The Effects of Cultivation Practices and Fertilizer Use on the Mitigation of Greenhouse Gas Emissions from Kentucky Bluegrass Athletic Fields

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Abstract

Greenhouse gas emissions are known to contribute to global warming and thus climate change. The influence of cultural management practices need to be evaluated to determine the impact they have in contributing to greenhouse gas emissions. A two-year field study on a Kentucky bluegrass (*Poa pratensis*) football field evaluating cultivation practices (hollow tine aerification, verticutting, and control) and fertilizer use (221 kg N ha^{-1} yr^{-1} using Urea and 0 kg N ha^{-1} yr^{-1}) on greenhouse gas emissions. Samplings occurred weekly throughout the summer and fall of 2013-2014. Gas samples were taken using a vented closed gas chamber for 40 minutes following the USDA-ARS GRACEnet methods. Soil temperature, soil moisture, canopy greenness, and turfgrass quality were also collected. Cultivation practice was significant (p<.05) for 5 dates and fertilizer use was significant (p<.05) for 7 dates in 2013 where verticutting and the lack of urea decreased CO_2 emissions in 2013; similar results were observed in 2014. Cultivation practice was significant (p<.05) for only 4 dates during 2013-2014 for N_2O. Fertilizer use was significant (p<.05) all dates in 2014 where urea applications increased N_2O emissions. For CH_4, cultivation practice was not significant in 2013-2014. Fertilizer use was significant (p>.05) for only two dates in 2013 and four dates in 2014 where urea applications increased CH_4 emissions. For canopy greenness, cultivation practice was significant (p<.01) for all dates in 2013-2014 except for two dates in August 2013 and July 2014. The use of fertilizer was significant for all dates in 2013-2014 for canopy greenness except for one date. Fertilizer use significantly (p<.0001) increased turfgrass quality for all dates in 2013-2014. The results from this study will provide information about cultivation practices and fertilizer usage that minimize greenhouse gas emissions which can be utilized to evaluate the environmental efficacy of our current cultural management strategies.

Introduction

Greenhouse gas emissions from turfgrass has received attention recently, as their potent effects are known to contribute to climate change (BARTLETT and JAMES, 2011; BREMER, 2006; GROFFMAN et al., 2009; GU et al., 2015; KAYE et al., 2004; LI et al., 2013; MAGGIOTTO et al., 2000; TOWNSEND-SMALL and CZIMCZIK, 2010; ZHANG et al., 2013).

Research in this area has been primarily on GHG emissions from golf course turf since nutrient cycling on golf courses have the capacity to sequester GHG through the accumulation of soil organic carbon (QIAN and FOLLETT, 2002; MILESI et al., 2005). However, cultural management practices can offset sequestration by mitigating GHG emissions directly (fertilization) or indirectly (maintenance equipment) (BARTLETT and JAMES, 2011). Fertilizer application, irrigation, clipping management, and other turfgrass management practices have the potential to contribute to emissions and mitigation of greenhouse gases, leading to uncertainties in the net contribution of turfgrass ecosystems to climate change (ZHANG et al., 2013).

In sports turf management, aesthetics and player safety is extremely important. However, sports fields are extremely difficult to manage due to concentrated traffic on a regular basis. This intensity of use leads to thinning of the turf canopy decreasing turfgrass quality and increased soil compaction (CHRISTIANS, 2011). A variety of cultivation processes are used to loosen the soil and reduce compaction, to reduce thatch, or to groom the surface. These processes relieve compaction, allow better soil-oxygen penetration and encourage deep-rooting. Root function decreases under compaction due to the lack of oxygen needed for respiration and due to buildup of toxic gases such as carbon dioxide and methane which have the potential to impact climate change.

Therefore, the influence of cultivation practices need to be evaluated to determine the impact they have in contributing to GHG emissions (carbon dioxide [CO_2], methane [CH_4], and nitrous oxide [N_2O]) . A two-year field study was conducted on a Kentucky bluegrass (*Poa pratensis* L.) football field to evaluate cultivation practices (hollow tine aerification, verticutting, and control) and fertilizer use (221 kg N ha^{-1} yr^{-1} using Urea and 0 kg N ha^{-1} yr^{-1}) on GHG emissions.

Materials & Methods

- This two year field project (2013 & 2014) was located at the University of Minnesota Crookston football practice facility on Kentucky bluegrass (*Poa pratensis* L.) turf. The research area was set up as a split plot design with three cultivation regimes and two fertilizer regimes (Photo 5). Plot size was 1.5 m x 1.8 m and treatments were replicated four times.
  - HT - Hollow-tine aerification, September and May of each year, 0.10 m tines (Photo 1).
  - VC – Verticutting, September and May of each year, set on lowest setting, approximately 0.10 m depth (Photo 2).
  - CT – Untreated Control
- Plots were fertilized May through October with an annual nitrogen (N) rate of 221 kg N ha^{-1} yr^{-1}.
  - For May, September, and October, a rate of 49 kg N ha^{-1} was applied to each plot. For June, July, and August, 24.5 kg N ha^{-1} was applied to each plot.
  - Two fertilizer treatments: URE-Urea (46-0-0) & UNT-Untreated
  - Monthly applications were applied the first week of each month throughout the growing season.
- GHG sampling was initiated on 6/6/2013 and occurred weekly throughout the growing season (May-Oct) until 10/30/2014.
  - At each sampling date, gas samples were taken using a vented closed gas chamber that was placed over the plots for 40 minutes following the United States Department of Agriculture-Agricultural Research Service Greenhouse gas Reduction through Agricultural Carbon Enhancement network (USDA-ARS GRACEnet) methods (FOLLETT, 2010).
  - Samples were taken from the same location throughout the summer as the anchors for the gas chambers were tamped into the ground flush with the soil surface at the beginning of the season (Photo 3 & 4).
  - To ensure a good seal, the tops of the gas chambers were also tapped in after they were placed over the anchors (Photo 6).
  - Gas samples were taken at 0, 20, and 40 minutes post closure of the chamber (Photo 7). This method allows gas concentrations to build up inside of the chamber, and a flux rate of the gases from the surface to be calculated based on the change in concentration over time.
- At each sampling date air temperature, soil temperature, soil moisture, turfgrass quality and canopy greenness data were collected.
  - Turfgrass quality was on a visual rating of 1 to 9 where 1=bare soil, 6=minimally acceptable, 9=optimum uniformity, density, and greenness.
  - Canopy greenness was assessed using a CM 1000 (NDVI Meter; Spectrum Technologies) chlorophyll meter.

Photos

Photo 1: For the aerification treatment, plots were aerified each September and May. Photo 2: For the verticutting treatment, plots were also verticutted each September and May. Photo 3: At the beginning of the study, anchors were tamped into the soil surface to create a good seal with the greenhouse gas chambers on sampling days. Photo 4: Anchor tamped into the soil surface of an aerification plot.

Results

- For CO_2, cultivation practice was significant (p<.05) for 5 dates and fertilizer use was significant (p<.05) for 7 dates in 2013. Cultivation practice was also significant (p<.05) for 10 dates and fertilizer use was significant (p<.05) for 8 dates in 2014. In both years of the study, verticutting and the lack of urea decreased CO_2 emissions (Figure 1).
- Cultivation practice was significant (p<.05) for only 4 dates during 2013-2014 for N_2O where hollow-tine aerification increased N_2O emissions. Fertilizer use was significant (p<.05) only for 2 dates in 2013 and all dates from May through September in 2014 where urea applications increased N_2O emissions (Figure 2).
- For CH_4, cultivation practice was significant (p<.05) for only two dates from 2013-2014. Fertilizer use was significant (p>.05) for only two dates in 2013 and four dates in 2014 where urea applications increased CH_4 emissions.
- For canopy greenness, cultivation practice was significant (p<.01) for all dates in 2013-2014 except for two dates in August 2013 and July 2014. The use of fertilizer was significant for all dates in 2013-2014 for canopy greenness except for one date. The plots that were aerified and fertilized had the highest NDVI values in 2013. In 2014, the plots that had no cultivation practice implemented but were fertilized followed a similar trend as the plots that had been aerified and fertilized (Figure 3).
- Fertilizer use significantly (p<.0001) increased turfgrass quality for all dates in 2013-2014. Verticutting at the lowest setting (approximately 0.10 m) decreased overall turfgrass quality after the cultivation practice was implemented and was slower to recover in 2013. Turfgrass quality was the highest for the cultivation + fertilizer treatments (Figure 4).

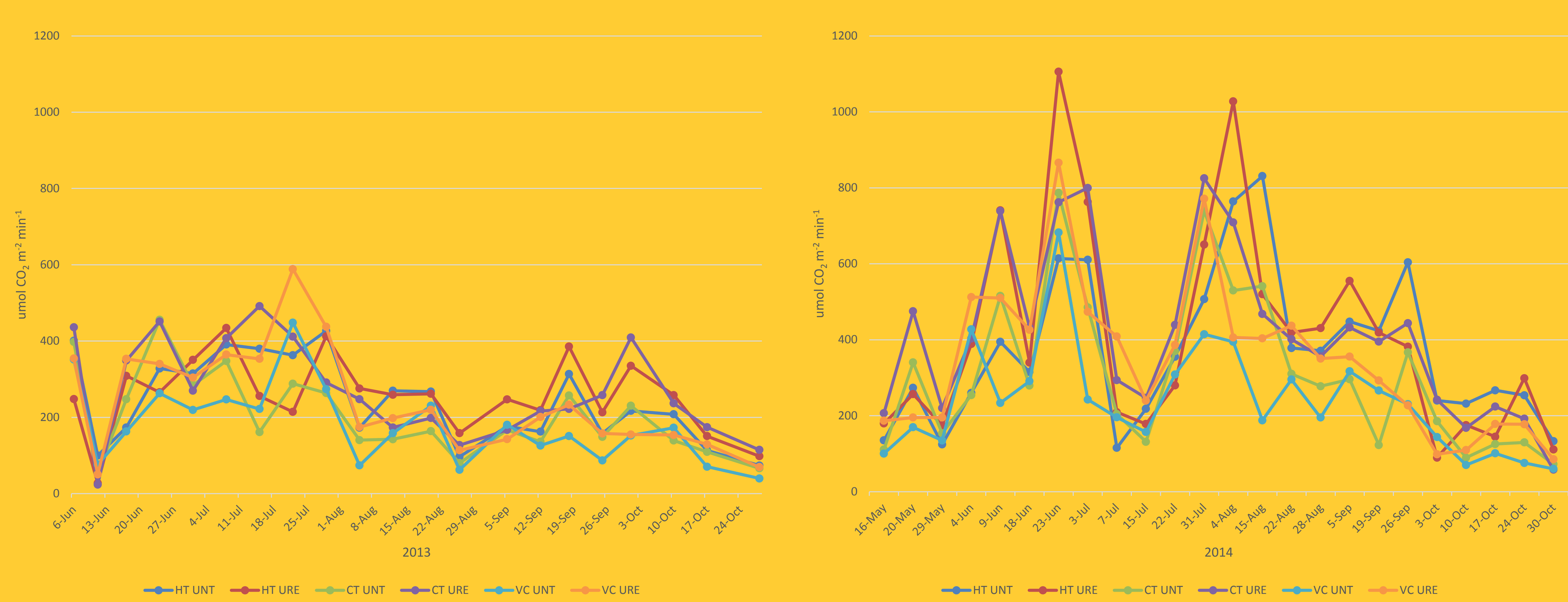

Figure 1. CO_2 flux by cultivation and fertilizer treatment during the 2013 and 2014 growing period (HT UNT=Hollow-tine aerification, Untreated fertilizer; HT URE= Hollow-tine aerification, Urea fertilizer; CT UNT= Cultivation control, Untreated fertilizer; CT URE= Cultivation control, Urea fertilizer; VC UNT=Verticutting, Untreated fertilizer; VC URE= Verticutting, Urea fertilizer).

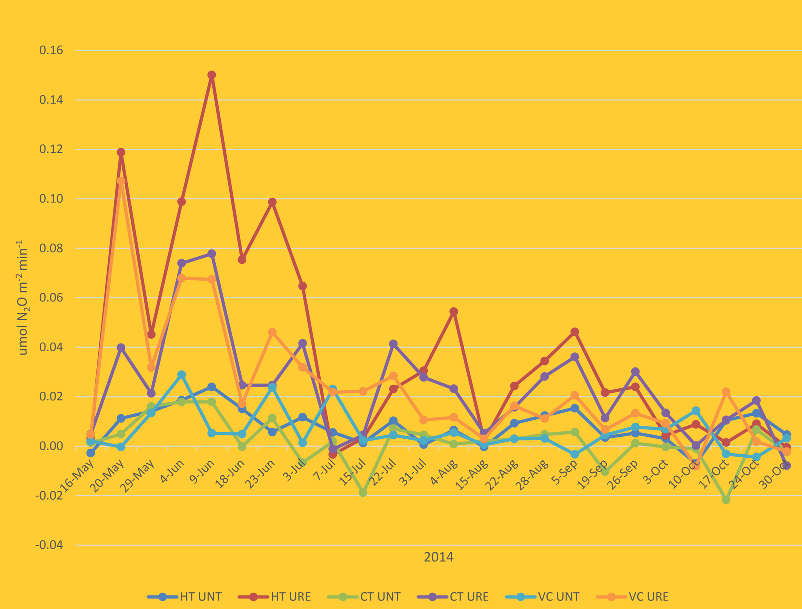

Figure 2. N_2O flux by cultivation and fertilizer treatment for the 2014 growing period (HT UNT=Hollow-tine aerification, Untreated fertilizer; HT URE= Hollow-tine aerification, Urea fertilizer; CT UNT= Cultivation control, Untreated fertilizer; CT URE= Cultivation control, Urea fertilizer; VC UNT=Verticutting, Untreated fertilizer; VC URE= Verticutting, Urea fertilizer

Photo 5: There were three cultivation regimes divided into three split plots, verticutting, untreated control, & hollow-tine aerification. Photo 5: Prior to sampling for greenhouse gases, the gas chambers were tamped onto the anchors to create a good seal. Photo 7: Gas samples were taken at 0, 20, and 40 minutes post closure of the gas chamber and anchor.

Figure 3: Canopy greenness (NDVI) for all cultivation and fertilizer regimes in 2013 and 2014 (HT UNT=Hollow-tine aerification, Untreated fertilizer; HT URE= Hollow-tine aerification, Urea fertilizer; CT UNT= Cultivation control, Untreated fertilizer; CT URE= Cultivation control, Urea fertilizer; VC UNT=Verticutting, Untreated fertilizer; VC URE= Verticutting, Urea fertilizer).

Figure 4: Turfgrass quality (1-9 Visual Scale; 9=Best, 6=Acceptable, 1=Worst) for all cultivation and fertilizer regimes in 2013 and 2014 (HT UNT=Hollow-tine aerification, Untreated fertilizer; HT URE= Hollow-tine aerification, Urea fertilizer; CT UNT= Cultivation control, Untreated fertilizer; CT URE= Cultivation control, Urea fertilizer; VC UNT=Verticutting, Untreated fertilizer; VC URE= Verticutting, Urea fertilizer).

Conclusions

The results from this study can provide information about cultivation practices and fertilizer usage that minimize greenhouse gas emissions which can be utilized to evaluate the environmental efficacy of our current cultural management strategies.

- Fertilizer use increased canopy greenness and overall turfgrass quality. Urea applications throughout the growing period also increased greenhouse gas emissions. To decrease greenhouse gas flux, slow-release fertilizers should be applied such as Milorganite (See Golf Course Greenhouse Gas Project).
- Greenhouse gas emissions were higher for the plots that were aerified (Hollow-tine). Verticutting even at the lowest setting reduced greenhouse gas flux throughout the growing season especially for CO_2 and N_2O.
- Future research should include the frequency of cultivation and the different types of cultivation on the influence of greenhouse gas emissions.

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