring decomposition of last year’s biomass. Despite an intensive sampling effort during March to May 2003, we found no evidence that this occurs to any substantive degree. Therefore, it appears that a constructed wetland system is highly useful for nitrogen removal from nursery runoff and contributes to phosphorus removal during vegetative growth flushes.

Nature of Work: Container-grown plants at commercial nurseries require large amounts of water and nutrients during the production cycle. Water is applied at application rates sufficient to ensure leaching of soluble salts and this results in substantial runoff. Thus, mitigation of offsite movement of nutrients in runoff is a serious concern. Constructed wetlands are one method used to remove nutrients from runoff before discharge to surface waters. Previous research by us has shown a strong seasonal pattern for nitrogen removal, lower in winter and above 90% in all other seasons, in constructed wetlands with phosphorus removal corresponding with vegetative growth flushes in the wetlands (Taylor et al., 2003). Substantial quantities of biomass are generated by constructed wetlands during the growing season and typically decompose rapidly as water temperatures rise in the spring. This presents the potential for substantial release of N and P as plant decomposition occurs, which could result in adverse environmental effects downstream.

To determine if this was a serious concern, we intensively monitored the spring regeneration of plants in 9.3 acres (3.77 ha) of mature constructed wetlands installed in 1997 by Wight Nurseries of Monrovia Growers, Cairo GA to receive direct runoff from a 120 acre (48.6 ha) drainage basin. Wetland system design was a two stage design, with a deep water first stage, averaging 30 inches (75 cm), planted in bands of California bullrush (*Schoenoplectus californicus*), maidencane (*Panicum hemitomon*), and pickerelweed (*Pontederia cordata*) and a shallow second stage wetland, averaging 8 inches (20.5 cm) in depth, originally planted in bands of maidencane, pickerelweed, and duck potato (*Sagittaria* *lancifolia*) but now dominated by cat-tail (*Typha latifolia*). Water flow through the system ranged from 423,280 to 582,011 gallons (1.6 to 2.2 million liters) per day. Water samples and water temperatures were taken daily (~0830 hrs) in early March and two (~0830 and 1630 hrs) to three times (~0830, 1200, and 1630 hrs) daily from late March through mid-May. Sampling sites included inflow to first stage wetland, discharge/inflow to second stage wetland, discharge from second stage wetland, and final effluent from the constructed wetland system. Water samples were analyzed for chloride, nitrate, nitrite, phosphate, and sulfate using a Dionex AS50 ion chromatograph with an AS50 autosampler.

Results and Discussion: There were no consistent diurnal patterns in nitrogen concentration or removal efficiency by either the first or second stage of the constructed wetlands throughout the sampling period. Overall nitrogen export by the constructed wetlands was not evident during the spring of 2003 with nitrogen removal efficiency averaging 98.26% (s.d. 1.47%, max 99.95%, min 92.55%). However, there was a small quantity of nitrogen exported in the form of nitrate from the second stage wetland for three days in late March. On the 19th, 20.9 gm nitrogen (of 2,729 gm entering the wetland system for the day) entered the second stage wetland and 22.8 gm was discharged, resulting in a 1.9 gm nitrogen export as nitrate. For the 20th of March, 11.4 gm of excess nitrogen was exported from the second stage wetland and for the 25th of March, 31.5 gm of excess nitrogen was exported. This can most likely be attributed to decomposition of cat-tail detritus, the predominant plant species by mass in the second stage wetland.

Nitrite was detected in the inflow to the wetlands in all samples. Nitrite removal remained at 100% in the first stage wetland throughout March but declined in April to 89.6% as loading increased by a factor of 5. However, the second stage wetland removed 100% of the remaining nitrite so that no nitrite was detected (detection limit-0.0125 mg/L) in any discharge sample. Nitrate removal in the first stage wetland was high during March (98.99%) but low in second stage wetland (24.47%) until loading increased 5 fold during the first two weeks of April, whereupon second stage efficiency rose to 94.49%. During the first half of May, nitrate removal by the first stage wetland declined from April's average of 91.59% to 70.96% but second stage efficiency rose to 99.27%, which maintained the overall wetland system efficiency above 99%. The mean nitrogen discharge throughout the sampling period was 0.09 mg/L, 100-fold lower than the US EPA drinking water standard.

Phosphorus assimilation occurred from late March through mid May in the second stage wetland and during April in first stage wetland although loading rose 3-fold during the month. This corresponded to the observed vegetative growth patterns in the wetland system. Mean phosphorus discharge was 1.34 mg/L throughout the sampling period. Neither water temperature nor rainfall was correlated with wetland efficiency.

Literature Cited:

1. Taylor, M.D., S.J. Klaine and T. Whitwell. 2003. Use of a Constructed Wetland System to Mitigate Nutrient Contaminants in Offsite Drainage from a Commercial Nursery. Proc. SNA Res. Conf. 48:468-470.

Irrigation Volumes and Tree Growth of *Quercus virginiana* in Porous Bottom Containers and #25 Pot-in-Pot.

R.C. Beeson, Jr.[1], T.H. Yeager[2] and J. Kahoun[1]
[1] MREC, IFAS, University of Florida, Apopka, FL
[2]Dept. of Environmental Horticulture, IFAS,
University of Florida, Gainesville, FL
rcbeeson@ifas.ufl.edu

Index Words: water conservation, irrigation requirements, tree production, tensiometers

Significance to industry: With increasing labor cost and increased interest in root system quality, there is a growing trend in using non-traditional containers with air root pruning sides and porous bottoms. Sixteen months into a 2-year production cycle, irrigation volumes were generally less for the non-traditional containers than for pot-in-pot, with similar tree height, but significantly larger calipers.

Nature of Work: In 2000, Sun City Tree Farm began growing trees in Root Control Bags (Root Control, Stillwater, OK) above ground. When questioned about irrigation scheduling, there was little scientific basis for a firm answer. Replacing the solid bottom of a plastic container for a porous fabric bottom eliminated the “perched water table” found in the bottom of most plastic containers, and created a conduit from the container substrate to the drier soil beneath. Preliminary research found a 30% decrease in the amount of available water after drainage (1 hr) between a common container substrate (7:3:1 pine bark: Fla. peat : sand) in a #7 plastic container and similar size porous bottom container (Beeson, unpubl. data). Second, the porous sides that supposedly increase root quality through air pruning also allowed evaporation through the sides. It was thought this evaporation, though likely cooling the root ball, would be greater than the surface evaporation from a black plastic container.

In late November 2002, a project was initiated to answer the question of irrigation requirements for porous bottom containers. Five commercially available porous bottom containers were acquired from vendors. These were Accelerators (Hold Em, Inc., West Palm Beach, FL), Florida Cool-Rings, (Florida Cool Ring Co., Lakeland, FL), Air Pot, (Cherry Lake Tree Farm, Groveland, FL.), Root Control Bags, (Root Control Inc.) and Holloway Tree Farm solid vinyl rings (Holloway Tree Farm, Leesburg, FL). All were each vendor’s equivalent to a #25 container and included their companion porous bottom material, except for Holloway’s ring, which was placed on top of the Cool Ring porous fabric. A pot-in-pot system for #25 containers (Nursery Supply Corp., Kissimmee, FL) was installed as a control. In addition, a second set of Holloway’s rings were included using the same vinyl material underneath as an impervious bottom. The experiment was set up as a randomized complete block, with 2 trees of each system adjacent to each other within a block (row) and systems randomized within each block. Blocks were replicated 5 times. Trees were the vegetative propagule of *Quercus virginiana* `Cathedral` (Shadow Lawn Tree Farm, Penny Farms, FL), and were transplanted from #1 containers.

Irrigation was controlled using switch tensiometers (Model RSU, Irrometer Co., Inc., Riverside, CA) placed only in the middle block. For porous bottom containers, a tensiometer was placed in the container substrate and in the soil underneath in series. For solid bottom containers, tensiometers were only placed in the substrate. Tensiometers were installed in both trees within a container system and were placed in parallel for irrigation control. Thus if either or both trees required irrigation, it would run until the substrate of both trees were saturated. Trees could receive up to 3 irrigations daily. Irrigation was based on soil matric potential below the equivalent of 50% plant available between saturation and 200 centibar (20 kPa). A water meter was installed for each container system, with the volume applied across the 10 trees per system measured. For the first 4 months, trees were irrigated daily, independent of the tensiometers. Beginning in mid-March 2003, irrigation was controlled by the tensiometers in the substrates. In February 2004, both substrate and soil tensiometers were employed for irrigation control.

Data presented was taken at the beginning of the 2004 growing season. Final growth data and irrigation volumes will be determined in November 2004. Tree height and caliper were analyzed by Anova (SAS, Cary, NC). Means separation was by F-Protected LSD where appropriate (Snedecor and Cochran, 1980).

Results and Discussion: When transplanted, trees averaged about 24 in. (0.61 m) in height and 0.28 in (7.2 mm) in caliper. Height growth was about 4 to 5ft (1.2 -1.4 m), and comparable among all treatment except trees in the Holloway ring on vinyl, which were significantly ($P<0.05$) shorter than all other treatments (Table 1). Calipers in the Spring of 2004 for porous container treatments averaged near 1in. and were generally significantly ($P<0.05$) larger than those in the two solid bottom containers (Table 1). Irrigation volumes were highest for Cool Rings and Pot-in-Pot and lowest for the aluminum Accelerators. At this stage in production, with the exception of the Cool-Rings, porous bottom containers have required less irrigation than those on solid bottoms.

Literature Cited:

1. Snedecor, G.W. and W.G.Cochran. 1980. Statistical Methods, 7th Ed. Iowa State University Press. Ames. IA. pps. 507.

Table 1. Height, trunk caliper and cumulative irrigation volume (for 10 trees) for *Quercus virginiana* `Cathedral' for each container system as of the beginning of the 2004 growing season. Each system is the vendor's equivalent to a #25 container. Means represent 10 individual tree replicates.

	Acc[z]	CR	AP	RCB	HP	HS	PnP
Height (m)	2.06 a	1.83 a	2.00 a	187.4 a	1.87 a	1.48 b	1.79 a
Caliper (cm)	2.485 ab	2.319 bc	2.669 a	2.371 b	2.617 a	2.00 d	2.125 cd
Irrigation (gal)	7672	9967	8075	8405	8822	9074	9912

[z] Abbreviations: Acc = Accelerator, CR = Cool Ring, AP= Air Pot, RCB = Root Control Bags, HP = Hollow rings porous, HS = Holloway rings solid, PnP = Pot-in-pot.

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

This research was supported by the Florida Agricultural Experiment Station and approved for publication as Journal Series No. N-02527.