Trace Gas Emissions from Nursery Crop Production Using Different Fertilization Methods©

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Research on agriculture's role in mitigation of greenhouse gas (GHG) emissions has been conducted in row crop, forestry, and animal production systems, but there has been little focus on contributions from specialty industries such as horticulture. Our objective was to determine efflux patterns of CO_2, CH_4, and N_2O associated with three different fertilization methods (dibble, incorporated, and topdressed) commonly used in nursery container production. Dibbling fertilizer reduced CO_2 emissions when compared to incorporation or topdressing. Dibbling and topdressing reduced N_2O emissions (68 and 70%, respectively) when compared to the incorporated treatment. These data begin to provide evidence of mitigation strategies which can be implemented in container plant production to help growers adapt to possible future legislation, improve the environmental impact from the industry, and benefit financially from potential carbon trading or offset programs.

INTRODUCTION

Over the past several decades, climate change and its possible effects on the global environment have received increased attention from the scientific community. Experts in almost every industry are searching for ways in which GHG emissions can be reduced to lessen their respective carbon (C) footprint.

One area in which scientists have identified as having great potential in GHG mitigation is agricultural production. High levels of the three most important, long-lived trace gases (CO_2, CH_4, N_2O) are emitted from agricultural production making it the second largest source of GHG behind only energy production (Johnson et al., 2007).

Agricultural production is different from other industries in that it can act as a GHG source, but can also act as a GHG sink through changes in management practices. Carbon storage through conservation or "no-till" has been shown increase soil C levels and also reduces fossil fuel use (Smith et al., 1998). Methane emissions have been shown to be reduced by using proper manure handling practices (Lin et al., 1994), and N_2O emissions can be reduced by improving nitrogen (N) use efficiency, timing, and placement (CAST, 2004).

Several best management practices have been developed for reducing GHG emissions from agricultural production, but almost all of this work has focused predominately on larger sectors (agronomy, forestry, etc.), with little attention given to specialty industries such as horticulture. The green industry (nursery, greenhouse, and sod production) is one of the fastest growing sectors in agriculture (Hall et al., 2005); however, almost no research has focused on the impacts of this industry on GHG emissions.

Providing best management options for reducing GHG would not only reduce the environmental impact of the industry, but could benefit growers financially. There are now government and industry programs which provide tax incentives and payments to encourage farmers to reduce emissions and provide C offsets by altering current production practices (NFU, 2009; Schmidt, 2009). There is also speculation that agricultural GHG emissions could be "capped" or taxed in the future (Blanford and Josling, 2009; Moore and Bruggen, 2011). There is a need to develop mitigation strategies for nursery production practices to help growers adapt to possible future legislation and benefit from C trading or offset programs.

A possible mitigation strategy that has been previously investigated in agronomic production is fertilizer placement. Placement of fertilizers into the soil near the zone of active root uptake may reduce N loss from leaching and increase plant N use efficiency, which would reduce the amount of N that could be lost via N_2O emissions (CAST, 2004). Fertilizer placement has been shown to affect shoot and root growth of container-grown nursery crops (Altland et al., 2004) which could indirectly impact net GHG emissions as increased crop growth will sequester more C in growing biomass. Our objective was to determine efflux patterns of CO_2, CH_4, and N_2O associated with three different fertilization methods (dibble, incorporated, and topdressed) commonly used in nursery container production.

MATERIALS AND METHODS

This experiment was initiated at the Paterson Greenhouse Complex, Auburn University, Alabama on 17 May 2011, *Rhododendron* 'Gumpo White' (white gumpo azalea) that were ~15 cm (6 in.) in height with a 10 cm (4 in.) canopy width were transplanted from 72 cell-pack liners (2.5 cm; 1 in.) into 3.8-L (1 gal) containers. Containers were filled with a pinebark:sand (6:1 v:v) media which had been previously amended with 3.0 $kg{\cdot}m^{-3}$ (5 lb yd^{-3}) of ground dolomitic limestone and 0.9 $kg{\cdot}m^{-3}$ (1.5 lb yd^{-3}) of Micromax® micronutrient (The Scotts Company, LLC, Marysville, OH). Polyon® (Harrell's LLC, Lakeland, Florida) 17N-2.2P-4.2K (17-5-11) control-release fertilizer (10-12 month) was applied at potting at a rate of 25 g per container using the three different methods: dibble; incorporation; and topdressing. An additional treatment received only incorporated lime and Micromax® amendments with no other fertilization. The study used seven replicates for each fertilizer placement treatment. After potting, all containers were placed in a retractable roof shade structure in a randomized complete block design and received 1.3 cm (0.5 in.) of daily overhead irrigation.

Trace gases emitted from the containers were sampled in situ weekly for 6 months (17 May to 17 November) 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 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 (Parkin and Kaspar, 2006). Gas samples were then analyzed using a gas chromatograph (Shimadzu GC-2014, Columbia, Maryland). Gas fluxes were calculated 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). Estimates of cumulative efflux were calculated from gas efflux at each sampling date integrated over time using a basic numerical integration technique (i.e., trapezoidal rule). Trace gas data were analyzed on each individual sampling date (data not shown), across all dates, and cumulatively. All data were analyzed using the Proc Mixed procedure in SAS (SAS® Institute version 9.1, Cary, North Carolina). Means were separated using Fishers Least Significance Difference Test in the Proc Mixed procedure. In all cases, differences were considered significant at $p \leq 0.05$.

RESULTS AND DISCUSSION

Methane efflux patterns were inconsistent but remained relatively low in all treatments for most of the study with no differences observed in daily averages among treatments (data not shown). On many sampling dates, it is likely CH_4 efflux values were close to or below the detection limits of the gas chromatograph. Based upon results from this study, CH_4 emissions do not appear to contribute significantly to total trace gas emissions from container production.

Average daily trace gas emissions indicated that CO_2-C efflux was lower in the dibble treatment (160.16 mg CO_2-C) when compared to incorporated or topdressed treatments (193.59 and 192.58 mg CO_2-C, respectively); all fertilized treatments had higher values than the nonfertilized containers (Fig. 1). This pattern was also observed for cumulative CO_2-C losses (Table 1). The reason for these differences is unclear, although one possible explanation could be differences in root growth early on in the study (impacting autotrophic respiration) which were not captured. Although all fertilized azaleas had similar shoot and root growth at the conclusion of the study (data not shown), shoot growth measurements taken half-way through the study indicated that azaleas receiving the dibble treatment were slightly smaller in first few months after potting (data not shown).

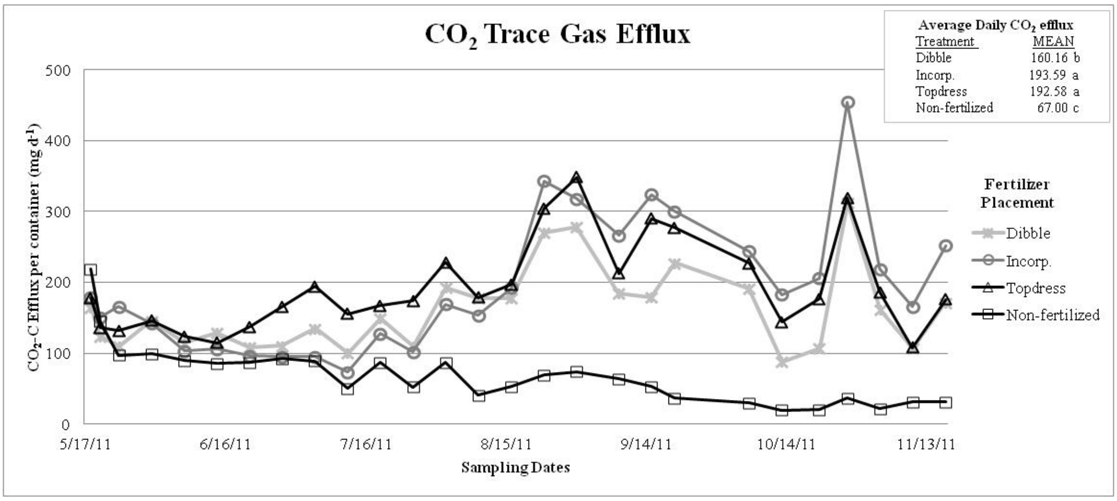

Fig. 1. CO_2-C efflux ($mg \cdot d^{-1}$) for gumpo white azaleas grown with three different fertilizer placements for 6 months (May 17 - November 17, 2011). The insert shows average daily efflux (means followed by the same letter are not significantly different from each other, $p \leq 0.05$).

Table 1. Cumulative[z] trace gas (CO_2 and N_2O) efflux from container-grown azaleas using three different fertilization placements.

Fertilizer placement[y]	Cumulative efflux	
	CO_2-C (mg)	N_2O-N (µg)
Dibble	651.80 b	602.62 b
Incorporate	785.93 a	1883.84 a
Topdress	781.45 a	572.27 b
Non-fertilized	325.19 c	21.09 c

[x] Means were separated using Fishers Least Significance Difference Test in the Proc Mixed procedure (p=0.05).

[y] The same fertilizer rate (25 g of product (Polyon® 17-5-11 per 3 L container) was used for all placement treatments with the exception of control pots which received no Polyon® fertilizer. Media in all treatments was amended with dolomitic limestone [3.0 kg m^{-3} (5.0 lbs yd^{-3})], and Micromax® (0.9 kg m^{-3} (1.5 lbs yd^{-3})].

[z] Cumulative efflux was calculated using the trapezoid rule n=7.

Average N_2O efflux was highest in the incorporated treatment (489.02 µ N_2O-N), with no differences observed between dibble and topdressed treatments (156.82 and 148.96 µg N_2O-N, respectively; Fig. 2); all placement treatments had significantly higher N_2O-N efflux than the nonfertilized containers. Cumulative N_2O efflux also illustrated that more N_2O-N was lost from the incorporated treatment (Table 1). As fertilizer was placed closer to roots in the dibble treatment, the plant was likely able to utilize the fertilizer more efficiently, especially at earlier dates when plant roots were small and localized. Additionally, the controlled release fertilizer used has a release rate that is highly dependent upon temperature and moisture. The incorporation treatment had much greater contact with media (and subsequently moisture) than the topdressed treatment, and likely had a faster release rate.

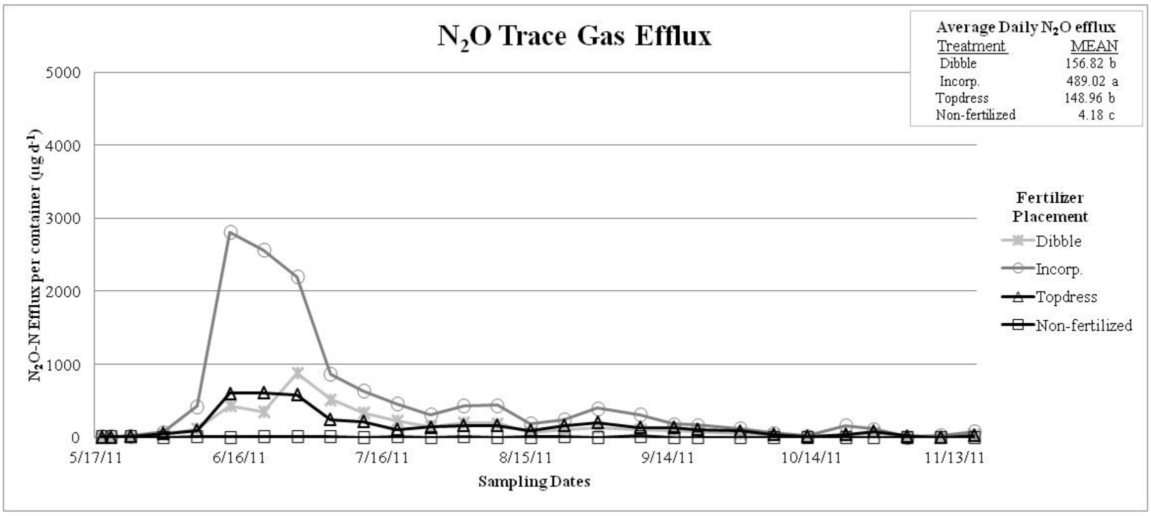

Fig. 2. N_2O-N efflux ($\mu g \cdot d^{-1}$) for gumpo white azaleas grown with three different fertilizer placements for 6 months (May 17 - November 17, 2011). The insert shows average daily efflux (means followed by the same letter are not significantly different from each other, $p \leq 0.05$).

Results from this study indicate that dibbling fertilizer may reduce trace gas emissions CO_2, and N_2O from container-production systems. Dibbling reduced CO_2 emissions compared with incorporation and topdressed treatments while plant growth was statistically similar at the conclusion of the study. Dibbling and topdressing also significantly reduced N_2O emissions (68 and 70%, respectively) compared to the incorporated treatment. Further work is needed to determine the impact of different production variables on trace gas emissions from container plant production. However, results from this study begin to provide evidence of mitigation strategies which can be implemented in container plant production to help growers benefit from C offset programs, adapt to future legislation, and improve the environmental impact from container plant production without negatively affecting crop growth.

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