Nitrous Oxide Emissions and Nitrate Leaching from Synthetic and Alternative Turfgrass Management Programs

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INTRODUCTION

Identifying best management practices for turfgrasses while achieving environmental sustainability is imperative. Regulations and restrictions are increasing for synthetic fertilizer and pesticide use on amenity turf. It remains unclear if the use of organic fertilizers poses less environmental concern than synthetic fertilizers. Research is needed in order to determine the environmental fate and efficacy of the products.

HYPOTHESIS AND OBJECTIVES

Our hypothesis was that nitrous oxide emissions, nitrate leaching, and aesthetic qualities would be similar among organic and synthetic management strategies. The objective of this study was to compare the effect of organic and synthetic management programs on nitrous oxide gas emissions, nitrate loss, and turf quality.

MATERIALS AND METHODS

Establishment and Maintenance

- RCBD, 2 establishment methods, 5 management treatments (Table 1) and 4 replications
- Established 25 Aug. 2010 in Madison, Wisconsin USA
  - Seed mixture: *Poa pratensis* L., *Lolium perenne* L., and *Festuca rubra* L. ssp *rubra*
  - Mature sod: *P. pratensis*
- Professional management programs utilized restricted use pesticides and homeowner programs utilized general use products
- Troxel silt loam soil (fine-silty, mixed, superactive, mesic Pachic Argiudolls) ~3.5% organic matter
- 48.9-kg N ha^{-1} applied, August and October of 2010; May, August, and October of 2011; May, August, and October 2012
- Supplemental irrigation was applied only during establishment and to incorporate fertilizer
- Plots were mown at 7-cm, once weekly during periods of active growth

Table 1. Management treatments to study nitrous oxide emissions, nitrate loss during leaching, aesthetic quality, and weed coverage for swards of *Poa pratensis* L., *Lolium perenne* L., and *Festuca rubra* L. var. *rubra* established by seed or *P. pratensis* sod in Madison, WI USA.

Management Program	Fertilizer type	Analysis ($N-P_2O_5-K_2O$)	Total Nitrogen	Pesticide(s)
Professional (Synthetic)	Urea and SCU†	24-0-6	10% Urea-N‡ 14% slowly available urea-N	2,4-D Triclopyr Fluroxypyr
Home owner (Synthetic)	Urea and methyl urea	28-0-3§ 30-0-3 22-0-10	2.4-3.2% WIN¶ 16.2-22.2% urea-N 3.4-4.6% slowly available WSN#	2,4-D MCPP-p Dicamba
Home owner (Natural)	Organic poultry manure	5-2.5-4	2% WSN 3% WIN	FeHEDTA
Professional (Natural/Synthetic)	Blended-synthetic and organic	16-2-3	3% ammoniacal-N 10.6% urea-N 2.4% WIN	Mesotrione
Control	No fertilizer	---	---	No pesticide

† Sulfur coated urea.
‡ Nitrogen.
§ Analysis varied when granular herbicides were included.
¶ Water insoluble nitrogen.
# Water soluble nitrogen.

MATERIALS AND METHODS continued

Nitrous oxide flux

- Collected weekly, unless snow cover present, and 5 consecutive days following fertilization
- Monitored on the control, the professional synthetic and the home owner natural fertilizer treatments of the plots established by seeding
- Flux measured by an INNOVA 1412 photoacoustic field gas-monitor connected to a vented static chamber (20-cm x 11-cm) (Figure 1)
- Measurements over 15 minutes (0, 3, 6, 9, 12, and 15), starting 1 hour after sunrise to reduce diurnal variation
- Soil moisture measured with time domain reflectometry (Fieldscout TDR 300 Soil Moisture meter, Spectrum Technologies Inc. Plainfield, IL 60585)
- Soil and air temperatures were measured with a thermocoupler thermometer

Figure 1. INNOVA 1412 photoacoustic field gas-monitor and collection chamber used for N_2O flux measurements

Leachate

- Low tension wicking lysimeters (20-cm diameter), modified design of Holder et. al. (1991), constructed of polyvinyl chloride were used to collect leachate from a depth of 36-cm
- Leachate samples were collected as necessary and tested for nitrate concentration (EPA, 1993)

Aesthetics

- Normal Difference Vegetation Index (NDVI) measurements every two weeks (April to November) using a GreenSeeker Hand Held™ Optical Sensor Unit (NTech® Industries, Inc., Ukiah, CA 95482)
- Color and quality measurements were assessed visually once monthly (April to November)
- Weed cover was assessed May and August of each year
- Herbicide treatments were made when weed abundance of any single replication within a treatment exceeded 5% (table 1).

Data analysis

- Nitrous oxide flux was modeled using the HMR package in the statistical program R (Pedersen et al., 2010)
- Analysis of variance was used to separate means of N_2O, NO_3, NDVI, color, quality and weed abundance (Statistix, 2008)
- Tukey's HSD was used to determine significant difference among treatments

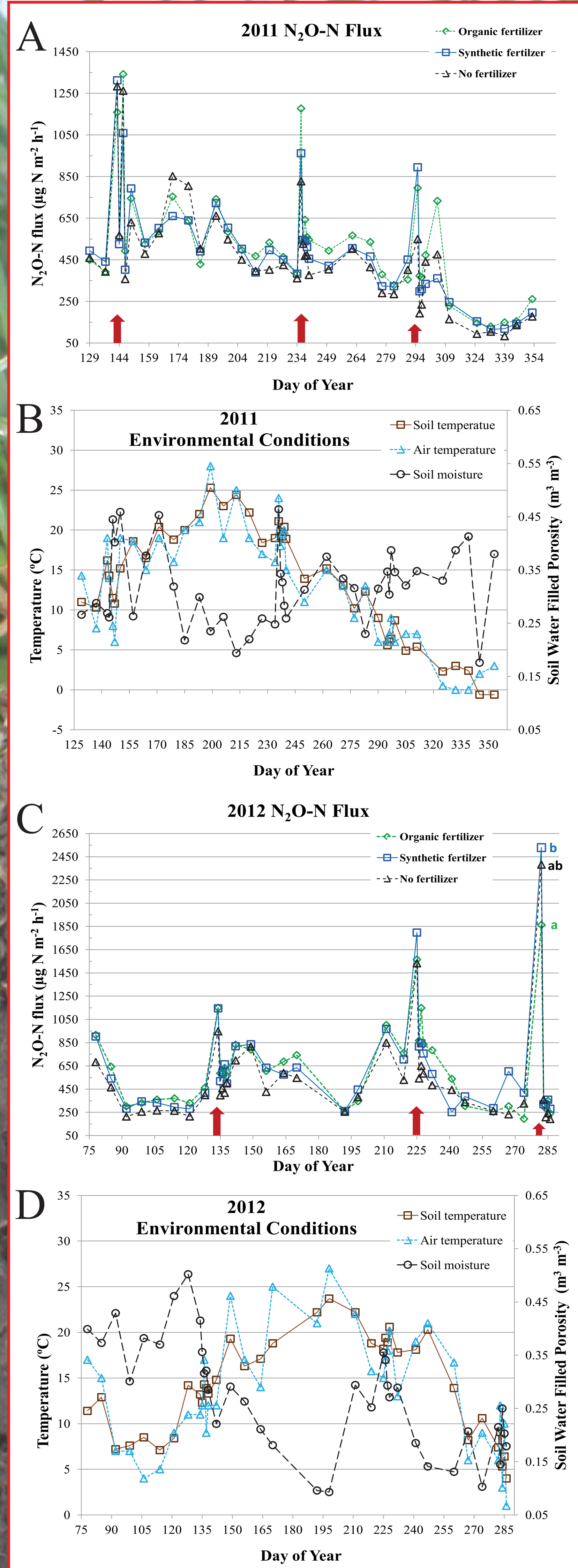

Figure 2. Nitrous oxide flux and environmental conditions observed during 2011 (A and B) and 2012 (C and D) N_2O measurements from synthetic fertilizer, organic fertilizer, and unfertilized treatments of cool season turfgrass swards in Madison, WI USA. Arrows indicate date of fertilizer and irrigation application. Lower case letters adjacent to day 282 of 2012 indicate statistical difference ($P \leq 0.05$) among treatments. No statistical difference existed among treatments on all other dates. Critical value for comparison among treatments for each measurement date = 524-µg N m^{-2} h^{-1}.

Table 2. Management programs used to study nitrate nitrogen (NO_3-N) content in the leachate collected from a depth of 36-cm beneath swards of *Poa pratensis* L., *Lolium perenne* L., and *Festuca rubra* L. var. *rubra* established by seed or mature *P. pratensis* sod in Madison, WI USA.

Management Program	Annual mean flow-weighted NO_3-N loss through leaching (NO_3-N mg m^{-2})† — Established by seed 2011 (SE)	Established by seed 2012 (SE)	Established by sod 2011 (SE)	Established by sod 2012 (SE)
Professional (Synthetic)	896 (15)	118 (4)	260 (6)	89 (6)
Home owner (Synthetic)	686 (14)	106 (3)	943 (16)	38 (3)
Home owner (Natural)	722 (10)	145 (5)	429 (7)	120 (7)
Professional (Natural/Synthetic)	858 (15)	51 (2)	924 (9)	30 (3)
Control	671 (9)	86 (5)	615 (9)	21 (2)

†There were significant differences between years ($P \leq 0.05$), but not among management programs, establishment methods, or any of their interactions.

RESULTS

- Nitrous oxide flux measurements fluctuated tremendously (80- to 2530-µg N m^{-2} h^{-1}) and were highest on the day of and within a few days following the irrigation of fertilizer applications (Figure 2A & C)
- The rate of N_2O flux did not exhibit a significant difference ($P \leq 0.05$) among the treatment means during 2011 and was significant during one collection date during 2012 (Figure 2A & C).
- On day 282 of 2012, the synthetic treatment had a greater N_2O-N flux than the organic treatment, though the flux of the synthetic and organic treatments did not differ from the control (Figure 2C)
- The annual pattern of N_2O flux (Figure 2A & C) appears to rise and decline with changes in environmental conditions (Figure 2B & D) and may be influenced by air temperature, soil temperature and soil moisture
- The annual means of flow-weighted NO_3-N from leaching were significantly different between years ($P \leq 0.05$), but not among management programs, establishment methods, or any of their interactions (table 2)
- Mean NO_3-N of leaching events ranged among treatments from 3.19- to 12.34-mg N L^{-1} during the first year following establishment and 1.17- to 8.45-mg N L^{-1} during the second year (data not shown)
- Mean color, quality, and NDVI ratings for the plots established by sod were equal or greater than plots established by seed (data not shown)
- For each establishment method, all treatments that received inputs had better color and quality ratings than the unfertilized control (data not shown)
- Control plots established by seeding averaged 59% weed cover 2-years after establishment (Table 3)
- All seeded treatments receiving a weed control product, synthetic or natural, reduced weed encroachment significantly (Table 3)
- The homeowner synthetic seeded treatment and all treatments established with sod required fewer pesticide applications to control weed encroachment than the other treatments (Table 3)

Table 3. Management programs used to study weed coverage for swards of *Poa pratensis* L., *Lolium perenne* L., and *Festuca rubra* L. var. *rubra* established by seed or mature *P. pratensis* sod in Madison, WI USA.

Management Program	Pesticide(s)	% Weed cover (✓)† — Established by seed: Spring 2011	Fall 2011	Spring 2012	Fall 2012	Established by sod: Spring 2011	Fall 2011	Spring 2012	Fall 2012
Professional (Synthetic)	2,4-D Triclopyr Fluroxypyr	18 Ab‡ (✓)	6.8 Aa (✓)	0.3 Aa	2.0 Aa	0.5 Aa	1.5 Aa	0.0 Aa	0.5 Aa
Home owner (Synthetic)	2,4-D MCPP-p Dicamba	18 Ab (✓)	15 Bb (✓)	1.0 Aa	5.5 ABa (✓)	2.8 Aa	2.3 Aa	0.3 Aa	1.0 Aa
Home owner (Natural)	FeHEDTA	13 Ad (✓)	10 ABbcd (✓)	8.8 Aabcd (✓)	11 Bbcd (✓)	3.3 Aabc	1.3 Aab	0.5 Aa	1.8 Aab
Professional (Natural/Synthetic)	Mesotrione	18 Ac (✓)	12 ABc (✓)	3.3 Aab	11 Bab (✓)	0.3 Aa	0.5 Aa	0.8 Aa	0.8 Aa
Control	No pesticide	18 Ab	34 Cc	58 Bd	59 Cd	5.0 Aa	6.5 Aa	4.3 Aa	10 Bab

†(✓) indicates treatment threshold was exceeded and a pesticide application was made following the weed cover rating.
‡ Letters indicate statistical difference ($P \leq 0.05$), upper case letters within columns (Critical Value for comparison (CV)=7.6), lower case letters within rows (CV=8.5).

DISCUSSION

- Fertilizer treatments did not result in a significant increase in N_2O flux over the control during all of the 79 measurement dates observed over an 18 month period, May 2011 to October 2012
- The one measurement date when N_2O flux was significantly different between the synthetic and organic treatments occured during a fertilization event and neither treatment was statistically different than the control
- The influence of temperatures and moisture on the fluctuation rate was likely a result of changes in the metabolic activity of N_2O producing microbes (Denmead et.al, 1979; Situala and Bakken, 1993; Smith et al., 1998)
- The increase in N_2O flux rates of the unfertilized control on fertilization application dates were likely a result of soil gas displacement and/or microbial stimulation due to irrigation (Denmead et.al, 1979)
- The lack of dates when significant difference of N_2O flux and NO_3 leaching between the control and fertilizer treatments may also be a remnant of site history or mechanical tillage prior to plot establishment (Choudhary et al., 2002)
- The decrease in mean flow-weighted NO_3-N loss (Table 2) and number of leaching events (data not shown) during the second year after establishment is likely due to turf maturity and an increase in root development (Geron et al., 1993)

CONCLUSION

To date, N fertilization has not produced greater nitrous oxide emissions or nitrate loss through leaching events among the nitrogen sources or when compared to the non-fertilized turf. The visual aesthetic qualities for all fertilizer programs were equal and within each establishment method, fertilizer treatments were better than the control with no inputs. In the absence of an irrigation program, the majority of the nitrous oxide gas emissions and nitrate leaching appear to be a result of natural nitrogen cycling from sources other than fertilization.

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