Effect of Cotton Gin Compost on Substrate Properties and Growth of Azalea under Differing Irrigation Regimes in a Greenhouse Setting

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SUMMARY. 'Formosa' azalea (*Rhododendron indicum*) was grown for 4 months in 7.6-L (2 gal) containers in four substrate blends: 100% pine bark (PB) (by volume), 1 PB:1 cotton gin compost (CGC), 3 PB:1 CGC, and 3 PB:1 peat (PT) at three irrigation levels [600, 1200, and 1800 mL·d⁻¹ (20.3, 40.6, and 60.9 fl oz/d)] in a polyethylene-covered greenhouse. Plants were evaluated for growth on a biweekly basis using a growth index. Roots were evaluated visually at the end of the study using a 0 (no root growth) to 5 (root bound) scale. Initial physical properties were determined and leachates were collected every 30 days. There was no difference in percent increase in growth across irrigation and substrate treatments. Visual root rating was greatest (4.5) for azaleas grown in 3 PB:1 PT and least (3.5) in 1 PB:1 CGC. The two PB/CGC blends improved water-holding capacity (WHC) in comparison to 100% PB, with 1 PB:1 CGC exhibiting the greatest WHC among all four substrates. Bulk density was greatest with the CGC-amended substrates. Leachate pH tended to increase and electrical conductivity (EC)

tended to decrease with increasing irrigation volume. Leachates from the CGC-amended substrates were less acidic and EC tended to be similar or greater than leachates from the 100% PB and 3 PB:1 PT substrates.

Water use restrictions are becoming more widespread and more stringent each year. Nursery growers are forced to use creative and innovative solutions to adjust to the decrease in available water and continue to produce quality crops. Strategies that have been evaluated to increase the efficiency of irrigation outputs have involved close monitoring of irrigation outputs, adjusting systems to provide more uniform coverage, adjusting container spacing, transplanting to larger containers before maximum growth occurs, and use of recycled runoff water to reduce water use (Beeson and Knox, 1991; Fare et al., 1992; Wright, 1992). Delaying irrigation until soil water is depleted just until the point that it becomes difficult for the plant to extract water can reduce irrigation. Waiting to irrigate until the threshold is reached prevents leaching, water loss to surface evaporation, and water runoff from the surfaces not covered by the containers (Caron et al., 1998). Despite efforts to manage water use and irrigation, more needs to be done to increase irrigation efficiency.

Physical properties of substrates have a major impact on water use efficiency. High water-holding capacity is a primary reason that peat is such a widely used substrate component (Papafotiou et al., 2001; Reilly, 1981; Wang and Blessington, 1990). Alternatives to peat continue to be evaluated as substrate components for commercial production (Evans, 2004). Composts have been introduced to nursery growers as a way to alleviate the expense of PT, yet WHC of composts has been overlooked as a benefit, particularly as a means of increasing irrigation efficiency.

Cotton gins throughout the southeastern U.S. need economical and beneficial avenues for distribution of the great amount of by-products generated by the ginning process. When composted, cotton gin by-products are transformed into a beneficial substrate component called cotton gin compost (CGC). Studies using CGC as a rooting

substrate have shown that it is suitable for cutting propagation of 'Defiance' sun coleus, (*Coleus × hybridus*), 'Natchez' crapemyrtle (*Lagerstroemia indica* × *L. faurei*), and dwarf heavenly bamboo (*Nandina domestica* 'Atropurpurea Nana') (Cole et al., 2002). CGC has excellent WHC (Papafotiou et al., 2001) and could potentially contribute to decreasing irrigation needs of some plants.

The objective of this study was to evaluate CGC-containing substrates for their potential in reducing irrigation requirements in containerized plant production. This study compared PB, PT, and CGC-containing substrates along with three irrigation regimes for their effects on growth of 'Formosa' azalea and their influence on pH and EC during the growing period. Physical properties of the substrates were also examined prior to planting.

Materials and methods

Cotton gin waste was obtained from the Milstead Farm Group near Shorter, Ala. (lat. 32°48'N, long. 85°89'W), and composted in windrows at E.V. Smith Research Center near Shorter, Ala. In July 2002, four substrates were blended (by volume): 100% PB, 1 PB:1 CGC, 3 PB:1 CGC, and 3 PB:1 PT. Substrates were amended with 7.83 kg·m⁻³ (13.2 lb/yard³) Osmocote 18-6-12 (18N-2.6P-10K; Scotts Co., Marysville, Ohio) and 0.89 kg·m⁻³ (1.5 lb/yard³) Micromax (Scotts Co.). Twelve 'Formosa' azaleas were transplanted from 3.8-L (1 gal) into 7.6-L containers filled with each substrate blend. Plants were grown in a double-layer polyethylene-covered greenhouse at the Paterson Greenhouse Complex, Auburn University, Ala. (lat. 32°36'N, long. 85°29'W), for 4 months. Each substrate treatment was irrigated under one of three irrigation regimes using one, two, or three drip emitters using a split application (three equal applications daily at 0800, 1100, and 1500 HR) for a total of 600, 1200, or 1800 mL·d⁻¹ municipal tap water.

Plant growth measurements were collected in terms of growth index (GI) [(height + width at widest point + width perpendicular to width at widest point)/3] every 14 d. A final root rating was conducted upon completion of the study using the following scale: 0 = no root growth; 1 = root ball falls apart; 2 = root ball crumbles, but stays

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somewhat intact; 3 = root ball stays intact, but does not fill the container; 4 = roots reach bottom of container, but do not fill the container; 5 = root bound. Initial physical properties of three representative samples from each substrate blend were determined using the North Carolina State University Porometer (NCSU-P) (Fonteno et al., 1981). Air space (AS), WHC, total porosity (TP), and bulk density (BD) were the parameters determined by the NCSU-P. Leachates were collected every 30 d using the Virginia Tech Extraction Method (VTEM) (Wright, 1984). Leachate pH and EC were measured using a pH and conductivity meter (model 63; YSI Inc., Yellow Springs, Ohio).

Plants were arranged in a randomized complete-block design with 12 treatments per block and four blocks. Data were analyzed using linear regression analysis, analysis of variance, the Waller-Duncan k-ratio *t*-test ($P = 0.05$) for mean separation, Fisher's *t*-test for paired-sample comparisons, and Pearson correlation coefficients using the SAS System, Release 8.02 (SAS Institute, Cary, N.C.).

Results and discussion

Change in GI of azaleas was similar among the three irrigation regimes and among the four substrates throughout the experiment; therefore, only the initial and final GI measures are presented (Table 1). Change in GI of azaleas over the growing period was significant for individual irrigation regimes and substrate blends, indicating that plants grew in all treatments. Although not statistically different, plants receiving 1800 mL·d⁻¹ of irrigation visually appeared to be larger than those from the other two irrigation regimes as the experiment progressed.

In addition to similar change in GI, plant growth in any one substrate generally did not appear visually superior to any other throughout the experiment. These results differ somewhat from those of Wang and Blessington (1990), who found that poinsettia (*Euphorbia pulcherrima*) plants grown in substrate containing composted cotton burrs were slightly smaller than those grown in equal parts of PT and PB. Papafotiou et al. (2001) found that height of chrysanthemum (*Dendranthema grandiflora*), oleander (*Nerium oleander*), and lantana (*Lantana camara*) was slightly

reduced when up to 60% of PT in a 1 PT:1 perlite control substrate was replaced by CGC, while height of geranium (*Pelargonium zonale*) was unaffected. No bark was included in the substrate treatments evaluated in this latter study.

Root rating was not different across irrigation levels (Table 1). Root balls for all substrate blends were fully intact, so differences were according to the degree of fullness of roots in relation to the container. Roots of plants grown in 3 PB:1 PT had grown to fill the containers and had the highest mean rating. No difference was observed between roots of plants grown in 100% PB and 3 PB:1 CGC. There was no interaction between irrigation regime and substrate blend. Root rating appeared to be most closely (and inversely) correlated with levels of soluble salts as measured by EC [$r = -0.39$ at 60 d after planting (DAP); $r = -0.38$ at 90 DAP; $r = -0.48$ at 120 DAP], with EC levels closer to recommended levels for general nursery crops (0.8 to 1.0 mS·cm⁻¹) (Yeager et al., 2000) with the non-CGC-amended substrates than with the CGC blends (Table 2). Leachate EC from all irrigation and substrate treatments remained higher than recommended levels through-

out the study. Wang and Blessington (1990) also reported higher EC values in leachate from substrate containing composted cotton burrs.

Leachate EC did not differ by irrigation treatment at initial collection date, but showed a decrease with increasing irrigation volume on all subsequent sampling dates (Table 2). Leachates from 1 PB:1 CGC had the highest initial EC, while 100% PB had the lowest. EC of leachates collected from one or both of the CGC blends were typically higher than for the 3 PB:1 PT substrate throughout the experiment and typically higher than for 100% PB through the midpoint of the experiment, suggesting that salts from the CGC were contributing more to EC levels than were the 100% PB and 3 PB:1 PT substrates.

Initial pH values among the three irrigation regimes were similar, while subsequent leachate samples (beginning at 30 DAP) showed higher pH values with increasing irrigation volume (Table 2). Both CGC blends typically exhibited higher pH values than the 100% PB and 3 PB:1 PT substrates on all sampling dates. Leachate pH from the 1 PB:1 CGC substrate was similar to or higher than the 3 PB:1 CGC substrate during the growing period,

Table 1. Effect of irrigation volume and four bark-based substrates (with and without cotton gin compost) on change in growth index (GI) and visual root rating of 'Formosa' azalea grown for 112 d in 7.6-L (2 gal) containers under greenhouse conditions.

Treatment	Initial/final ^b GI ^y	Change in GI ^x (%)	Visual root rating ^w
Irrigation (mL·d ⁻¹) ^v			
600	38.69/70.50	82.7	3.9
1200	38.57/70.95	86.7	4.0
1800	37.72/72.40	94.2	4.2
Substrate ^u			
100% PB	37.94/73.14	95.9 a ^t	4.2 b
1 PB:1 CGC	37.67/66.15	77.1 a	3.5 c
3 PB:1 CGC	36.85/68.67	88.8 a	3.9 b
3 PB:1 PT	40.85/77.17	89.6 a	4.5 a
Significance			
Irrigation (I)		NS	NS
Substrate (S)		NS	***
I × S		NS	NS

^v112 d after planting.

^yGI = (height + greatest width + width perpendicular to greatest width)/3.

^xChange in GI for each irrigation and substrate treatment was significantly different from zero by Fisher's *t*-test ($P < 0.001$).

^wRoot rating scale: 0 = no root growth; 1 = root ball falls apart; 2 = root ball crumbles, but stays somewhat intact; 3 = root ball stays intact, but does not fill the container; 4 = roots reach bottom of container, but do not fill the container; 5 = root bound.

^v29.6 mL·d⁻¹ = 1 fl oz/d.

^uPB = pine bark; CGC = cotton gin compost; PT = peat moss.

^tMean separation for change in GI and root rating among substrates within columns by the Waller-Duncan k-ratio *t*-test at $P = 0.05$.

ns, ***, Nonsignificant or significant at $P < 0.001$, respectively, for linear regression response (Irrigation), treatment response (Substrate), and interaction (I × S).

Table 2. Effect of irrigation volume and four bark-based substrates (with and without cotton gin compost) on pH and electrical conductivity (EC) of leachate collected from 'Formosa' azalea grown for 4 months in 7.6-L (2 gal) containers under greenhouse conditions.

Treatment	Initial	30 DAP ^z	60 DAP	90 DAP	120 DAP
-----pH ^y -----					
Irrigation (mL·d ⁻¹) ^x					
600	4.80	4.69	4.41	4.61	4.21
1200	4.83	5.10	4.64	4.91	4.47
1800	4.89	5.15	4.85	5.06	4.72
Substrate ^w					
100% PB	3.88 b ^v	4.55 b	4.31 c	4.32 c	4.10 c
1 PB:1 CGC	6.14 a	5.90 a	5.00 a	5.26 a	5.11 a
3 PB:1 CGC	5.68 a	5.25 a	4.68 b	5.13 a	4.48 b
3 PB:1 PT	3.65 c	4.23 c	4.55 b	4.74 b	4.16 c
Significance					
Irrigation (I)	NS	***	***	**	***
Substrate (S)	***	***	***	***	***
I × S	NS	**	NS	NS	**
-----EC (mS·cm ⁻¹) ^u -----					
Irrigation (mL·d ⁻¹)					
600	1.92	2.43	3.19	2.76	1.59
1200	2.12	1.65	1.76	1.31	0.81
1800	1.71	1.22	1.44	0.87	0.48
Substrate					
100% PB	0.96 c	1.48 b	1.89 ab	1.47 ab	0.95 a
1 PB:1 CGC	1.94 a	2.04 ab	2.57 a	2.16 a	1.15 a
3 PB:1 CGC	1.92 b	2.06 a	2.36 ab	1.82 a	1.10 a
3 PB:1 PT	1.84 b	1.49 ab	1.72 b	1.14 b	0.63 b
Significance					
Irrigation	NS	***	***	***	***
Substrate	***	NS	NS	*	**
I × S	NS	**	NS	NS	*

^zDAP = days after planting.

^yA recommended range for interpretation of the Virginia Tech Extraction Method when using container substrate containing controlled-release fertilizer for general nursery production is pH 5.0 to 6.0 (Yeager et al., 2000).

^x29.6 mL·d⁻¹ = 1 fl oz/d.

^wPB = pine bark; CGC = cotton gin compost; PT = peat moss.

^vMean separation by substrate within columns by the Waller-Duncan k-ratio *t*-test at *P* = 0.05.

^uA recommended EC range for interpretation of the Virginia Tech Extraction Method is 0.8 to 1.0 mS·cm⁻¹ for general nursery crops (Yeager et al., 2000).

^{ns}, *, **, ***Nonsignificant or significant at *P* < 0.05, 0.01, or 0.001, respectively, for linear regression response (Irrigation), treatment response (Substrate), and interaction (I × S).

Table 3. Air space (AS), water-holding capacity (WHC), total porosity (TP), and bulk density (BD) of four bark-based substrates (with and without cotton gin compost) at container capacity.

Substrate ^z	AS ^y	WHC	TP	BD ^x
100% PB	41.0 a ^w	35.9 c	76.9 ab	0.12 c
1 PB:1 CGC	20.4 c	55.8 a	76.2 b	0.20 a
3 PB:1 CGC	33.2 b	45.9 b	79.1 ab	0.14 b
3 PB:1 PT	31.1 b	49.0 b	80.1 a	0.11 c
Desirable range ^v	10–30	45–65	50–85	0.19–0.70

^zPB = pine bark; CGC = cotton gin compost; PT = peat moss.

^yAS, WHC, and TP are based on percent volume of the substrate.

^xBD measured in g·cm⁻³.

^wMean separation within columns by the Waller-Duncan k-ratio *t*-test at *P* = 0.05.

^vRecommended ranges for substrates used in general nursery production (Yeager et al., 2000).

suggesting that higher pH values might be expected with increasing amounts of CGC. Low pH values were evident in the 100% PB and 3 PB:1 PT substrates; dolomitic limestone was not incorporated during substrate preparation to raise pH levels as studies have shown that incorporation of dolomitic limestone does not improve the growth of azalea cultivars (Murphree et al., 1997; Yeager and Ingram, 1986).

Percent AS was highest in the 100% PB substrate (41%) (Table 3). Only 1 PB:1 CGC (20%) was within the desirable range for AS. There was no difference in AS between 3 PB:1 CGC and 3 PB:1 PT substrate blends. 1 PB:1 CGC had the highest WHC (56%), while 100% PB had the lowest WHC (36%). There was no difference in WHC between 3 PB:1 CGC and 3 PB:1 PT and both were within suggested parameters. TP of all substrate blends was at the upper end of the desirable range. No difference in TP was observed between 3 PB:1 CGC and 3 PB:1 PT. The substrate blend 1 PB:1 CGC was the only one that was within guidelines for BD. The other substrates were very light, but in a greenhouse situation there is no concern about containers blowing over. PB- and PT-based substrates typically have a very low BD. CGC increased the BD of PB-based substrates used in this study.

Growth of 'Formosa' azalea in CGC blends was comparable to growth in a traditional 3 PB:1 PT blend. Plant growth did not vary by irrigation from substrate to substrate, so irrigation could be reduced and still produce crops of similar quality to those with increased irrigation. There was no difference in the percent change in GI during the experiment across substrate blends. Adding CGC to a PB base substrate improved the physical properties of the substrate by increasing WHC and BD. Leachate pH and EC were consistent throughout the study. Incorporating CGC into substrate blends for greenhouse production is a viable alternative to straight PB or PB:PT.

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Effect of Ozonated Water on Creeping Bentgrass Growth in a Sand Medium

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ADDITIONAL INDEX WORDS. greens, root zone, leachate, chlorophyll, mineralization, aeration, nitrate, phosphorus

SUMMARY. Irrigation of sand-based golf greens with ozonated water may affect grass growth and chemical processes in the root zone. The objective of this study was to evaluate the effects of ozonated and aerated water on bentgrass growth and root zone chemistry in sand-based greens over a 12-month period. Creeping bentgrass (*Agrostis stolonifera*) cores [10 cm diameter × 12 cm depth (3.9 × 4.7 inches)] were collected from a sand-based bentgrass nursery and placed in columns designed to collect leachate water. Cores were placed in a greenhouse and irrigated with 1) municipal tap water [6 to 8 mg·L⁻¹ (ppm) dissolved oxygen (DO)], 2) aerated tap water (12 mg·L⁻¹ DO), or 3) ozonated tap water (aerated plus 0.8 mg·L⁻¹ ozone). Leachate was periodically collected and analyzed for pH, electrolytic conductivity (EC), and nutrients. Grass clippings were weighed and analyzed for total nitrogen (N) and phosphorus (P). Roots were periodically collected from selected cores to determine root distribution. At 40 and 90 days after initiating water treatments, bentgrass irrigated with ozonated water had a higher chlorophyll index than bentgrass irrigated with tap water. After 128 and 157 days, bentgrass clipping weights were significantly greater for the cores irrigated with ozonated water and, to a lesser extent, aerated water. At 61 and 149 days, nitrate (NO₃-N) and EC levels were elevated in leachate from aerated and ozonated samples, sug-

gesting increased mineralization of organic matter in those bentgrass cores. Ozonated water increased bentgrass crown weights, but had no effect on root mass. Ozonated water did not affect bentgrass tissue N and P concentrations. Statistically significant effects from ozonated water occurred within the first few months, but sustained benefits were negligible.

Ozone (O₃) is a reactive molecule that is produced from atmospheric oxygen (O₂) by passing air through a high voltage corona discharge. Ozone has been used for disinfecting drinking water (Camel and Bermond, 1998), different types of wastewater (Beltran et al., 1999; Kearney et al., 1988), food processors (Restaino et al., 1995), and other applications where there is a need to reduce microbial populations. Ozone has been used to oxidize organic substances ranging from pesticides (Dong and Doo, 2000) to algae (Yun et al., 1997) and to degrade humic substances in water and reduce turbidity (Amirsardari et al., 1998; Gracia et al., 1996). More recently, ozone has been added to irrigation waters with reported benefits that include increased water infiltration, increased disease resistance, and reduced need for fertilizers (Raub et al., 2001). Although there is limited scientific data to demonstrate these benefits, the results are consistent with the predicted effects one would see when adding a strong oxidizer, such as ozone, to soil. Ozone may oxidize soil organic matter and plant residues, thus releasing essential plant nutrients. Oxidation of organic matter coatings on clay particles could change their surface charges and cause them to flocculate (Raub et al., 2001). This effect could improve water infiltration by preventing clay dispersion, which can clog the soil pore system. The effects of using ozonated water in a sand-based growing medium, such as a putting green, are unknown. Although there may be beneficial short-term effects, it is possible that long-term effects would be detrimental due to the breakdown of organic matter. We need a greater understanding of the effects of ozonated water on chemical and physical properties in the rooting zone of a sand-based growing medium so that we can make knowledgeable decisions on how to use ozonated water in managing golf course greens. The

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