Root Growth of Three Horticultural Crops Grown in Pine Bark Amended Cotton Gin Compost[1]

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Abstract

In the southeastern United States, inconsistent pine bark (PB) supplies and overabundance of cotton gin by products warrant investigation about the feasibility of replacing PB with cotton gin compost (CGC) for container horticultural plant production. Most research on the use of composted organic substrates for horticultural plant production has focused on shoot growth responses, so there is a need to document the effect of these substrates on root growth. In 2004 'Blitz' tomato (*Lycopersicon esculentum* L.), 'Hot Country' lantana (*Lantana camara* Mill. 'Hot Country'), and weeping fig (*Ficus benjamina* L.) were placed in Horhizotrons™ to evaluate root growth in 100% PB and three PB:CGC substrates containing by volume, 60:40 PB:CGC, 40:60 PB:CGC, and 0:100 PB:CGC. Horhizotrons™ were placed in a greenhouse, and root growth in all substrates was measured for each cultivar. Physical properties (total porosity, water holding capacity, air space, and bulk density) and chemical properties (electrical conductivity and pH) were determined for all substrates. Physical properties of 100% PB were within recommended guidelines and were either within or above recommended ranges for all PB:CGC substrate blends. Chemical properties of all substrates were within or above recommended guidelines. Root growth of all species in substrates containing CGC was similar to or more enhanced than root growth in 100% PB.

Index words: agricultural waste, Horhizotron™, substrate, root establishment, media.

Species used in this study: 'Blitz' tomato (*Lycopersicon esculentum*); weeping fig (*Ficus benjamina*); 'Hot Country' lantana (*Lantana camara* 'Hot Country').

Significance to the Nursery Industry

Inconsistent and potentially unreliable supplies of pine bark and environmental concerns over mining peat encourage the evaluation of alternative container substrates. Three horticultural crops were grown in pine bark (PB) substrates containing 0, 40, 60, and 100% cotton gin compost (CGC). Results herein demonstrate that PB can be amended with CGC for an increase in root growth rate and development when compared to root growth in 100% PB. Utilizing CGC as a substrate or substrate component with PB can provide a reliable and beneficial substrate option for plant growers.

Introduction

Research has been conducted through the years to evaluate the use of various composted materials as potential substrates for horticulture plant production. Substrates must have physical and chemical properties conducive for plant growth and be uniform, consistent, light weight, affordable (8, 9),

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and absent of weed seeds and harmful pathogens (5). Choosing an adequate potting substrate is a critical step in meeting the demands for growth of healthy plants.

Pine bark (PB) and peat are two of the most common substrate components currently used in horticultural crop production. The supply, consistency, and cost of these materials has often been a concern for growers throughout the United States. These concerns have prompted the search for alternative substrates and substrate components that can be successfully utilized for quality crop production.

Cotton gin trash (CGT) is the term used to describe the by-products of the cotton ginning process that includes the leaves, stems, hulls, and some lint from cotton (*Gossypium* sp. L.) (6, 17). One use of CGT requires the materials to be composted to produce cotton gin compost (CGC), a potential substrate component for the production of horticultural crops. 'Golden Bedder' coleus (*Solenostemon scutellarioides* L.) grown in substrates containing 20–60% (volume basis) CGC produced plants with height, shoot dry weight, and visual quality equal to or higher than plants grown in a 100% PB substrate (10). 'Purple Rain' pansy (*Viola* x *wittrockiana* Gams) and 'Carolina Beauty' crapemyrtle (*Lagerstroemia indica* L.) grown in a PB substrate with 33% CGC had a more vigorous shoot growth response than plants grown in 100% PB (15). Most recently, Cole (3) reported that 'Winter Gem' boxwood (*Buxus microphylla* Sieb. & Zucc.), 'Firepower' dwarf nandina (*Nandina domestica* Thunb.), and 'Renee Mitchell' azalea (*Rhododendron indicum* L. & Sweet) grown in CGC amended substrates had similar shoot growth and visual root system quality as plants grown in 100% PB.

When plants are produced in containers their roots are restricted to a small volume; consequently the demands made on the substrate for water, air, nutrients, and support are more intense than those made by plants grown in a field production situation where unrestricted root growth can occur (2). Vigorous root systems are essential for growth and development of healthy plants. A healthy, functioning root system increases the surface area available for the uptake of water and mineral elements. In addition, the root system architecture provides physical support, storage, and anchorage needed by plants (14, 18, 20).

Frequently excluded from horticultural research, root growth and root system architecture are important factors influencing plant performance and survival (21). Understanding root growth and development is important to improving plant quality and production success. When stepping up plants to a larger container size, uninterrupted growth and overall plant health are highly dependent on the formation of new roots outside of the original root ball into the substrate of the new container. The capability to observe and measure roots as they grow into a substrate is very useful in determining root growth preference in various substrates. In addition, studying the location and depth of root formation within the container profile provides valuable information to understanding root architecture and development. Some techniques used to study root growth in the past include the container-type rhizotron, rhizobox, and portable rhizotron (1, 7, 11, 19). These devices are often expensive and may provide limited information. Other methods limit root growth studies to either visual observations using a rating scale or dry weight analysis, both of which are destructive. Recently, the Horhizotron™, a light weight, inexpensive, and easily constructed instrument for measuring horizontal root growth has been developed (21). This new instrument provides a simple, non-destructive method for measuring root growth and development in various root environments and substrates. Unlike other container-type rhizotrons where roots are hidden until they reach the edge of the container, the Horhizotron™ allows roots to be observed and quantified as they grow from the original root ball and penetrate into the surrounding substrate. The design of this instrument allows the effect of several different substrates on root growth to be evaluated on an individual plant.

The objective of this study was to utilize the Horhizotron™ to evaluate root growth of 'Blitz' tomato, weeping fig, and 'Hot Country' lantana when grown in various blends of PB and CGC. Physical and chemical properties of substrates in this study were also compared.

Materials and Methods

CGW was obtained from the Milstead Farm Group, Inc., Shorter, AL, and windrowed for six months to compost at E.V. Smith Research Center, Shorter, AL. In July 2004, the CGC was sifted through a 15 mm screen to remove foreign debris, rocks, and clods of CGC. Four substrate blends of milled PB and CGC were mixed (by vol) in the following ratios: 100:0 PB:CGC (100% PB), 60:40 PB:CGC, 40:60 PB:CGC, and 0:100 PB:CGC (100% CGC). Based on initial pH values, varying rates of dolomitic limestone were added to substrates to achieve pH levels near 6.0. 100:0 PB:CGC was amended with 2.1 kg/m^3 (3.6 lb/yd^3), and 60:40 PB:CGC was amended with 1.1 kg/m^3 (1.8 lb/yd^3). No amendment was made to 40:60 and 0:100 PB:CGC substrates where pH was already in the desired range of 6.0. On July 3, 2004, eight-week-old seedlings of 'Blitz' tomato were removed from 11.3 liter (3 gal) containers and placed individually in separate Horhizotrons™ [2 × 2 × 1 ft (0.6 × 0.6 × 0.3 m)] (21) on greenhouse benches at the Plant Science Research Center at Auburn University, Auburn, AL. On August 16, 2004, weeping fig and 'Hot Country' lantana were removed from 11.3 liter (3 gal) containers and placed in separate Horhizotrons™ on greenhouse benches at the Paterson Greenhouse Complex, Auburn University. Root balls of all plants were positioned in the center of each Horhizotron™, firmly touching the edges of each wedge-shaped quadrant [8 × 10.5 in (20.3 × 26.67 cm)] (21). Each of the four quadrants were randomly filled with one of the substrate blends to the height of the root ball. Horhizotrons™ containing 'Blitz' tomato plants were under drip irrigation supplying water and fertilizer at rates according to recommended guidelines for greenhouse tomato production (16). Four emitters were evenly distributed down the center of each quadrant supplying 240 ml of Veg-Gro 3–15–27 (3N–6.6P–22.41K) (Veg-Gro Supplies Ltd., West Auckland, New Zealand) at 100 ppm N and Calcium nitrate 15.5–0–0 (Grower's Supply Center, Lynn Haven, FL) at 120 ppm Ca at each of six daily watering cycles. Horhizotrons™ with weeping fig and 'Hot Country' lantana were hand watered daily and fertilized weekly with Polyon®20–20–20 (20N–8.8P–16.6K; Pursell Industries, Sylacauga, AL) liquid feed applied at the rate of 200 ppm N. This study was a randomized complete block design (RCBD) with each Horhizotron™ representing an individual block. There were five blocks per species used in this study.

Root length and location in the quadrant profile were measured as newly formed roots grew out from the root ball and along the face of the glass quadrants. A transparent grid placed on the two glass sides of each quadrant allowed observation and measurement of the five longest roots on each side of the quadrant. Frequency of root measurements was related to the rate of root growth for each species. The five longest roots of 'Blitz' tomato on each side of the four quadrants were measured three days after transplanting (DAP) and every three days thereafter until they reached the end of the 25 cm (10 in) quadrants. Roots of weeping fig and 'Hot Country' lantana were measured 7 DAP and then once weekly using the same method. Over the course of the study root measurements were discontinued when roots reached the end of the Horhizotron™ quadrant.

At the conclusion of the study root development in each quadrant was evaluated visually. A rating scale of 0–5 was used (0 = no root growth; 1 = 20% of the quadrant face was filled with roots; 2 = 40% of the quadrant face was filled with roots; 3 = 60% of the quadrant face was filled with roots; 4 = 80% of the quadrant face was filled with roots; 5 = 100% of the quadrant face was filled with roots). Due to the design of the Horhizotron™, each individual plant grows in all four substrate blends simultaneously, rendering shoot growth measurements unnecessary.

Physical properties including air space (AS), water holding capacity (WHC), total porosity (TP), and bulk density (BD) were determined for each substrate blend at experiment initiation using the North Carolina State University Porometer (NCSU-P) (4). Properties were determined using three representative samples of each substrate. Initial nutrient element concentrations in each substrate blend were determined from saturated media extracts using inductively coupled plasma analysis. Initial EC for each substrate was also measured from three leachate samples per substrate.

Data were analyzed using GLM procedures, and regression analysis of root growth over time was performed for all species within each substrate treatment (13). Fisher's Least Significant Difference ($P = 0.05$) was used to separate means of the visual root evaluation at the end of the experiment (13).

Results and Discussion

Root growth. All species exhibited linear rates of root growth over the course of the experiment in all four substrates (Figs. 1, 2, and 3).

Through the first two measurement dates (6 DAP) 'Blitz' tomato grown in all CGC blended substrates had similar or more root growth than that of plants grown in 100% PB (data not shown). Beginning with the third measurement (9 DAP) through the conclusion of the study (21 DAP), root growth was similar among all treatments (Fig. 1). At all measurement dates there was more root growth in CGC amended substrates than in 100% PB for weeping fig. At 21 DAP, root growth of weeping fig in substrates containing 60 and 100% CGC reached the end of the quadrants and were no longer measured (Fig. 2). After 28 DAP, roots in substrate containing 40% CGC reached the end of the quadrants (data not shown). Roots grown in 100% PB were the last to reach the end of the quadrants after 35 DAP (data not shown). 'Hot Country' lantana exhibited more root growth in all treatments containing CGC compared to 100% PB through the third measurement date (3 weeks) at which time, roots in these treatments had grown to the end of their quadrants (Fig. 3). Roots in 100% PB took twice as long (6 weeks) to reach the end of the quadrant (data not shown).

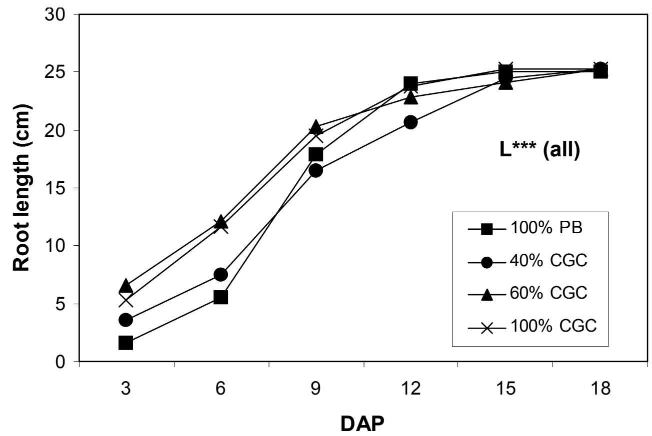

Fig. 1. **Root growth of 'Blitz' tomato measured 3 to 18 days after transplanting (DAP) when greenhouse grown in pine bark (PB) and three PB amended cotton gin compost (CGC) substrates. Plants were greenhouse grown in Auburn, AL in July 2004.**

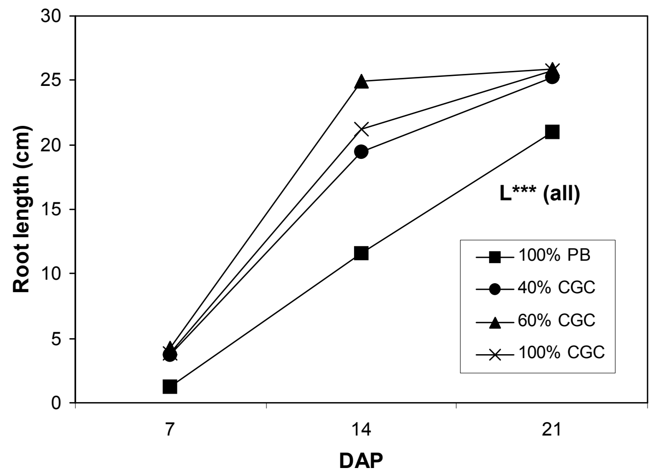

Fig. 2. **Root growth of weeping fig measured 7 to 21 days after transplanting (DAP) when greenhouse grown in pine bark (PB) and three PB amended cotton gin compost (CGC) substrates. Plants were greenhouse grown in Auburn, AL in August 2004.**

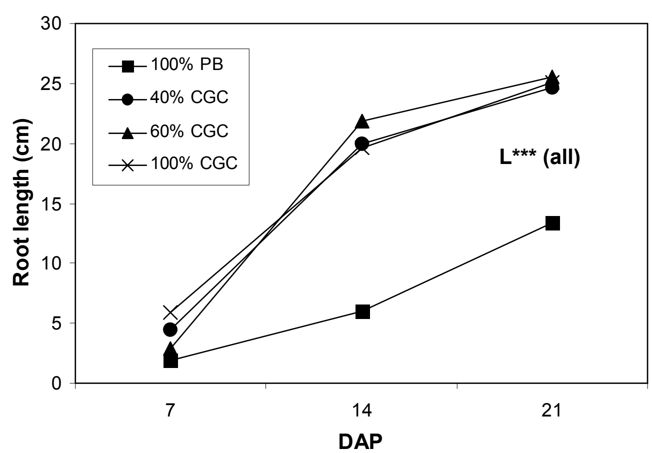

Fig. 3. **Root growth of 'Hot Country' lantana measured 7 to 21 days after transplanting (DAP) when grown in pine bark (PB) and three PB amended cotton gin compost (CGC) substrates. Plants were greenhouse grown in Auburn, AL in August 2004.**

Table 1. **Effect of substrate on final[z] root rating of three species grown in a four-quadrant Horhizotron™.**

Species	PB:CGC ratio[y]	Root rating[x]
'Blitz' tomato	100:0	3.6c[w]
	60:40	3.1c
	40:60	4.2b
	0:100	4.8a
weeping fig	100:0	2.6c
	60:40	3.8b
	40:60	4.5a
	0:100	4.4ab
'Hot Country' lantana	100:0	2.0b
	60:40	4.2a
	40:60	4.5a
	0:100	4.7a

[z]'Blitz' tomato was evaluated 18 days after transplanting; weeping fig and 'Hot Country' lantana were evaluated 21 days after transplanting.

[y]PB = pine bark, CGC = cotton gin compost.

[x]Roots were evaluated visually using a scale of 0–5 (0 = no root growth; 1 = 20% of the quadrant was filled with roots; 2 = 40% of the quadrant was filled with roots; 3 = 60% of the quadrant was filled with roots; 4 = 80% of the quadrant was filled with roots; 5 = 100% of the quadrant was filled with roots).

[w]Means separation within species by Fisher's LSD at $P = 0.05$.

Visual rating of root growth of 'Blitz' tomato was significantly higher in the two substrates containing 60 and 100% CGC when compared to root growth in 20% CGC and 100% PB substrate blends (Table 1). Root ratings of weeping fig and 'Hot Country' lantana reflected the increased root development across all substrates containing CGC when compared to 100% PB (Table 1). At the conclusion of this study, root development in all CGC blended substrates was considerable enough to firmly hold the substrates together when plants were pulled vertically from the Horhizotrons™. The quadrant containing 100% PB shattered upon being pulled from the Horhizotron™ as a result of the lesser developed root system. Once the 100% PB quadrant shattered, the contour of the original 3 gal container could still easily be seen.

Physical properties. Air space (AS) was highest in 100% PB, but was within the desirable range recommended by *The Best Management Practices Guide for Producing Container-Grown Plants* (BMP) for physical properties of container substrates (22, Table 2). AS was lowest in 40% and 60% CGC substrates, falling slightly below recommended ranges (Table 2). Water holding capacity (WHC) was highest in all substrate blends containing CGC, with each slightly above the BMP recommended range of 45–65% (Table 2). Because irrigation was the same for all substrates in this experiment, this higher WHC possibly contributed to the increased root growth in substrates containing CGC. In some cases, the management of irrigation when using CGC as a container substrate is particularly important to avoid situations of overwatering. Total porosity was highest in 100% CGC which was expected due to the smaller particle size of the CGC and decreased as the amount of CGC decreased in each substrate. The TP of all substrates, including 100% PB, were within the recommended BMP range of 50–85% (Table 2). Bulk density was lowest in 100% PB and highest in 100% CGC. BD increased as the percent of CGC increased in each of the four substrates. All substrates were well within the range of 0.19 to 0.70 g/cm^3 recommended by BMP guidelines (Table 2).

Chemical properties. After adjusting the initial pH of the 100% PB and 40% CGC, all substrates were measured again, and all four substrate blends had consistent pH values, and were within, or slightly above the BMP recommended guidelines (Table 2). EC values were also measured, and substrates containing CGC were well above the desired ranges (Table 2), with EC values increasing as the percent of CGC increased in each substrate. High EC values are likely due to high organic nitrogen (N) that can be present in CGC at rates as high as 3% dry weight (12). With irrigation, EC levels quickly decreased as salts were leached from the substrates, likely explaining why root injury of plants growing in the CGC substrates did not occur. As the percentage of CGC in each substrate increased macronutrient element concentrations also increased (Table 3).

At 6 DAP, root growth of 'Blitz' tomatoes grown in CGC amended substrates was similar to those grown in 100% PB. PB is one of the conventional, and most widely used substrates for greenhouse tomato production. It is probable that substrate showed no effect on root growth after only a few days due to the vigorous growth rate and development of tomatoes when grown under ideal conditions in a greenhouse environment. These results suggest that CGC can be used as

Table 2. **Physical and chemical properties of four pine bark (PB):cotton gin compost (CGC) substrates.**

PB:CGC Ratio[z]	Water holding capacity[y] (%)	Air space[y] (%)	Total porosity[y] (%)	Bulk density (g/cm^3)	EC (mmhos/cm)	pH
100:0	53.2b[x]	18.5a	71.7c	0.20c	0.3d	6.1a
60:40	67.9a	8.4c	76.2b	0.21c	2.0c	5.9a
40:60	69.6a	7.6c	77.2b	0.24b	4.9b	6.1a
0:100	69.1a	12.4b	81.5a	0.27a	9.8a	6.2a
BMP Guidelines[w]	45–65	10–30	50–85	0.19–0.70	0.8–1.0	5.0–6.0

[z]PB = pine bark, CGC = cotton gin compost.

[y]Values are based on percent volume of the substrate and were measured at container capacity.

[x]Means separation within columns by Fisher's LSD at $P = 0.05$.

[w]BMP = Best Management Practices recommended ranges (in percentages) for substrates used in general nursery production (Yeager et al., 2000).

Table 3. **Nutrient element concentrations in four pine bark (PB) : cotton gin compost (CGC) substrates.**[z]

PB:CGC Ratio	N (%)	P (ppm)	K (ppm)	Ca (ppm)	Mg (ppm)
100:0	0.2	1.0d	42.0d	23.0d[y]	8.4d
60:40	1.2	38.5c	505.0c	56.0c	38.0c
40:60	1.9	58.6b	1185.0b	157.5b	131.7b
0:100	3.0	77.3a	2774.0a	323.7a	324.2a

[z]Elements not shown were present in concentrations <0.1 ppm.

[y]Means separated within columns by Fisher's Protected LSD at $P = 0.05$.

a substrate or substrate component for tomato greenhouse production based on the positive response in root growth and development exhibited in this study. Research is underway to evaluate the yield and quality of tomatoes when grown in the same CGC blended substrates used in this study. Future data on tomato fruit yield and quality in conjunction with the results of root growth and development in this study will provide further evidence of the potential use of CGC as a substrate in commercial greenhouse tomato production.

Results show that weeping fig and 'Hot Country' lantana had more root growth in CGC amended substrates than when grown in PB alone (Figs. 2 and 3). Considering that this study was conducted in only a few weeks, it is important to note that even though root growth in these two species occurred more quickly in CGC amended substrates, root growth in 100% PB was not necessarily undesirable. This experiment provides strong evidence that roots can grow effectively and vigorously into substrates containing CGC. This can be important in nursery production operations where plants are transplanted to larger containers to obtain larger sized plants needed for commercial and retail sale.

The incorporation of CGC is shown to enhance the physical properties of a PB substrate, however irrigation must be carefully managed due to higher WHC of this substrate. Increased WHC can be beneficial to plants that prefer wetter soils or it could decrease the irrigation needed to maintain optimum moisture levels for plant production. When added to PB, CGC can increase the pH and EC of the substrate. With increasing interest to facilitate and maintain healthy root growth and establishment of horticultural crops, utilizing CGC can be an effective way to achieve production of various horticultural crops.

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