Nitrous Oxide Emissions in a Turfgrass Environment

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INTRODUCTION

Nitrous oxide (N_2O) is an important greenhouse gas that has been implicated in global climate change. Nitrous oxide, a natural and anthropogenic by-product, is potentially the most ozone-depleting gas (IPCC, 2007). Human activities of fertilizing agricultural land with nitrogen (N) is responsible for significant amounts of the N_2O emitted into the atmosphere each year (Mosier et al., 1998), including in turfgrass systems (Bremer, 2006; Kaye et al. 2004; Lewis and Bremer, 2013; Maggiotto et al., 2000, Ryden, 1981).

In 2005, it was calculated that turfgrass covered ~50 million acres in the U.S., an area three times greater than irrigated corn (*Zea mays* L.), making turfgrass the most irrigated crop at that time (Milesi et al., 2005). Because of the large acreage of turfgrass, it may have significant impacts on the global atmospheric N_2O inventory. There has been minimal work investigating the effects of controlled-release forms of N-fertilizers and different irrigation regimes (e.g. deficit irrigation) on N_2O fluxes and cumulative emissions in turfgrass. Further research is required to develop management practices that may mitigate emissions of N_2O in turfgrass systems.

Figure 1. (A) Study area with the automated rainout shelter currently not covering the plots; (B) Recording volumetric soil water content of a plot with a time-domain reflectometry handheld meter while sampling N_2O; (C) Sampling N_2O on DOY 174.

OBJECTIVES

- Quantify the magnitude and patterns of N_2O emissions in turfgrass and determine how N fertilization and irrigation may be managed to reduce N_2O emissions.

MATERIALS AND METHODS

- A field experiment was conducted under an automated rainout shelter at the Rocky Ford Turfgrass Research Center in Manhattan, KS. The soil was a Chase silt loam (Figs. 1A-2A).
- 'Meyer' zoysiagrass (*Zoysia japonica* Steud.) was sodded on DOY 155, 2013. Thirty six plots (1.14 by 1.23 m each) were established at a 2.54 cm (simulated golf course fairway) mowing height and thirty six poly-vinyl chloride (PVC) base collars were installed before the study began.
- Experimental design was a randomized complete-block design with 6 blocks. Treatment design was a two-way factorial.
- Fertilizer main effect consisted of three levels; 1) Urea (46-0-0) applied on DOY 151 and DOY 202 in 2014, DOY 153 and DOY 197 in 2015, and DOY 158 and DOY 202 in 2016 for a total rate of 98 kg N $ha^{-1} yr^{-1}$, 2) Polymer-coated (urea) N-fertilizer (41-0-0) applied on DOY 152 in 2014, DOY 153 in 2015 and DOY 158 in 2016 for a total rate of 98 kg N $ha^{-1} yr^{-1}$, and 3) Untreated "Control" (No nitrogen fertilizer applied).
- Irrigation main effect consisted of two levels of deficit irrigation; 1) medium-low irrigation (33% reference evapotranspiration [ET_o] replacement) and 2) medium irrigation (66% ET_o replacement). Both irrigation levels were applied twice a week by hand watering (Fig. 2B).
- Researchers observed minimal to no drought stress at the two deficit irrigation levels in both 2014 (54% and 72% ET_o replacement) and 2015 (45% and 68% ET_o replacement), therefore in 2015 starting 20 July (DOY 201) to 1 September (DOY 244) and all summer in 2016 the levels were lowered to 33% and 66% ET_o replacement, respectively.
- The automated rainout shelter was activated during summer (June, July, and August) period of 2014, 2015, and 2016 when fertilization and irrigation treatments were applied. Irrigation amounts were calculated from daily ET from an on-site weather station using the ASCE standardized reference evapotranspiration equation (Walter et al., 2001).
- From September through May the automated rainout shelter was off and plots received precipitation and irrigation from an automatic irrigation system.

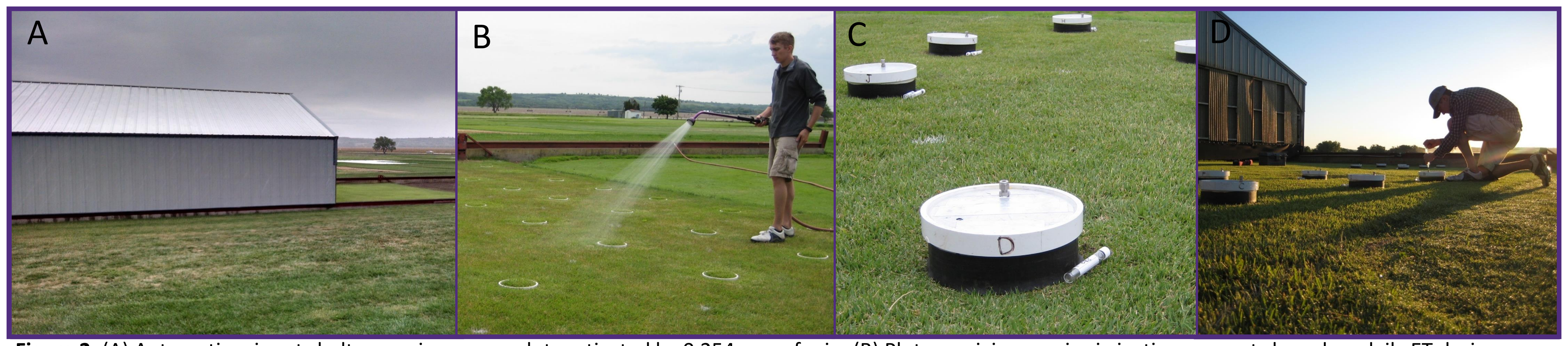

Figure 2. (A) Automatic rainout shelter moving across plots activated by 0.254 mm of rain; (B) Plots receiving precise irrigation amounts based on daily ET during summer period; (C) Close-up of one of twelve static chambers used for sampling N_2O; and (D) Sampling on DOY 157.

DATA COLLECTION AND ANALYSIS

- From 29 October 2014 (DOY 302) to 3 October 2016 (DOY 277), field sampling measurements of soil-surface N_2O fluxes were measured using static, vented PVC chambers (7.5 cm high by 20-cm diam.) with 25-ml of gas removed at 0, 20, 40 minutes (Figs. 1C, 2C-D).
- Gas samples were analyzed by a gas chromatograph (Shimadzu GC14B, Shimadzu Scientific Instruments, Columbia, MD).
- Sampling events included measurements of soil nitrate (NO_3^-) and ammonium (NH_4^+) from a 0 to 12.7 cm depth, soil water content at a 7.6 cm depth by TDR (Fig. 1B), and soil temperature measured at a 7.6 cm depth by a digital thermometer.
- To evaluate turfgrass performance during summer, visual quality (1-9 scale, 9=best quality turf) and digital images were taken under a light box to calculate percent green turfgrass cover.
- Mowing frequency of each plot was recorded in 2015 and 2016.
- Cumulative emissions of N_2O-N were calculated as the sum of the outputs of flux rates for each plot on each measurement date and the number of days between adjacent measurement dates.
- All data were subjected ANOVA using PROC GLIMMIX of SAS (9.4, SAS® Institute Inc., Cary, NC). Fisher's Protected LSD ($P \leq 0.05$) was used to detect treatment differences.

RESULTS

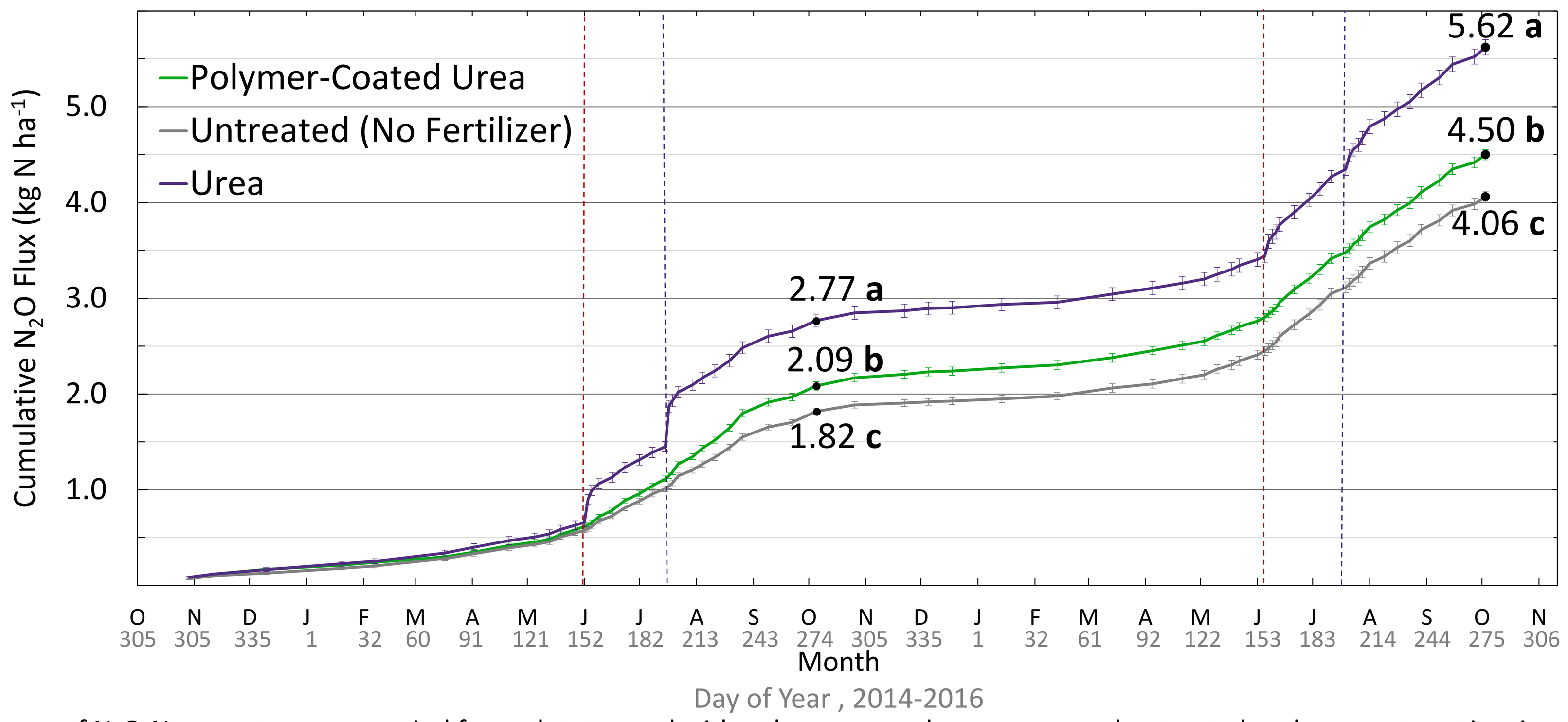

Figure 3. Cumulative fluxes of N_2O-N over a two-year period from plots treated with polymer-coated urea, urea, and untreated under an automatic rainout shelter in Manhattan, KS. Red vertical dashed lines at June dates represent fertilization (urea (46-0-0) applied a rate of 49 kg N ha^{-1} and polymer-coated urea fertilizer (41-0-0) applied at a rate of 98 kg N ha^{-1}) Purple vertical dashed lines at July dates represent the 2nd urea application at a rate of 49 kg N ha^{-1}. Vertical bars at each date represent SE of the mean. Means followed by the same letter at the end of year 1 and end of the study are not significantly different according to Fisher's protected least significant difference test ($P \leq 0.05$).

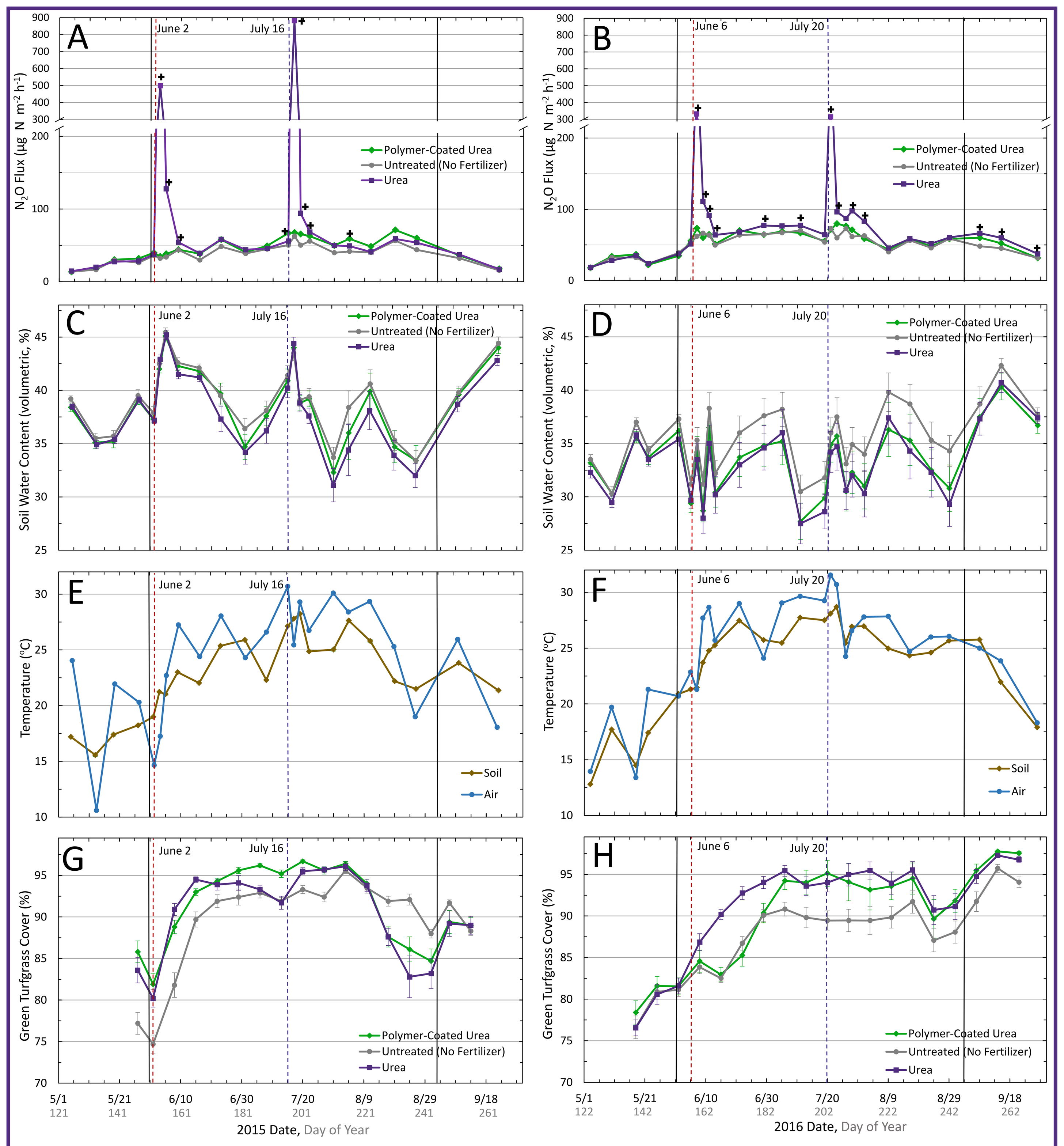

Figure 5. (A-B) Fluxes of N_2O-N from zoysiagrass with fertilization applications in 2015 (A) and 2016 (B); (C-D) average volumetric water content of the soil at 7.6 cm in 2015 (C) and 2016 (D); (E-F) average soil temperature at 7.6 cm among plots and air temperature at 2 m in 2015 (E) and 2016 (F); and (G-H) green turfgrass cover percentage of Meyer zoysiagrass prior to and following the summer period under the automated rainout shelter in 2015 (G) and 2016 (H). Black solid vertical lines represent the summer period when the rainout shelter was activated to prevent precipitation on plots. Red vertical dashed lines at June dates represent fertilization (urea (46-0-0) applied a rate of 49 kg N ha^{-1} and polymer-coated urea fertilizer (41-0-0) applied at a rate of 98 kg N ha^{-1}). Purple vertical dashed lines at July dates represent the 2nd urea application at a rate of 49 kg N ha^{-1}. Symbol plus (+) on sampling dates in (A-B) indicate significant differences ($P \leq 0.05$) between one and the other 2 treatments on that date. Vertical error bars at each date in (C-D, G-H) represent SE of the mean.

- Differences in N_2O emissions were negligible due to irrigation treatment.
- There were significant differences in cumulative emissions for fertilizer main effect (Fig. 3).
- Annual emissions (kg N_2O-N $ha^{-1} yr^{-1}$) for year 1 and year 2, respectively, were
  - Polymer-coated urea (2.09, 2.41)
  - Untreated (1.82, 2.24)
  - Urea (2.77, 2.85)
- Cumulative annual results were similar to past research that reported annual emissions ranging from 1 to 3.85 kg N_2O-N $ha^{-1} yr^{-1}$ across various turfgrass species and under different fertilization regimes (Bremer, 2006; Kaye et al., 2004; Lewis and Bremer, 2013).
- The highest fluxes and majority of emissions occurred in the summer because of the fertilization events and, presumably, higher soil temperatures (Fig. 5A-F).
- There were spikes after applications of urea fertilizer, but increases were much smaller after application of controlled-release polymer-coated urea fertilizer (Fig. 5A-B).
- Both urea and polymer-coated urea resulted in significantly higher visual quality (data not shown) and percent green turfgrass cover than untreated control, however all three treatments maintained acceptable quality during deficit irrigation treatments (Fig. 5G-H).

CONCLUSIONS

The majority of differences measured between treatments was due to the fertilizer main effect treatments. There were minimal differences in N_2O-N fluxes, visual quality, and percent green cover of turfgrass due to irrigation levels of the irrigation main effect, further research is required with deficit irrigation levels. All treatments maintained acceptable turf quality and greater than 75% green cover throughout the summer period. The urea and polymer-coated urea treatments provided higher turf quality and green cover percentage than the untreated control and the polymer-coated urea fertilizer resulted in more consistent visual quality ratings compared to urea and untreated. Urea fertilizer had higher peak fluxes after fertilization and greater overall annual emissions than polymer-coated urea fertilizer. Thus, controlled released N fertilizers such as polymer-coated urea in turfgrass systems could potentially help mitigate N_2O emissions.

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