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Determining Trace Gas Flux From Container-Grown Woody Ornamentals©

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In recent years, anthropogenic climate change and its effects on the global environment has garnered significant attention from the scientific community. Increased trace gas emissions (CO_2, CH_4, and N_2O) are widely believed to be the driving force behind global warming. Agriculture is a large contributor to trace gas emissions. Much of the work on reducing greenhouse gas (GHG) emissions has focused on row crop, forestry, and pasture systems, with little work in specialty crop industries such as horticulture. Our objective was to determine efflux patterns of CO_2, CH_4, and N_2O associated with different nursery container sizes under common production practices. These data are needed to develop Best Management Practices for reducing trace gas emissions from container nursery production systems.

INTRODUCTION

There is widespread belief in the scientific community that anthropogenic climate change poses a serious global threat. While it is still uncertain that man-made emissions are causing an increase in global temperatures, it is known that concentrations of the three most important long-lived greenhouse gases (GHG) in the atmosphere have increased dramatically over the past 255 years (IPCC, 2007). Atmospheric concentrations of carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) have increased by approximately 38%, 157%, and 19%, respectively, since 1750 (WMO, 2009).

The agriculture industry in the U.S.A. is a large contributor to GHG emissions, behind only energy production (Johnson et al., 2007). 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 radiative forcing from agriculture production is one third of the man-made greenhouse effect (Cole et al., 1997).

Mitigation of GHG by altering agriculture production practices has been heavily researched (Cole et al., 1997; Lal et al., 1998) with the majority of this work focusing on row crop and animal production systems. Virtually no research has centered on contributions from specialty crop industries such as horticulture.

The ornamental horticulture industry impacts the landscape of rural, suburban, and urban environments. The economic impact of the "green industry" (nursery, greenhouse, and sod) is $148 billion annually in the U.S.A. (Hall et al., 2005) and was $2.8 billion in Alabama alone in 2008 (AAES, 2009). There is a need for the horticulture industry, as well as other sectors of agriculture, to determine ways in which current production practices can be altered to reduce GHG emissions. Currently there is speculation that legislation limiting CO_2 and other GHG emissions could occur in the near future. There could also be opportunities for growers to profit financially by reducing GHG. Multiple organizations and federal agencies have proposed programs in which growers could be paid to reduce carbon emissions or to provide carbon credits to other industries to offset their carbon footprint (EPA, 2008; NFU, 2009). There is a need for all agricultural sectors to take preemptive action and examine alternative management practices that would comply with possible new legislation and reduce GHG emissions while balancing production goals and profitability.

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 (Jawson et al., 2005). 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.

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. Determining gas flux from different container sizes will establish both a baseline for common nursery container production practices and the relative importance of container size on GHG fluxes. Estimates are now available on the number of container-grown plants in various pot sizes produced in Alabama (Marble et al., 2011). If a direct relationship between potting media volume and gas emissions can be established and other states develop estimates on numbers of container-grown plants in different pot sizes, then future measurements can be scaled to industry-wide levels. 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, Alabama. On 1 April 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 and sand (6 : 1, v/v) medium that had been previously amended with 8.3 kg • m^{-3} (14 lbs/yd^3) of 17–5–11 Polyon control-release fertilizer (10–12 month), 3.0 kg • m^{-3}(5 lb/yd^3) of lime, and 0.9 kg • 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 (1 April 2010 to 31 March 2011) using the static closed chamber method (Hutchinson and Livingston, 1993; Hutchinson and Mosier, 1981). Custom-made gas flux chambers were designed and constructed based upon criteria described in the GRACEnet protocol (Baker et al., 2003; Parkin and Kaspar, 2006) 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 × 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 (2006). Gas samples were analyzed by a gas chromatograph (Shimadzu GC-2014, Columbia, Maryland) 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, Pennsylvania). 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 min) as described by Parkin and Venterea (2010). Calculations in this study were used to express data as mg (CO_2-C) and µg (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, North Carolina).

RESULTS AND DISCUSSION

Methane efflux was consistently around 0 in all containers for the entire duration of study (data not shown). It is likely these values were close to or below the detection limits of the gas chromatograph. It is not surprising, given the media was well drained, the anaerobic conditions needed for methane production did not occur in this system. Based on our results, methane efflux does not appear to have a significant effect on total trace gas emissions from container-grown nursery crops.

Weekly trace gas emissions indicate a significant relationship between container size and CO_2 efflux, with flux increasing as container size increased (Fig. 1). On 30 of the 50 sampling dates, #3 (3 gal) containers had higher efflux than any other container size. This trend continued when total CO_2 efflux was estimated over the course of one year (Table 1). On many sampling dates (13), #3 had the highest flux, and #2 (2 gal) had higher flux than #1 (1 gal) or TG containers (Fig. 1). Obviously, decomposition (heterotrophic respiration) of larger quantities of growth media resulted in greater loss. Also, since plants grew larger in #2 and #3 containers (data not shown), higher losses (in #2 and #3 containers) were likely influenced by the larger plant sizes (autotrophic respiration), especially at later dates (Fig. 1). In addition to effects of container size, CO_2 efflux generally increased as temperature increased. Efflux was consistently highest during late spring and summer months with larger differences among container sizes (Fig. 1). Carbon dioxide efflux is known to be highly dependent upon temperature and water content (Fang and Moncrieff, 2001). While water content was not monitored in this study, container moisture levels were uniform due to daily controlled irrigation.

Average N_2O efflux (µg• d^{-1}) was highest in #3 containers, followed by #2 containers, with no difference among the other two container sizes (Fig. 2). Yearly estimates of N_2O efflux (mg/yr) also show that most N_2O-N was lost in #3 containers (Table 1). Over the course of the study, #3 containers had higher N_2O efflux than all other containers on 32 of the 50 sampling dates. Because fertilizer was incorporated into the media prior to planting on a volume basis, larger containers had more fertilizer than smaller containers, likely causing a higher N_2O efflux. Further, all plants were similar in size at the beginning of the study and less fertilizer could be utilized by the plant in the larger containers, resulting in higher losses via N_2O efflux. Nitrous oxide emissions increased dramatically beginning in May, 2010 and increased again in June and July of the same year before leveling off in September (Fig. 2). This is likely because the release rate of the controlled-release fertilizer used in this study is highly dependent upon soil temperature, causing higher N_2O fluxes during warmer months. No increases in N_2O flux were observed as temperatures increased in 2011 as most of the fertilizer (10–12 month formulation) was likely utilized or depleted.

Our results show that loss of both CO_2 and N_2O were greatest in the largest containers. Trace gas emissions reported in this study show that container production may emit more trace gas per acre than has been reported in some row crops (Collins

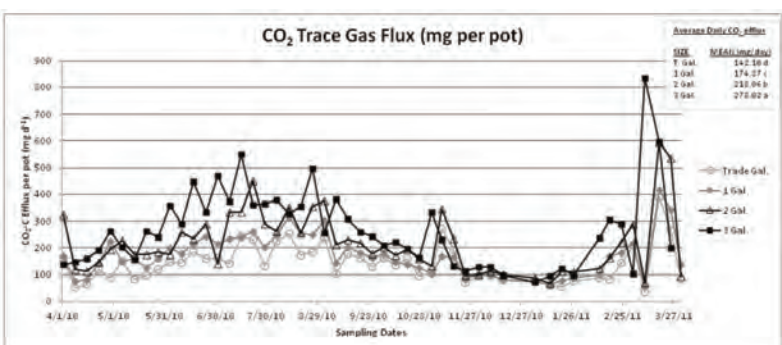

Figure 1. CO_2-C efflux (mg/d^{-1}) for dwarf yaupon holly grown in four container sizes over 1 year (1 April 2010 – 31 March 2011). The insert shows average daily efflux (means followed by the same letter are not significantly different from each other, $p = 0.05$).

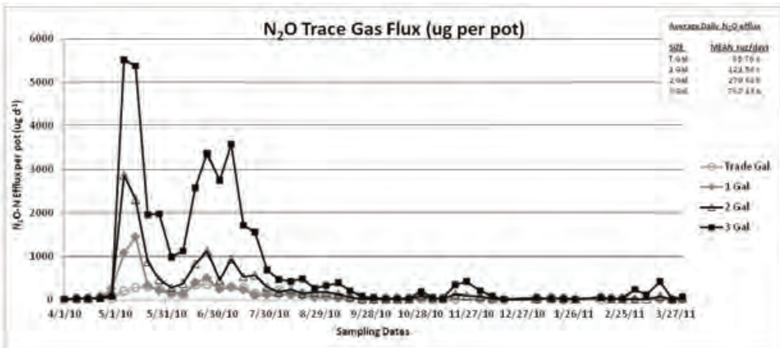

Figure 2. N_2O-N efflux (µg• d^{-1}) for dwarf yaupon holly grown in four container sizes over one year (1 April 2010 – 31 March 2011). The insert shows average daily efflux (means followed by the same letter are not significantly different from each other, $p = 0.05$).

Table 1. Estimation of yearly CO_2 and N_2O efflux from container-grown nursery ornamentals.[Z]

		Yearly Efflux	
Container size	**Volume (L)**[Y]	**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	01.48 a	280.00 a

[Z]Pots measured contained dwarf yaupon hollies (Ilex vomitoria 'Nana') in each pot size listed (n = 7).
Estimates were made by extrapolating daily averages over the course of one year.
[Y]Pot volumes show the amount of substrate [pinebark : sand (6 : 1 v:v)] contained in each pot size.
[X]Means were separated using Fishers Least Significance Difference Test in the Proc Mixed procedure ($p = 0.05$).

et al., 2008); however nursery production acreage is minuscule when compared to most agronomic crops. The National Agricultural Statistics Service (2009) reported that approximately 90 million acres of corn were harvested in the U.S.A. in 2007. When comparing acreage of nursery stock reported in the same study (455,000 acres), the nursery industry is likely producing only a fraction of total GHG emissions from agricultural production. It should be noted that the container flux data do not necessarily reflect net emissions as they do not account for carbon sequestered in growing biomass. Further, container nursery systems contribute to carbon sequestration by placing large amounts of carbon-rich growing media belowground when plants are transplanted into the landscape (Marble et al., 2010). 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. While uncertainty still remains regarding the overall impact of the nursery industry on climate change, results from this study begin to provide baseline data of trace gas emissions from container-nursery production systems.

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