The Effects of Fertilizer Sources on the Mitigation of Greenhouse Gas Emissions from Creeping Bentgrass Greens and Kentucky Bluegrass Roughs

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Abstract

The purpose of this project was to determine the impact cultural management strategies have on greenhouse gas emissions which are known to contribute to global climate change. A two year field study evaluating fertilizer source (Urea, Encapsulated Polyon, and Milorganite), turfgrass species (*Agrostis stolonifera* and *Poa pratensis*), and site location (soil moisture regime) on greenhouse gas (carbon dioxide [CO_2], methane [CH_4], and nitrous oxide [N_2O]) 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. Site location was significant ($p<.0001$) for canopy greenness in 2013-2014 except for two dates in September 2013 following fertilization. Canopy greenness was significantly higher for Milorganite on roughs and higher for Urea on greens. Turfgrass quality was significantly higher for Polyon and Urea on greens and Milorganite and Urea on roughs. Results from 2013 indicate higher CO_2 emissions ($p<0.1$) on the green than on the roughs, while in 2014 the dry rough had significantly ($p<0.05$) higher emissions than the green. Methane (CH_4) emissions were significantly ($p<0.05$) higher in the control than for Polyon across sites in 2013. In 2014, Milorganite had significantly higher methane emissions than Polyon and Urea on two sampling dates. In both years, site location showed significant ($p<0.001$) influence on N_2O emissions; treatment effects were not significant. The dry rough showed significantly higher N_2O emissions than the other two sites. Soil temperature and soil moisture were significant predictors of CO_2 and N_2O emissions in 2013, with only CO_2 showing significant trends in 2014. Future research should focus on identifying water conservation practices that will decrease greenhouse gas emissions while maintaining adequate soil moisture needed for plant health and turfgrass quality.

Introduction

The concentration of carbon dioxide (CO_2) in the atmosphere is increasing at an unprecedented rate, due primarily to fossil fuel burning and land use change. The increased awareness of this global problem has led to increased pressure by society to minimize the impacts of elevated atmospheric concentrations of greenhouse gases (GHG).

Nutrient cycling on golf courses has 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, 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). Fertilization of turfgrass has been shown to increase soil nitrous oxide (N_2O) emissions ranging from 0.5 to 6.4 kg N ha^{-1} yr^{-1} (GUILBAULT and MATTHIAS, 1998; KAYE et al., 2004; BREMER, 2006; GROFFMAN et al., 2009; LIVESLEY et al., 2010; TOWNSEND-SMALL and CZIMCZIK, 2010; ZHANG et al., 2013). MAGGIOTTO et al. (2000) found that urea-based fertilizers minimized N_2O emissions and indicated that long-term effects of slow-release urea based fertilizers still need to be studied.

Choice of fertilizer release (fast versus slow release) and mechanism of fertilizer break-down needs to be considered as a method for mitigating GHG emissions. Therefore, the purpose of this project was to determine the impact of fertilizer source (Urea, Encapsulated Polyon, and Milorganite), turfgrass species (*Agrostis stolonifera* L. and *Poa pratensis* L.), and site location (soil moisture regime) have on GHG (carbon dioxide [CO_2], methane [CH_4], and nitrous oxide [N_2O]) emissions and overall turfgrass quality.

Materials & Methods

- This two year field project was located at Lincoln Park Golf Course in Grand Forks, North Dakota. Three sites were selected based on cultural intensity, turfgrass species, and soil moisture regime. Plot size was 0.61 m x 0.61 m and treatments were replicated four times.
    - Site 1 - Creeping bentgrass (*Agrostis stolonifera* L.) practice putting green consisting of a sand-based root zone.
    - Site 2 - Kentucky bluegrass (*Poa pratensis* L.) rough with low soil moisture.
    - Site 3 - Kentucky bluegrass (*Poa pratensis* L.) rough with high soil moisture.
- 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.
    - Three sources of fertilizer were used: Urea (46-0-0), Encapsulated Polyon (30-0-15), and Milorganite (5-2-0). Urea is a fast-release N source whereas both Encapsulated Polyon and Milorganite are slow-release N sources. Milorganite is a natural organic fertilizer.
    - Monthly applications were applied the first week of each month throughout the growing season.
- GHG sampling was initiated on 6/5/2013 and occurred weekly throughout the growing period (May-Oct) until 10/23/2014.
    - 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 1 & 2).
    - To ensure a good seal, the tops of the gas chambers were also tapped in after they were placed over the anchors (Photo 3).
    - Gas samples were taken at 0, 20, and 40 minutes post closure of the chamber (Photo 4). 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: Anchors for each plot were tamped into the soil at the beginning of the study to provide a base for the gas chambers. Photo 2: Plot layout of the putting green with anchors installed into the turf root zone. Photo 3: Prior to sampling for greenhouse gases, the gas chambers were tamped onto the anchors to create a good seal. Photo 4: Gas samples were taken at 0, 20, and 40 minutes post closure of the gas chamber and anchor.

2013 Results

- Results show a trend indicating higher CO_2 emissions on the green and wet rough than on the dry rough. For the green, there were four dates that showed statistical differences between treatments (Figure 1a & Figure 3). Milorganite had significantly higher flux than Polyon and Urea on July 17. On August 7, all fertilized treatments showed significantly higher flux than the unfertilized treatments. Milorganite also showed significantly higher flux than Polyon on August 27. Urea and the Polyon had significantly higher emissions than the other treatments on September 4. Similarly, on the wet rough there were seven dates showing statistically significant differences (Figure 1b & Figure 3). Polyon had the highest CO_2 emissions on 5 sampling dates, and was significantly higher than at least one other treatment on those dates (7/3, 8/14, 9/4, 9/14, and 10/17). On three of the sampling dates (9/4, 9/26, 10/17) urea was either not statistically different from the highest flux rate or was the highest flux rate. Milorganite had significantly higher emissions than Polyon on August 21.
- Methane (CH_4) emissions were not significantly different between treatments for any of the site locations.
- Nitrous oxide (N_2O) emissions was highest for the wet rough site location where Polyon had a higher emission rate than the other treatments on July 24 and August 21 (Figure 2 & Figure 3).
- Soil temperature and soil moisture were found to be significant predictors of CO_2 and N_2O emissions (Figure 4).
- Site location was significant for canopy greenness on all sampling dates in 2013 except for two dates in September following fertilization (Figure 5).
- Fertilizer source was significant on four of the sampling dates where turfgrass quality was significantly higher for the Milorganite and Urea treatments compared to the control (Figure 6).

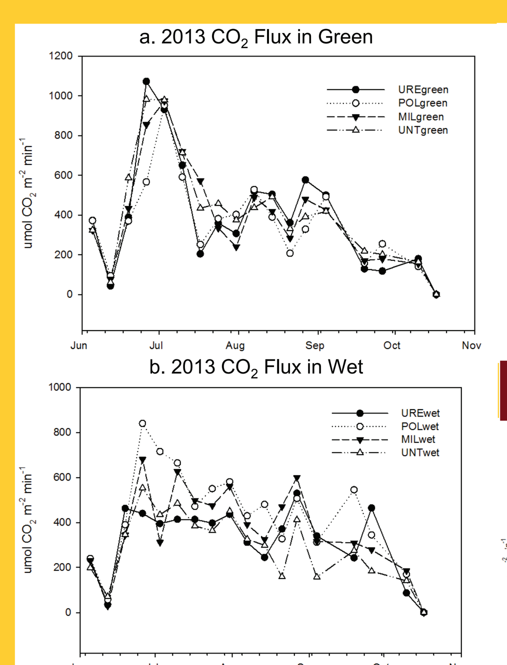

Figure 1. a) CO_2 flux by fertilizer treatment for the green during the 2013 growing period. b) CO_2 flux by fertilizer treatment for the wet rough during the 2013 growing period. (URE=Urea, POL=Polyon, MIL=Milorganite & UNT=Untreated control).

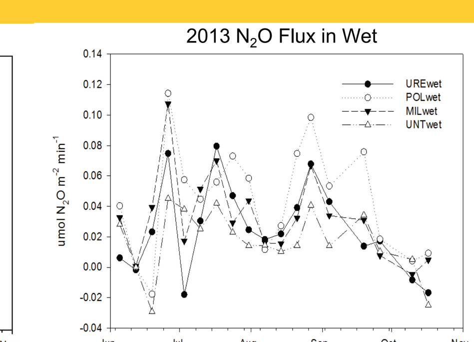

Figure 2. N_2O flux by fertilizer treatment for the wet rough during the 2013 growing period. (URE=Urea, POL=Polyon, MIL=Milorganite & UNT=Untreated control).

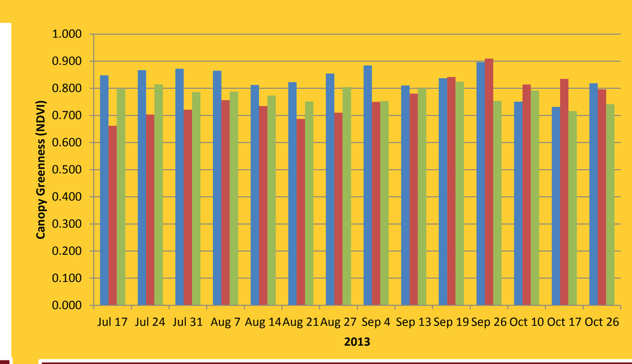

Figure 5: Canopy greenness (NDVI) by turfgrass area in 2013 (WRO=Wet Rough, DRO=Dry Rough, GRE=Green) in 2013.

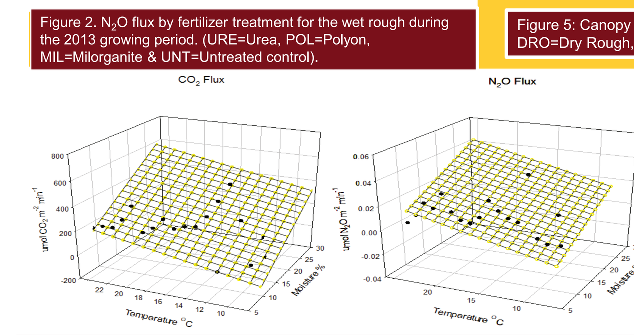

Figure 4. Soil temperature and soil moisture plotted against soil CO_2 and N_2O flux. The black dots represents the data points and the matrix represents the model generated using SAS to explain 99.99% of the data. CO_2 = [(0.09201)*temperature + (0.05011) moisture + 1.29697]^4; N_2O = [(-0.000316)*temperature + (-0.0002943) moisture + 0.13343]^(-1/3) – 2.

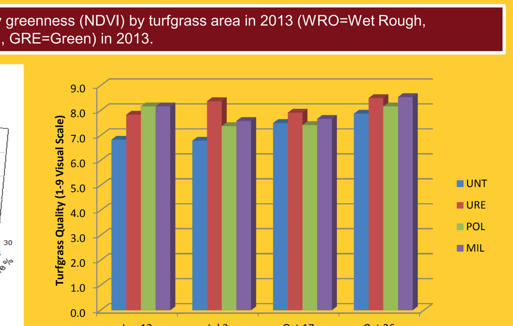

Figure 6: Turfgrass quality (1-9 visual scale; 9=Best, 6=Acceptable, 1=Worst) for all site locations by fertilizer treatment (UNT=Untreated, URE=Urea, POL=Polyon, MIL=Milorganite) in 2013.

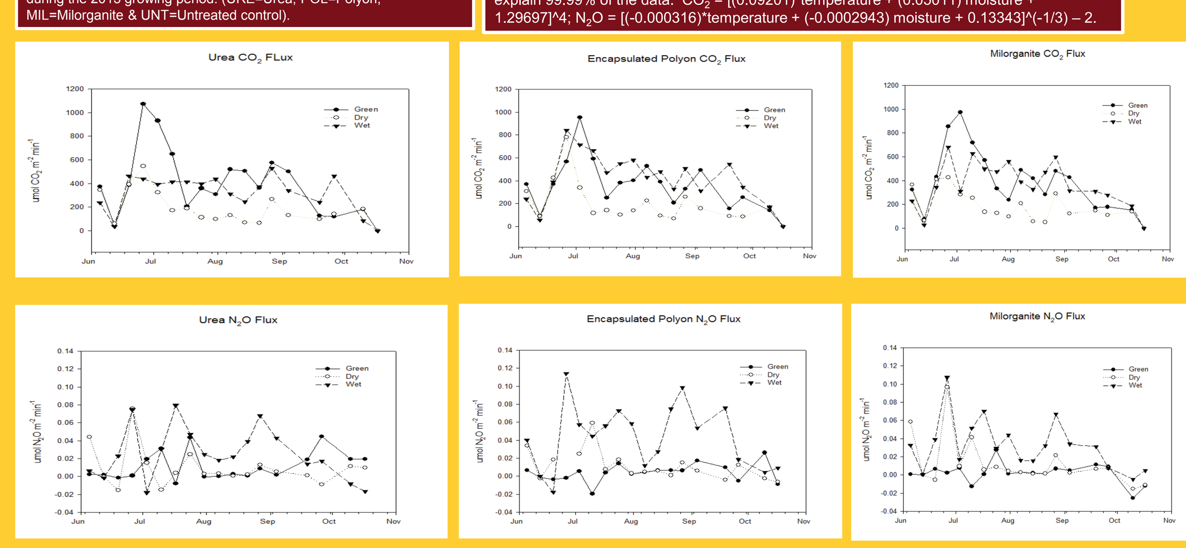

Figure 3. The three fertilizer sources and the impact each had on soil CO_2 and N_2O flux by location. The largest separations noted are between the wet and dry treatments; although the green behaved similarly to the wet site for the CO_2 flux and the dry site for the N_2O flux.

Photo 5: Canopy greenness and turfgrass quality differences on the putting green especially for the Milorganite and Urea treatments (photo taken August 6, 2014).

2014 Results

- For CO_2, there were three dates in 2014 for the putting green in which there were significant differences in fertilizer treatment (Figure 7a, 9). On two of the three dates, the untreated control had the highest GHG flux and on the other date Polyon had the highest GHG flux. Milorganite was the lowest on two of the dates and urea was lowest on the other date. On the wet rough, Polyon had significantly higher GHG flux on four dates whereas the untreated control had the lowest emissions (Figure 7b, 9).
- Milorganite had significantly greater GHG flux for N_2O on the green for one date in July than Polyon and Urea (Figure 8a, 9). On the dry rough, Milorganite had a significantly higher GHG flux than the other fertilizer treatments for one date in September (Figure 8b, 9). Also in September, Urea had higher GHG emissions than both Milorganite and the untreated control. For the wet rough in June, Milorganite and Polyon had significantly greater GHG emissions than Urea and the untreated control Figure 8c, 9).
- More seasonal rainfall resulted in more uniform moisture conditions thus site location was not a significant predictor of GH gas flux (2013:10 inches of rainfall and 2014:17 inches of rainfall during the growing period).
- Soil temperature and soil moisture were found to be significant predictors of CO_2 and N_2O emissions (Figure 10).
- Canopy greenness was significant by golf course area for all sampling dates in 2014. Fertilizer source was significant on 8 sampling dates in 2014. In the dry and wet rough, CG was higher for Milorganite than the other fertilizer sources. CG was highest on the green when using urea (Figure 11).
- Fertilizer source was significant on six of the sampling dates where turfgrass quality was significantly higher for the Polyon and Urea treatments on greens and Milorganite and Urea treatments on roughs compared to the control (Figure 12).

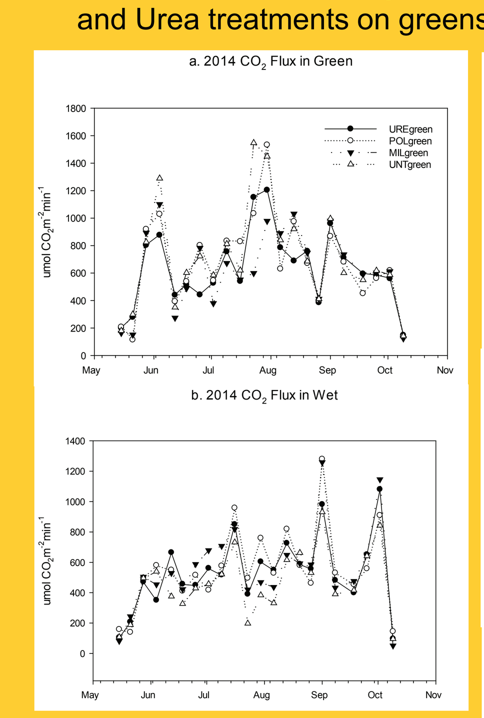

Figure 7. a) CO_2 flux by fertilizer treatment for the green during the 2014 growing period. b) CO_2 flux by fertilizer treatment for the wet rough during the 2014 growing period. (URE=Urea, POL=Polyon, MIL=Milorganite & UNT=Untreated control).

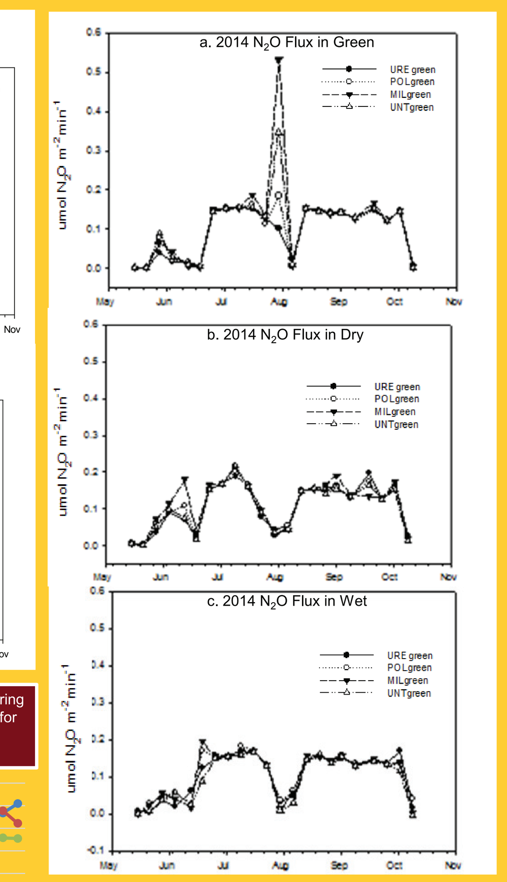

Figure 8. a) N_2O flux by fertilizer treatment for the green during the 2014 growing period. b) N_2O flux by fertilizer treatment for the dry rough during the 2014 growing period. c) N_2O flux by fertilizer treatment for the wet rough during the 2014 growing period. (URE=Urea, POL=Polyon, MIL=Milorganite & UNT=Untreated control).

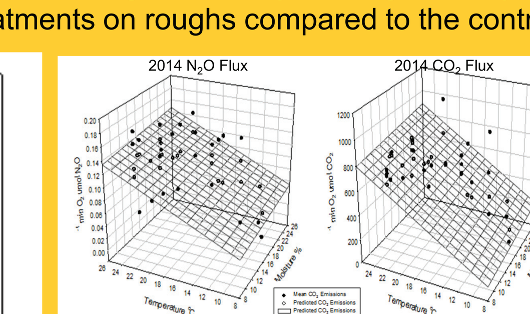

Figure 10. Soil temperature and soil moisture plotted against soil CO_2 and N_2O flux. The black dots represents the data points and the matrix represents the model generated using SAS to explain 99.99% of the data. CO_2 = [(0.09201)*temperature + (0.05011) moisture + 1.29697]^4; N_2O = [(-0.000316)*temperature + (-0.0002943) moisture + 0.13343]^(-1/3) – 2.

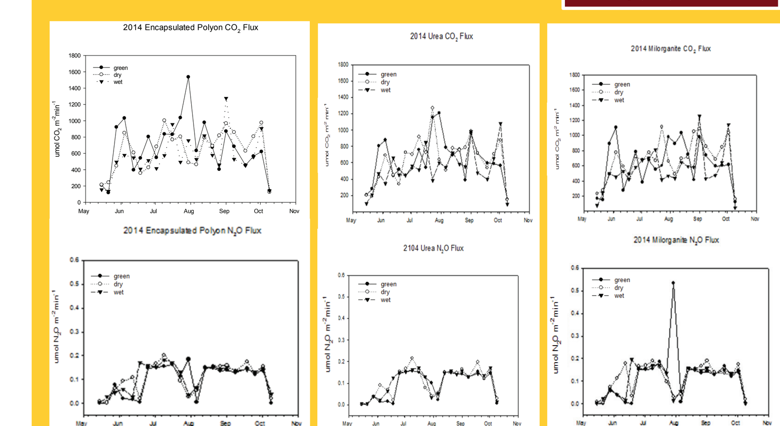

Figure 9. The three fertilizer sources and the impact each had on soil CO_2 and N_2O flux by location in 2014.

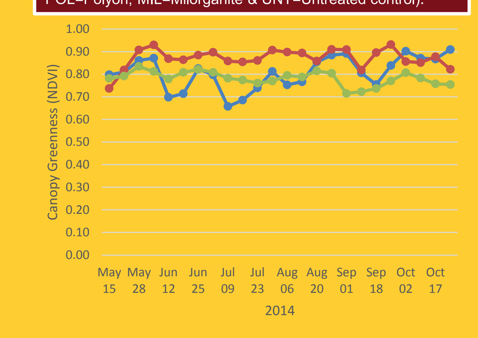

Figure 11: Canopy greenness (NDVI) by turfgrass area (WRO=Wet Rough, DRO=Dry Rough, GRE=Green) in 2014.

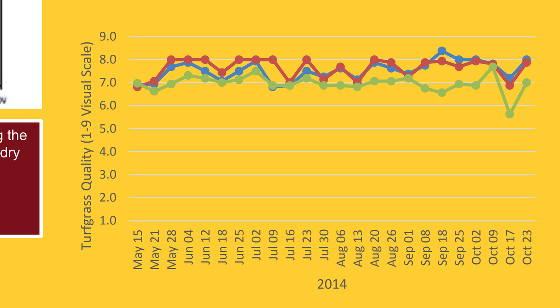

Figure 12: Turfgrass quality (1-9 visual scale; 9=Best, 6=Acceptable, 1=Worst) for all site locations in 2014 (WRO=Wet Rough, DRO=Dry Rough, GRE=Green).

Conclusions

- Carbon dioxide (CO_2) emissions were highest in the green and wet rough and Nitrous oxide (N_2O) emissions were highest in the wet rough where Polyon tended to show significantly higher emissions than other treatments.
- Soil temperature and soil moisture were found to be significant predictors of CO_2 and N_2O emissions.
- Canopy greenness was highest in the wet rough site location where Milorganite significantly increased canopy greenness for both the wet and dry rough. On the green however, Urea significantly increased canopy greenness.
- Turfgrass quality was highest for the roughs when using Milorganite and Urea whereas turfgrass quality was highest for Urea and Polyon on the green.

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