Effects of Media and Species on Soil CO_2 Efflux in the Landscape©

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Increasing concentrations of greenhouse gases (GHG) including carbon dioxide, methane, and nitrous oxide are widely believed to be the main contributing factors leading to global climate change. The horticulture industry has the potential to improve GHG conditions through sequestering carbon (C) in urban landscapes. In order to determine effects of growth media on soil CO_2 efflux, a study was conducted in which two common landscape species were grown in containers using three different growing media: (1) pine bark [PB], (2) clean chip residual [CCR], or (3) whole tree [WT]; after one growing season they were outplanted into the field. Initial soil samples were collected for C content determinations. Automated carbon efflux systems (ACES) were installed adjacent to three plants of each species in each media for continuously monitoring (24 h/day) of C lost via soil respiration and to determine media C sequestration potential. Increased soil C was primarily noted in the upper soil depth (0–15 cm), where PB was higher than the other media; a similar pattern was observed for the 15–30 cm depth although C values were much lower. Crape myrtle had higher soil CO_2 efflux than magnolia possibly due to crape myrtle having a larger root system or faster growth rate. All media had different soil CO_2 efflux values in crape myrtle (CCR was highest and WT lowest), while for magnolia PB was higher than the other media. Across both species WT had lower efflux than PB and CCR possibly due to its higher wood content causing it to break down slower. Placing containerized plants into the landscape transfers a large amount of C belowground, suggesting that opportunities exist for the horticulture industry and homeowners to contribute positively to mitigating climate change via soil C sequestration. However, further investigation is needed to fully understand the impact of various growing media and ornamental species on soil CO_2 emissions and the residence time of this C in soil when planted into urban and suburban landscapes.

INTRODUCTION

Concentrations of the three most important long-lived greenhouse gases (GHG) in the atmosphere have increased dramatically over the past 255 years. Carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) concentrations in the atmosphere have increased by approximately 35% (Keeling and Whorf, 2005), 155%

(Dlugokencky et al., 2005), and 18% (Prinn et al., 2000) since 1750. Annual C emissions have increased approximately 80% from 1970 to 2004 (IPPC, 2007). Fossil fuel combustion along with land use changes such as deforestation, biomass burning, soil cultivation, and drainage of wetlands are the main contributors to increased C emissions. Increased concentration of atmospheric CO_2 and other GHG in widely accepted as the main factor causing global warming (Florides and Christodoulides, 2008). While it has not been proven that GHG are causing global climate change, data has been presented which indicates the earth's surface temperature is increasing which could lead to possible negative environmental impacts (Lal, 2004; IPCC, 2007).

The agriculture industry in the United States is one of the highest contributors to GHG emissions behind only energy production (Johnson et al., 2007). These three (CO_2, CH_4, and N_2O) are the most important GHG because of their atmospheric concentrations and because elevated levels of these gases are primarily due to human activity. Emissions of CO_2, CH_4, and N_2O from agriculture collectively account for an estimated one-fifth of the annual increase in GHG emissions. When land use changes involving clearing of land, biomass burning, and soil degradation are included, the overall impact from agriculture is one-third of the total man-made greenhouse effect (Cole et al., 1997).

Opportunities to reduce GHG in agriculture have been the focus of much research (Hogan et al., 1993; Sommer and Hutchings, 1995; Cole et al., 1997; Kroeze et al., 1999); however, it is widely believed long-term capture and storage of these gases is necessary to mitigate climate change. Unlike many other industries, agriculture has the potential to offset emissions by altering production practices which have the capacity to increase C uptake and storage in biomass and soils, referred to as carbon sequestration (USDA, 2008). Research has shown that row-cropping systems utilizing conservation or "no-till" farming practices can reduce fossil fuel consumption while increasing C storage in soil (Reicosky et al., 1999). Changes in forestry management practices such as nutrient management, density control, and use of genetically improved species has been shown to increase C uptake and storage in biomass and soils (USDA, 2008).

Horticulture is a large-scale industry which impacts the landscape of rural (production facilities) and urban environments. The economic impact of the "green industry" (nursery, greenhouse, and sod) is $148 billion annually (Hall et al., 2005) and was $2.8 billion in Alabama alone in 2008 (AAES, 2009). Nationally, the green industry generates 1.9 million jobs, $64.3 billion in labor income, and $6.9 billion in indirect business taxes (Hall et al., 2005). While horticulture is one of the fastest growing sectors in agriculture, its potential impacts on climate change (either positively or negatively) have been virtually ignored. Farmers and ranchers in other agricultural sectors are now earning additional income in the emerging carbon trading market in which farmers may be paid to reduce their C emissions or sign contracts pledging to alter production practices which provide C offsets (i.e., C credits) to other industries which want to reduce their C footprint (CCE, 2009; NFU, 2009). In order for the horticulture industry to reduce GHG emissions and benefit from these new emerging programs, baseline estimates of C emissions and the ability of growers/landscapers to sequester C using current production practices must be established. The objective of this research is to develop baseline data to determine the ability of the nursery and landscape industry to mitigate climate change by sequestering C with the planting of ornamental trees and shrubs in the landscape.

MATERIALS AND METHODS

In order to determine the potential that the nursery and landscape industry has for C storage and to begin to understand the effects of growth media on soil CO_2 efflux, two commonly grown nursery crops including crape myrtle (*Lagerstroemia* 'Acoma') and southern magnolia (*Magnolia grandiflora*) were transplanted from 7.6-cm (3-in.) and 10.2-cm (4-in.) liners, respectively, into 11.6-L (3-gal) containers on 25 Mar. 2008. Plants were potted using one of three growing media; pine bark (PB), whole tree (WT), or clean chip residual (CCR). Each substrate was mixed with sand (6 : 1, v/v) and 8.3 $kg \cdot m^{-3}$ (14 lbs/yd^3) 18-6-12 Polyon control-release fertilizer, 3.0 $kg \cdot m^{-3}$ (5 lb/yd^3) lime, and 0.9 $kg \cdot m^{-3}$ (1.5 lb/yd^3) Micromax were added. Whole Tree (Fain et al., 2006) and CCR (Boyer et al., 2008), are by-products of the forestry industry which are currently being investigated as alternative media sources due to decreasing PB supplies (Lu et al., 2006). Plants were grown in the 11.6 L (3 gal) containers for an entire growing season and then outplanted to the field in December 2008. To monitor soil CO_2 efflux, automated carbon efflux systems (ACES, USDA Forest Service, Southern Research Station Laboratory, Research Triangle Park, North Carolina; U.S. patent #6,692,970) were installed adjacent to the two plant species previously mentioned to continuously monitor (24 $h \cdot d^{-1}$) C lost via soil respiration. Three replicate sampling chambers were placed on each potting media/species combination. Belowground soil C was also assessed in Summer 2009, prior to placement of ACES. Two soil cores [3.8 cm (1.5 in.) diameter × 60 cm (23.6 in.) depth] were collected from each treatment within all blocks according to methods described by Prior et al. (2004). Cores were divided into 15 cm (5.9 in.) depth segments, sieved (2 mm), and oven dried at 55 °C (131 °F). Ground subsamples of soil (0.15-mm sieve) were analyzed for C on a LECO TruSpec CN analyzer (LECO Corp., Saint Joseph, Michigan). The experiment was designed as a randomized complete block design. Soil CO_2 efflux data were analyzed using the Proc Mixed procedure and percent soil C was analyzed using the Proc GLM procedure of SAS (SAS version 9.1).

RESULTS AND DISCUSSION

Soil analysis at the beginning of the study period indicated that soil C in the top depth of soil (0–15 cm) was higher for PB compared to WT and CCR for both plant species (Figs. 1 and 2). Soil C for the other two media did not differ in either species. Although soil C was much lower at the 15–30 cm depth, the same treatment pattern was observed for both species. No soil C differences were observed among media in either species at the lower two depths (i.e., 30–45 and 45–60 cm). These initial soil C data indicate that the media were contained in the upper 15 cm of the soil profile with a possibility that some of the pine bark was incorporated slightly below that depth.

Crape myrtle had higher soil CO_2 efflux than magnolia when compared across all media; this was generally true when considering each medium separately (Table 1). This higher efflux may be due to crape myrtle having a larger root system or faster growth rate than magnolia. In crape myrtle, all three media had significantly different soil CO_2 efflux values; CCR was highest and WT lowest. In magnolia, PB was higher than the other media, which did not differ. Across both species, WT had lower efflux than PB or CCR which were similar. Given that all three media had similar C content at potting (49.2, 47.8, and 46.9% for PB, WT, and CCR, respec-

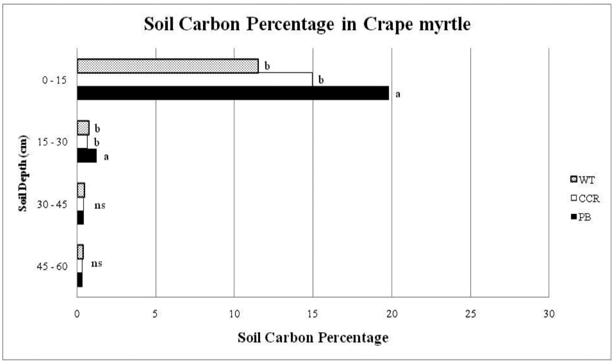

Figure 1. Media effects on soil carbon percentage in crape myrtle. Bars with the same letter are not significantly different according to the Least Significant Differences Test (alpha = 0.05). ns = not significant according to the Least Significant Differences Test. PB = Pine Bark, WT = WholeTree, CCR = Clean Chip Residual.

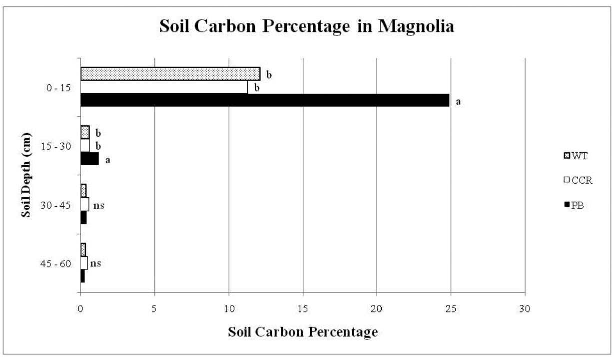

Figure 2. Media effects on soil carbon percentage in magnolia. Bars with the same letter are not significantly different according to the Least Significant Differences Test (alpha = 0.05). ns = not significant according to the Least Significant Differences Test. PB = Pine Bark, WT = WholeTree, CCR = Clean Chip Residual.

tively), the lower efflux for WT may be due to its higher wood content (~90% for WT versus ~40% for CCR) causing it to break down slower. Further, Boyer et al. (2008) reported that PB and CCR had equivalent microbial respiration suggesting that these materials decompose at similar rates which is supported by our findings.

It is interesting to note that, for magnolia, the soil CO_2 efflux data mirrored the initial soil C data; that is, PB had higher soil C values and higher efflux values than the other two media, which did not differ. This was not the case for crape myrtle where soil C followed the same pattern as magnolia but where efflux was highest

Table 1. Effects of species and growth media on soil CO_2 efflux. Means with associated separation statistics are shown.

Species effects on soil CO_2 efflux across all media		
Species[b]	**Soil Flux**	**P-value**
CM	7.68	<0.001
MG	7.01	
	% Difference	
MG vs CM	9.6	
Media effects on soil CO_2 efflux across both species		
Media[c]	**Soil Flux**	**P-value**
PB	7.46	<0.001
WT	7.01	
CCR	7.57	
	% Difference	**P-value**
PB vs WT	-6.0	<0.001
PB vs CCR	1.5	0.265
WT vs CCR	8.0	<0.001
Media effects on soil CO_2 efflux within Crape Myrtle		
Media	**Soil Flux**	
PB	7.68	
WT	7.12	
CCR	8.24	
	% Difference	**P-value**
PB vs WT	-7.3	<0.001
PB vs CCR	7.3	<0.001
WT vs CCR	15.7	<0.001
Media effects on soil CO_2 efflux within Magnolia		
Media	**Soil Flux**	
PB	7.24	
WT	6.89	
CCR	6.90	
	% Difference	**P-value**
PB vs WT	-4.8	0.016
PB vs CCR	-4.7	0.018
WT vs CCR	0.1	0.977
Species effects on soil CO_2 efflux within media		
	% Difference	**P-value**
MG vs CM in PB	6.1	0.002
MG vs CM in WT	3.3	0.099
MG vs CM in CCR	19.4	<0.001

[a]Efflux in μmol CO_2 $m^{-2} \cdot s^{-1}$; [b]CM = Crape Myrtle, MG = Magnolia

[c]PB = Pine Bark, CCR = Clean Chip Residual, WT = Whole Tree

for CCR, followed by PB, then by WT, with each being significantly different. The reason for this is not know but may involve interactions of media and root growth; this will be investigated at study termination.

It has been shown that changes in agricultural management practices which minimize soil disturbance (i.e., no-tillage) and increase surface crop residues (including use of cover crops) can enhance soil C sequestration potential (Smith et al., 1998; Lal, 2007), however this may be true only in the long term (Six et al., 2004). In the present study, soil C ranged from 11%–25% in the upper soil profile of the planting area compared with about 3% found in field soils (Simmons and Derr, 2007). These data clearly show that planting containerized ornamentals into the landscape transfers a large amount of C belowground instantly, suggesting that opportunities exist for the horticulture industry to contribute positively to soil C sequestration. However, uncertainty remains regarding how long this C will remain sequestered. Further investigation is needed to fully understand the impact of various growing media and ornamental species on soil CO_2 emissions and the residence time of this C in soil when planted into urban and suburban landscapes. These data will not only prepare the horticultural industry for possible future legislation, they also provide homeowners a means of directly contributing to the mitigation of climate change via soil C sequestration.

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