POLYMER COATED UREA: IMPACTS ON WATER/AIR QUALITY WITH SURFACE APPLICATON TO PERMANENT SOD

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ABSTRACT

Nitrogen (N) is the most commonly used fertilizer and is essential to sustain the world's populations. However, inherent inefficiencies in the soil-plant system result in losses of N to air and water, which can result in environmental quality problems. Two permanent sod turfgrass sites were fertilized with coated and uncoated urea and compared to an unfertilized control at 224 lb-N/ac. The polymer coated urea (PCU) was Duration 45 CR®. Fertilization resulted in increased growth and verdure in approximately equal fashion with both fertilizer products. However, the urea resulted in significantly greater NH_3 and N_2O gaseous losses during various times of the study and PCU generally did not. There were trends for increased NO_3^- leaching with urea over PCU and the unfertilized control, although this was not significant. Duration 45 CR® is a potentially valuable N fertilizer source that can meet both the agronomic and environmental demands society is striving for with new generation fertilizers.

INTRODUCTION

Nitrogen (N) is an essential plant nutrient and a common pollutant in the atmosphere and surface and groundwater. Increasing nitrogen use efficiency (NUE) from N applied as fertilizer can improve plant health and vigor while mitigating losses to the environment (Hopkins et al., 2008). Most of the work done to investigate anthropogenic inputs to the environment from fertilization has been performed in intensive agricultural systems (maize, wheat, and rice), and much less in grass systems (Bremer, 2006, Knight et al., 2007) despite N fertilizers having a large role in the turfgrass and permanent sod markets.

Nitrogen may be lost from fertilized soil systems as it is evolved as ammonia or nitrous oxide. Atmospheric ammonia is an environmental concern as it is more likely to deposit on land (through wet or dry deposition) than other forms of anthropogenic N. Deposition of this atmospheric ammonia to sensitive ecosystems can lead to soil acidification and surface water eutrophication. Additions of N in certain ecosystems can also lead to plant community loss (Sutton et al., 2008). Fenn et al. (1998) related that increased N availability due to NH_3 deposition in typically N-limited terrestrial, freshwater, and marine ecosystems across the globe is having unwanted and adverse consequences including increased aluminum mobility and forest decline.

On average, 1% of all nitrogen applied as fertilizer in inorganic forms is emitted as N_2O, and the actual amount lost is directly related to the type, quantity, and method of application of that fertilizer (GHG Working Group, 2010). Hirsch et al. (2006) related that emissions of N_2O have increased by approximately 50% over pre-industrial levels due to anthropogenic causes. Although agriculture generates less than 10% of the total anthropogenic greenhouse gas emissions in the United States, it is estimated that agricultural nitrous oxide emissions account for 78% of the total annual anthropogenic N_2O losses (USEPA, 2007). Nitrous oxide is a potent greenhouse gas, with a global warming potential 296 times that of CO_2 per unit. Long-lived in the atmosphere (up to 150 years), N_2O catalystically destroys ozone in the troposphere. Emissions via denitrification and nitrification are controlled by many interacting factors which complicate understanding the issue. Soil aeration, temperature, texture, ammonium concentration, nitrate concentration, as well as microbial community factors, all affect the rate of soil N_2O production (Snyder et al., 2007).

Nitrate can be easily leached due to its negative ionic charge and enter surface and ground waters. In addition to the decrease in plant available N that results, excess NO_3^- in watersheds can lead to toxicological problems (Mulvaney et al., 2009) such as eutrophication (large algal blooms which can lead to anoxic conditions), and drinking water contamination. Drinking water contaminated with NO_3^- can cause methemoglobinemia (blue baby syndrome) in young animals and human babies (Olson et al., 2009), and may react with free amines to form carcinogenic nitrosamines. Nitrate in watersheds can lead to nitrate-induced toxic effects on freshwater biota, disruption of nutrient cycling, and eutrophication of water bodies (Fenn et al., 1998).

By controlling the release of N from fertilizer into the soil, it is hypothesized that N inefficiencies and losses to the environment will be mitigated. Controlled-release N (CRN) and slow-release N (SRN) sources are fertilizers that release N into the soil over an extended period of time, ideally matching plant need, possibly reducing or eliminating labor-intensive and costly in-season N applications and increasing NUE and environmental quality (Hopkins et al., 2008). The concept of CRN and SRN fertilizer materials is not new, but success varied widely across plant species and environmental conditions, and expense prevented wide utilization (Hopkins et al., 2008).

Polymer-coated urea (PCU) fertilizer is one promising type of CRN that can potentially provide improved N-release timing. Soil temperature controls N release rate and simultaneously influences plant growth and nutrient demand (Hopkins et al., 2008). Diffusion is driven by the concentration gradient—temperature being the primary regulator under irrigated conditions. PCU has been shown to steadily supply the plant with N for longer periods of time following fertilizer application, leading to increased crop yield and quality (Blythe et al., 2002, Cahill et al., 2010, Knight et al., 2007, Miltner et al., 2004, Worthington et al., 2007), due to enhanced NUE (Wilson et al., 2010, Hutchinson et al., 2003, Hopkins et al., 2008, Patil et al., 2010). Hyatt et al. (2010) showed that the slower release of PCU can improve economics by eliminating additional in-season N applications. Research has also demonstrated PCU's ability to mitigate negative environmental impacts associated with N fertilizer (Halverson et al., 2010, Pack et al., 2006, Wilson et al., 2010).

Nitrate leaching has been shown to be significantly decreased by using PCU under some environmental conditions (Du et al., 2006, Guillard and Kopp, 2004, Nelson et al., 2009, Pack et al., 2006, Wilson et al., 2010). Ammonia volatilization can also be reduced using PCU (Knight et al., 2007, Pereira et al., 2009, Rochette et al., 2009). With the impending introduction of new air quality regulations, N_2O emissions have received a large amount of attention. PCU has been shown to reduce N_2O emissions under some conditions (Cao et al., 2006, Halverson et al., 2008, Halverson et al., 2010, Hyatt et al., 2010), yet some have reported no difference or even substantial increases when compared to soluble forms of N (Jassal et al., 2008, Jiang et al., 2010).

In this study, we tested the following hypotheses: 1) N gas evolution (as NH_3 and N_2O) from turfgrass will be significantly decreased by using PCU compared to urea as the N fertilizer source, 2) loss of N from turfgrass to the groundwater as NO_3^- may be mitigated by using PCU as opposed to urea, and 3) N levels in plant tissue may be higher in those areas treated with urea, although the plots receiving PCU as an N-fertilizer source will have adequate N in the tissue.

METHODS

Two field studies were conducted on Kentucky bluegrass (KBG). Site 1 in Provo, Utah, USA is used as a sports turf sod farm for Brigham Young University (BYU) with constructed sand soil (0.5% OM, 7.2 pH). Site 2 near Spanish Fork, Utah, USA is a turf area grown under a weather station at BYU's experimental farm (4.0% OM, 7.8 pH). At each site, 18 plots (1 m x 3 m each) were established in a RCBD with three treatments and six replicates. Treatments included an untreated check, urea at a conventional application rate of 224 lb-N/ac and polymer coated urea (Duration 45 CR®, Agrium) at the same rate.

Treatments were surface applied. Best management practices for growing turfgrass were generally used at both sites. At site 2, the plots received a small amount of irrigation (0.3 inches) immediately following application to incorporate fertilizer. At site 1, a higher rate (0.5 inches) was applied, but not until the following day after application. Soil volumetric water content was monitored using Watermark Soil Moisture Sensors (Spectrum Technologies, Plainfield, Illinois, USA) and logged using an AM400 soil moisture data logger (MK Hansen, Wenatchee, Washington, USA). Soil temperature was monitored and logged using the same data logger. At site 2, wind speed and direction and precipitation were monitored by an on-site weather station.

To measure NH_3 volatilization, modified passive flux collection devices were installed near the center of each plot (Woods et al., 2000). Passive flux samplers were vertically oriented (to minimize cross plot gas contamination) 15 cm above the plant interface. Each sampler consisted of a glass tube (0.7 cm inside diameter x 10 cm length), with the interior coated with 3% oxalic acid in acetic acid to readily react with and collect NH_3 from the air that flowed through the tube. Flux samplers were replaced daily for the first two days, then every three or four days for 21days until volatilization levels return to normal, and then weekly thereafter. When collected for analysis, samplers were capped to eliminate contamination. Flux samplers were then extracted for NH3 by adding 1 ml of deionized water, recapping with septa stoppers and shaken vigorously for 10 minutes. Extracts were then diluted with 2 ml of deionized water and analyzed for NH_4^+ using the automated cadmium reduction method (Mulvaney et al., 1996). Statistical evaluation of the NH_3 data resulted in a significant interaction between fertilizer source and time and, therefore, each sampling date was evaluated separately.

Nitrous oxide flux from the soil-surface was measured by installing a vented poly-vinyl chloride (PVC) static (18 cm x 28 cm) chamber on each plot. PVC collars fitted with rubber gaskets were permanently installed in each plot to a depth of 6-8 cm into the soil. When sampling, the chambers were installed into the collars and sealed with the rubber gaskets. Samples were taken three days a week for the first three to four weeks following application, and once or twice a week thereafter. Samples were taken through a septum on top of the chamber with a 10-ml glass syringe fitted with a black rubber stopper at intervals of 15, 30, and 60 minutes after installing the chamber. Samples were immediately taken to the lab and analyzed with a gas chromatograph coupled with an electron capture detector (Agilent 6890N, Agilent Technologies, Santa Clara, California, USA; Venterea et al., 2009). All samples were generally analyzed within 4-6 h following sampling and no later than 8 h. As with NH_3, the N_2O data resulted in a significant interaction between fertilizer source and time and, therefore, each sampling date was evaluated separately.

Root and shoot samples were taken and analyzed for total N as previously described.

Suction lysimeters (24” 1900 Series, Soil Moisture Corp., Goleta, CA) were installed in three blocks at each site with a 30° angle to a depth of 8-10”. Leachate was collected and NO_3-N concentrations were determined using an automated analyzer as previously described. Residual soil NO_3^- N samples were taken at 0-12” and 12-24” depths and concentrations were analyzed as described above.

RESULTS AND DISCUSSION

Urea resulted in significantly higher NH_3 volatilization than both the PCU and the unfertilized check through the first few days after fertilization for both sites evaluated (Figure 1). Urea fertilization also showed a significant increase in volatilization for the last sampling date at Site 1, although this was the same for PCU. The PCU fertilizer never resulted in more NH_3 loss than urea and only resulted in a significant increase over the unfertilized control during the last sampling date for Site 1. We correctly assumed that urea would have high volatilization losses at the beginning of the study, but we also speculated that PCU on the surface of the soil throughout the course of the study may result in significant total losses—since this controlled release urea was steadily discharging throughout the 45 day trial, including during times in which water was not being applied to water it into the soil. However, it is apparent that this concern was not valid in these studies and, we assume, that the NH_3 formed from urea occurred inside of the coating when water was absorbed. This NH_3 then converted to NH_4^+, which was eventually secreted through the polymer coating and absorbed by the soil, with only a small portion being lost to the atmosphere.

The evolution of N_2O gas was somewhat similar as the NH_3 volatilization. At Site 1, the second and third sampling dates showed uncoated urea resulted in significantly greater N_2O loss than both PCU and the unfertilized control (Figure 2). This difference temporarily dissipated, but then losses spiked again during the sixth through eighth sampling dates—although the increase was only significantly greater than the unfertilized control and not PCU. The PCU treatment had significantly greater N_2O losses than the unfertilized control during two sampling dates (sixth and eighth), but never greater than the uncoated urea treatment. As with NH_3, losses of N_2O were seemingly lower at Site 2 as compared to Site 1, with urea having significantly greater losses than PCU during one sampling date (seventh) and greater than the unfertilized control at one data (eighth). Again, we somewhat expected that uncoated urea would have higher N_2O losses initially, but that PCU would have relatively higher losses later in the trial as it N was released later and at the surface. However, this result did not occur, with PCU showing decreased N_2O losses during various periods of this trial.

Although there trends for higher NO_3^- leaching with the urea over PCU and the unfertilized control, these results were not statistically significant (data not shown).

As expected, the KBG had better verdure and increased growth with fertilization, with no perceived growth differences between urea and PCU (data not shown). Both fertilized treatments resulted in significantly greater tissue N concentrations shortly after fertilization, although the increase was greater for urea over PCU—with these differences mostly disappearing by the end of the 45 day trial.

SUMMARY

Polymer coated urea in the form of Agrium’s Duration 45 CR® resulted in similar visual response and growth response as compared to uncoated urea and yet resulted in less loss of NH_3 and N_2O gases. This reduced gaseous loss of N could have significant impacts on greenhouse gas and reactive N concentrations in the atmosphere if widely adopted and promoted. Impacts on water quality are also likely—as reported by other researchers, although reductions in NO_3^- leaching were not measured in this study. Further work needs to be done to assess cumulative N_2O emissions, as well as evaluation under other environmental conditions and with longer release PCU products.

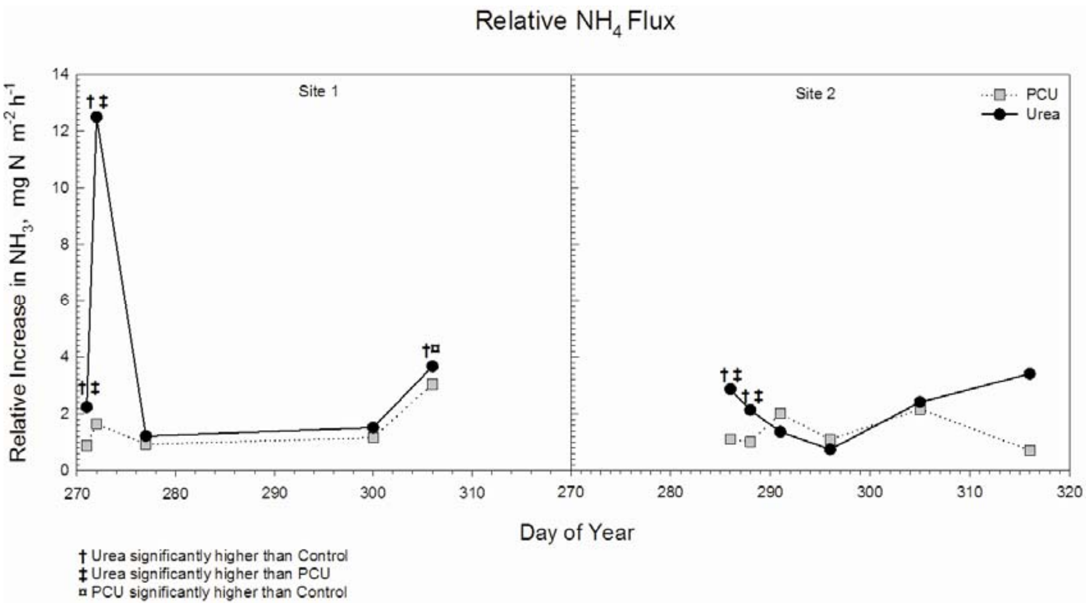

Figure 1. Cummulative ammonia (NH_3) gas volatilization as determined by passive flux cumulative sampling technique for two studies with urea fertilizer applied to turf using uncoated (urea) or coated (PCU-polymer coated urea; Duration 45 CR®) at two sites in Utah in 2010. Results shown are relative to an unfertilized control.

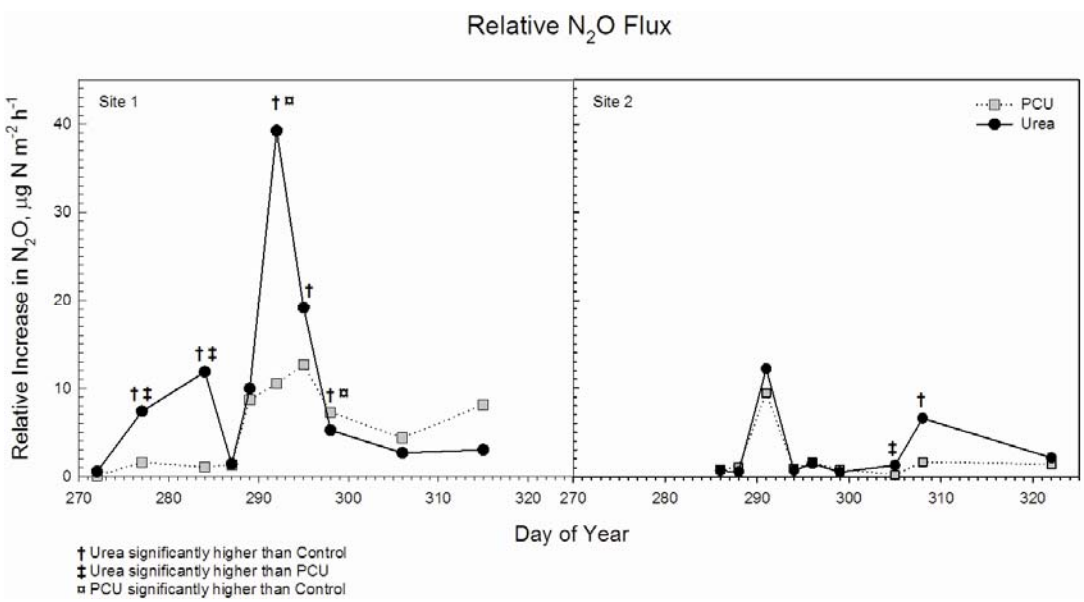

Figure 2. Point in time nitrous oxide (N_2O) gas evolution for two studies with urea fertilizer applied to turf using uncoated (urea) or coated (PCU-polymer coated urea; Duration 45 CR®) at two sites in Utah in 2010. Results shown are relative to an unfertilized control.

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