TITLE: Diurnal Trends in, and Transient Effects of Nitrogen Fertilization and Irrigation on, Nitrous Oxide Fluxes in Turfgrasses

OBJECTIVE: Investigate in turfgrasses: 1) diurnal fluxes of nitrous oxide (N_2O); and 2) transient patterns of N_2O emissions in the 2 to 3 days after irrigation or nitrogen (N) fertilization.

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SPONSORS: Kansas Turfgrass Foundation (KTF)

INTRODUCTION:

Fluxes of N_2O may differ by time of day (diurnally) and, perhaps even more significantly, in the hours and days after substantial rainfall or irrigation and N fertilization. This confounds attempts to calculate cumulative fluxes of N_2O based on infrequent (e.g., weekly or biweekly) measurements. Cumulative sums are important when estimating the contribution of seasonal or annual fluxes of N_2O, a greenhouse gas, from turfgrass ecosystems to regional and global atmospheric N_2O budgets.

MATERIALS AND METHODS:

Transient fluxes of N_2O were measured in a cool-season (perennial ryegrass; *Lolium perenne* L.) and warm-season turfgrass (bermudagrass; *Cynodon dactylon*) by using static surface chambers and analyzing N_2O by gas chromatography.

On July 14, 2004, diurnal measurements of N_2O-N fluxes were collected from six plots of perennial ryegrass at 5:00 a.m., 8:00 am, 10:00 a.m., 1:00 p.m., 4:00 p.m., and 7:00 p.m. (CST). The plots had been fertilized 5 days earlier with 0.5 lb per 1,000 ft^{-2} (25 kg ha^{-1}) of urea N on July 9, and had been well watered. On the day of these diurnal measurements (July 14), irrigation was inadvertently applied to two plots late in the day, at 5:00 p.m., which was 2 hours before the final N_2O measurement of the day. Therefore, average (diurnal) fluxes from the four unaffected plots are presented, as well as fluxes from the two plots that were accidentally irrigated; data from the latter are presented only from 4:00 p.m. (pre-irrigation) and 7:00 p.m. (post-irrigation) to illustrate transient effects of irrigation on N_2O emissions in turfgrasses.

On August 9 to 11, 2005, N_2O emissions were measured for 2 days after irrigation was applied to three of six plots of bermudagrass. Initial N_2O fluxes were measured from the six (dry) plots at 6:30 a.m. (CST) on August 9, immediately before irrigation was applied at 8:00 a.m. with 25 mm of water in three of the plots. Thereafter, fluxes were measured at 9:00 a.m., 1:00 p.m., 4:00 p.m., and 7:00 p.m. on August 9; at 6:30 a.m., 9:00 a.m., 1:00 p.m., 4:00 p.m., and 7:00 p.m. on August 10; and at 7:00 a.m. on August 11. All plots were extremely dry before irrigation, and “dry” plots received no irrigation during the 3-day study; no precipitation occurred, nor was any additional irrigation applied to plots during the 2-day period. Diurnal emissions of N_2O were thus measured from both irrigated and dry plots on 2 complete days.

On August 15 to 18, 2005, N_2O emissions were measured for 3 days after a N-fertilizer application, from the same six bermudagrass plots just described. All plots had been well watered in the 3 days before N fertilization. Initial measurements of N_2O fluxes were collected at

7:00 a.m. CST on August 15, immediately before N fertilization with 1.0 lb per 1,000 ft^{-2} (50 kg N ha^{-1} yr^{-1}) of urea nitrogen. After fertilization, all plots (including unfertilized plots) received about 9 mm of irrigation to minimize N losses due to ammonia volatilization. Thereafter, N_2O fluxes were measured at 1:30 p.m. and 6:00 p.m. on August 15, at 7:00 a.m. on August 16, and at 7:00 a.m. on August 18.

RESULTS:

With the notable exception of 5:00 a.m., fluxes of N_2O showed a clear diurnal trend in perennial ryegrass, with fluxes increasing between 8:00 a.m. and 1:00 p.m., and then decreasing to their lowest values of the day by 7:00 p.m. (Figure 1). Fluxes at midday were 20% higher than at 8:00 a.m. and 42% higher than at 7:00 p.m. The highest values of the day, however, were at 5:00 a.m., and were 16% higher than at midday. The reason for the higher fluxes at 5:00 a.m. is uncertain, given that N_2O fluxes generally increase with temperature, which also increased substantially during the day (Figure 1). Nitrous oxide emissions in biological ecosystems are affected by a number of variables that were not measured in this 1-day study (e.g., soil water content, soil N concentration, microbial activity, organic matter, pH) and could have impacted N_2O fluxes. The error bars indicate some uncertainty in the measurements as well, which was a result of high spatial variability that is typical in N_2O measurements. Measurements with more chambers would likely have reduced the inherent error resulting from spatial variability.

Irrigation increased N_2O emissions from perennial ryegrass and bermudagrass by 2 to 2.5 times within 1 to 2 hours (Figures 2 and 3). In bermudagrass, fluxes generally remained higher during the 2 days after irrigation (Figure 3). Diurnal trends in N_2O emissions were more evident in irrigated plots, and were amplified, compared with emissions from dry plots. This resulted in significantly higher fluxes in irrigated than in dry plots during midday, but not early and late in the day. Cumulative fluxes during the 2-day period were 1.5 times higher in irrigated (5.2 g ha^{-1}) than in non-irrigated (3.5 g ha^{-1}) bermudagrass.

Nitrogen fertilization in bermudagrass caused a 63-fold increase in N_2O emissions (i.e., from 9.4 to 588.1 ug m^{-2} h^{-1}) within 4 hours (Figure 4). Fluxes in non-fertilized plots also increased by 2.7 times (i.e., from 9.4 to 25.4 ug m^{-2} h^{-1}) during the 4-hour period, because of the post-fertilization irrigation applied to all plots. Emissions of N_2O remained significantly higher in fertilized than in unfertilized plots during the following 3 days. Cumulative fluxes during the 3-day period were more than 46 times higher in fertilized (157.9 g ha^{-1}) than in unfertilized (3.4 g ha^{-1}) plots.

Results indicated rapid responses of N_2O emissions to irrigation and N fertilization in cool- and warm-season turfgrasses. Irrigation increased N_2O fluxes by 2 to 2.7 times within 1 to 4 hours, and N fertilization increased N_2O emissions by up to 63 times within 4 hours. Diurnal patterns of N_2O fluxes were evident, although they did not always follow daily patterns of solar radiation and temperature. Further research is required to determine causes of differences in fluxes according to time of day.

ACKNOWLEDGEMENTS:

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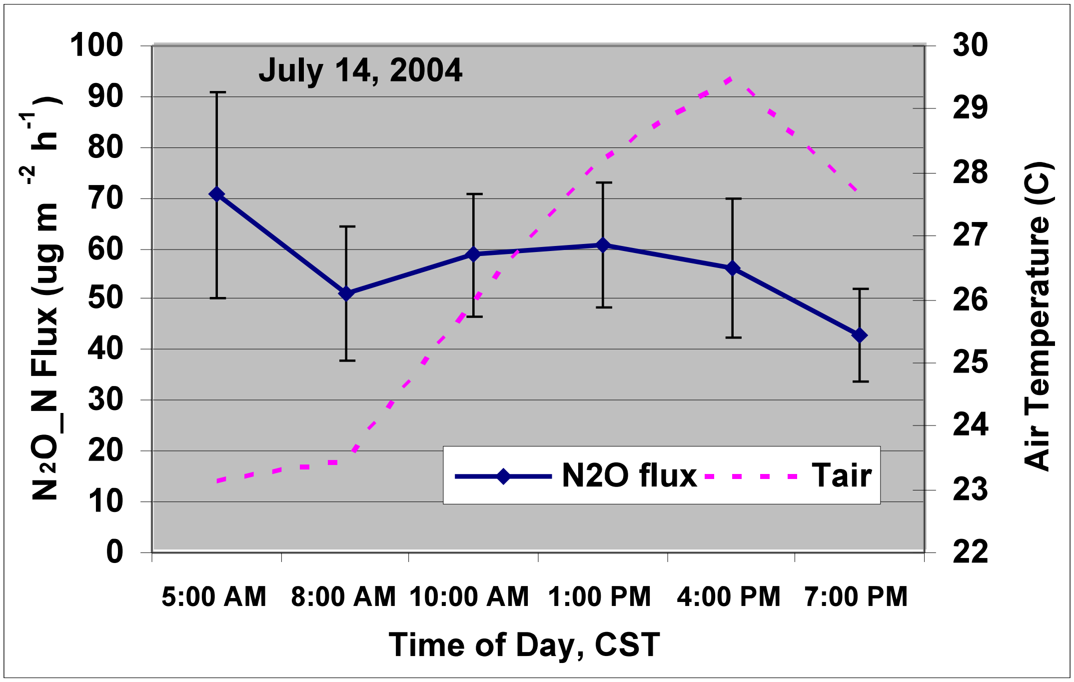

Figure 1. Diurnal pattern of nitrous oxide (N_2O-N) fluxes in perennial ryegrass and air temperature at 1.5 m between 5:00 am and 7:00 pm, CST.

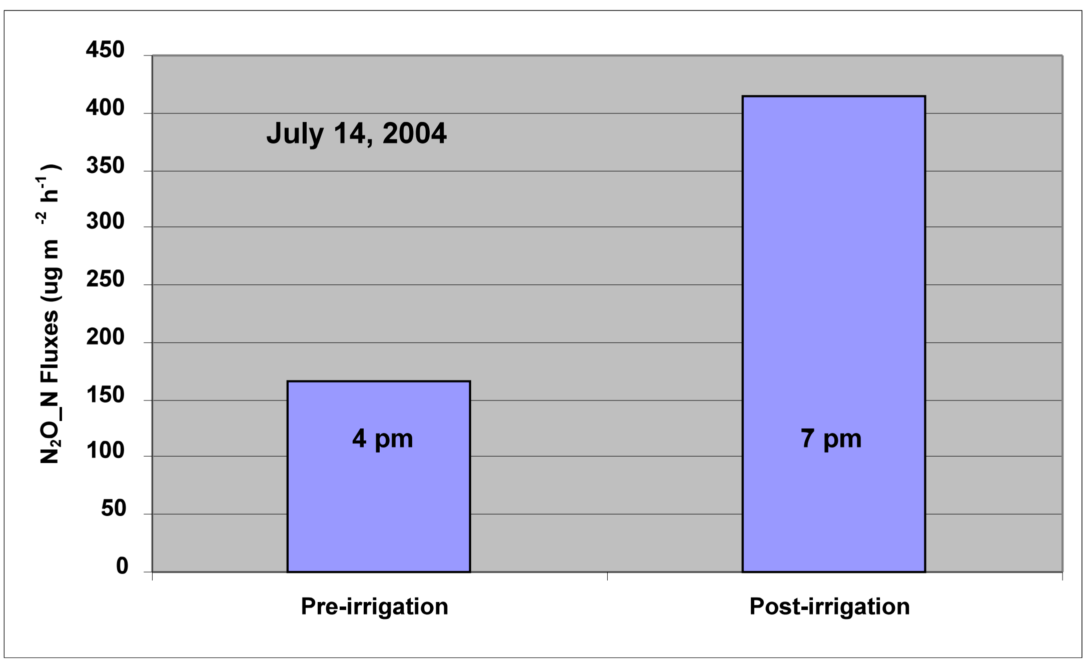

Figure 2. Fluxes of nitrous oxide (N_2O-N) at 4:00 p.m. (pre-irrigation) and 7:00 p.m. (post-irrigation) in perennial ryegrass plots; about 15 mm (0.60 inch) of irrigation was applied at 5 p.m. (CST).

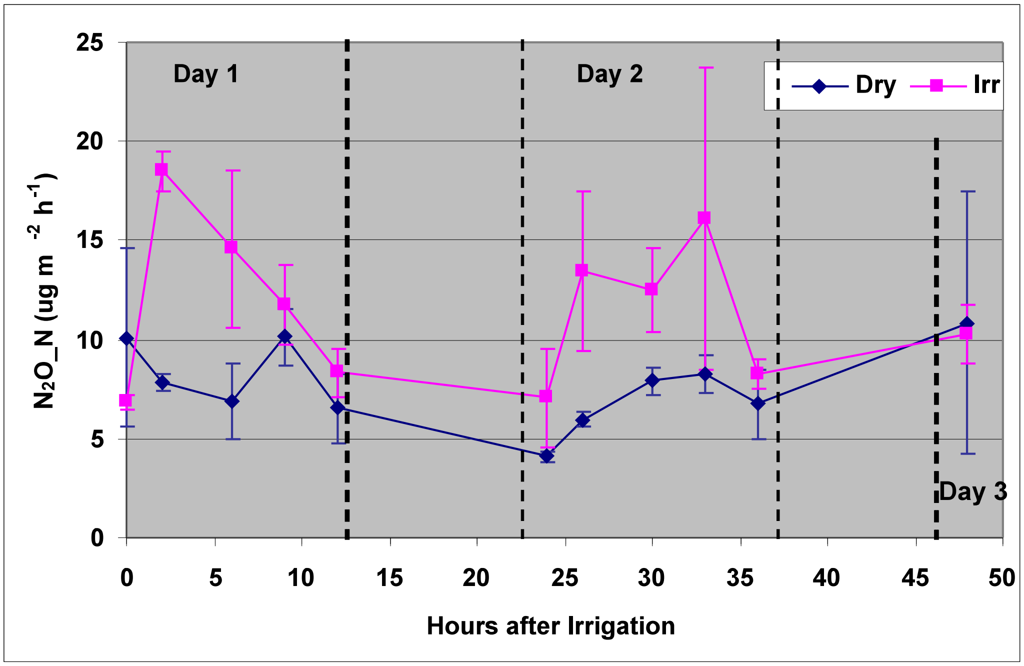

Figure 3. Fluxes of nitrous oxide (N_2O-N) in dry and wet plots of bermudagrass during a 48-hour period after irrigation (August 9 to 11, 2005). Vertical, dashed lines are placed at about 4:00 a.m. and 8:00 p.m. on each day to identify approximate time of day when measurements were collected.

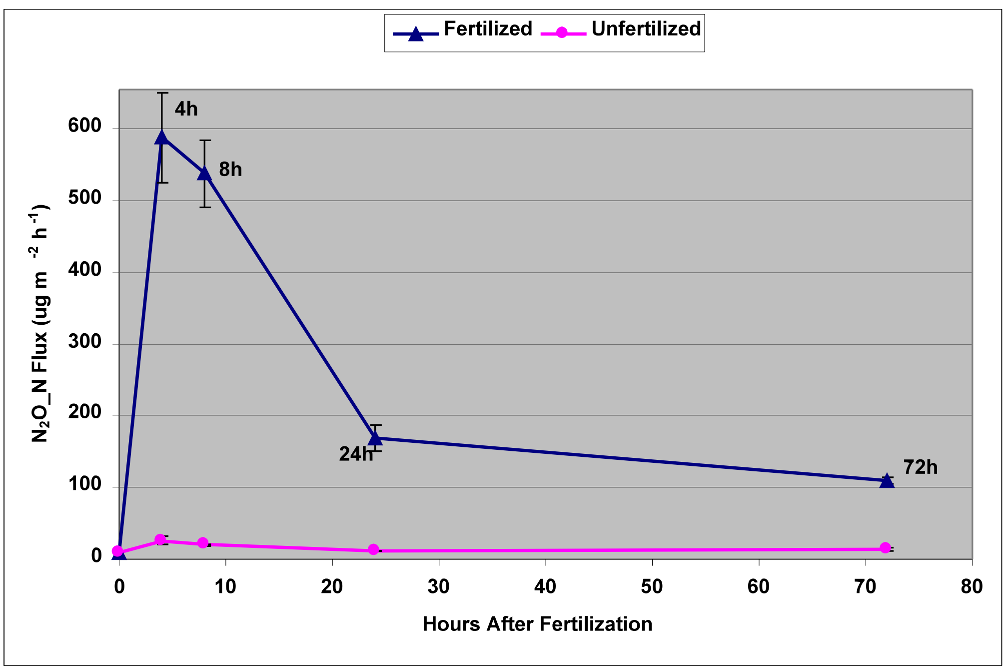

Figure 4. Fluxes of nitrous oxide (N_2O-N) in bermudagrass during a 72-hour period after fertilization with urea nitrogen (August 15 to 18, 2005). Initial measurements (0 h) were collected immediately before fertilization.