UNIVERSITY OF MINNESOTA CROOKSTON

Shade and Nitrogen Fertilizer Effects on Greenhouse Gas Emissions from Creeping Bentgrass Putting Greens

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ABSTRACT

Climate change mitigation requires creative solutions to reduce greenhouse gases (GHG). Little research has been done on GHG emissions from shaded turfgrass systems resulting in a lack of best management practices (BMP) development. The aim of this research was to investigate the soil flux of carbon dioxide (CO2), methane (CH4), and nitrous oxide (N2O) as impacted by shade [shade (93.8%) versus sun (100%] and differing sources (fast versus slow-release) and rates (147 versus 294 kg ha-1 yr-1) of nitrogen (N) fertilizers on creeping bentgrass putting greens. The results showed that emissions of soil CO2 and soil N2O were significantly lower (p<.05) in shaded plots versus sunny plots. Additionally, the presence of N fertilizer significantly (p<.05) increased soil CO2 emissions over unfertilized plots. Fast-release N fertilizer fluxed significantly (p<.05) more soil N2O than the slow-release N fertilizers while both fertilizers fluxed significantly (p<.05) more soil N2O than the unfertilized control. Turfgrass color was significantly (p<.001) higher on the sunny green versus the shaded green except in late summer where the shade provided relief from the high air/canopy temperatures. Turfgrass quality was significantly (p<.01) higher for the shaded green versus the sunny green. Milorganite improved turfgrass quality whereas urea (294 kg ha-1 yr-1) decreased turfgrass quality due to fertilizer burn. When N is needed to improve turfgrass color and quality, the use of slow-release N sources should be a BMP for shaded greens.

INTRODUCTION

Mitigating climate change will require all sectors of society to sharply reduce greenhouse gas emissions (CO2, CH4, and N2O) and engage in carbon storage strategies [4]. Many studies have observed higher soil organic carbon associated with turfgrass and are beginning to see urban soils as providing important ecosystem services such as carbon storage [8–10]. The intensity of management and the presence of trees in urban landscapes have been shown to impact soil CO2 flux and soil N2O flux [21]; however, further investigations into the impact of urban landscapes on the flux of greenhouse gases are needed.

One major environmental factor affecting overall turfgrass health (turfgrass color and quality) and, consequently, GHG emissions, is sunlight exposure. Trees and shrubs provide shade, affecting microbial activity, soil moisture, and temperature within turfgrass areas [29,30]. Increased sunlight can elevate soil temperature, stimulating microbial activity (thus impacting GHG flux) but potentially reducing root length and increasing mortality, ultimately impacting turfgrass quality [31]. Trees are desirable on golf courses for the overall aesthetics and golfer challenge; however, shade caused by trees is a major cause of turfgrass failure, especially on putting greens [32]. It is estimated that 20 to 25% of all turfgrasses are maintained under some degree of shade, whether from buildings or trees [33]. Trees not only cast shade but may also affect grass growth through competition for light, water, and nutrients.

Maintaining acceptable turfgrass color and quality on shaded golf course greens is difficult for superintendents due to a low ratio of photosynthesis:respiration, which reduces turfgrass growth [35]. Adjusting management techniques is the main approach a superintendent may employ to maintain turf in reduced light conditions. Reducing N fertility on shaded turf is a commonly recommended cultural management practice for maintaining turf in reduced light conditions. Goss et al. [32] found that using lower N rates (150–185 kg ha·1 yr·1) resulted in better turfgrass quality than higher N rates (212–235 kg ha·1 yr·1) when using a liquid N source (urea). Steinke and Stier [35] found that liquid N (urea) improved the turfgrass quality of creeping bentgrass but reduced the quality of Kentucky bluegrass when compared with a granular urea under 80% shade. Little research has been performed on GHG emissions from shade [37], other than one paper on lawns and urban green spaces [21]. Further research is needed as the management of crops, such as turfgrass, could become part of the solution as our society addresses climate change [38].

AIM OF RESEARCH

- The purpose of the current research was to evaluate the soil flux of CO2, CH4, and N2O as impacted by shade (shade vs. full sun) and differing sources and rates of N (fast- and slow-release) fertilizers on creeping bentgrass (Agrostis stolonifera) putting greens.
- We also evaluated turfgrass health to ensure environmental benefits did not compromise the overall color and quality of the turfgrass.
- The goal was to provide BMPs to superintendents fertilizing turfgrass greens in shade to reduce GHG emissions.

MATERIALS AND METHODS

- This two-year field study was conducted from May 2016 through October 2017 at Lincoln Golf Course in Grand Forks, ND, USA. Two putting greens were selected based on the amount of shade (98.8%) and sun (100%) they received (Figure 1) as determined by quantifying the area of shade vs. sun at the time-of-day sampling occurred.
- Both greens consisted of 80% 'Penncross' Creeping bentgrass (Agrostis stolonifera L.) and 20% annual bluegrass (Poa annua L.) grown on a sand-based root zone (90:10 sand:organic matter). The putting greens were constructed as native soil-based push-up greens. They have been modified over the years with the addition of topdressing (90:10 sand:organic matter).
- There were five fertilizer treatments: untreated control (UNT, 0 kg N ha-1 yr-1), urea low (UREL, 147 kg N ha-1 yr-1), urea high (UREH, 294 kg N ha-1 yr-1), milorganite low (MILL, 147 kg N ha-1 yr-1), and milorganite high (MILH, 294 kg N ha-1 yr-1). For the low fertilizer treatments (UREL and MILL, 147 kg N ha-1 yr-1), a rate of 24.5 kg N ha-1 was applied to each plot in May, June, July, August, September, and October. For the high fertilizer treatments (UREH and MILH, 294 kg N ha-1 yr-1), a rate of 49 kg N ha-1 was applied to each plot in May, June, July, August, September, and October.
- Canopy coverage (shade vs. sun) was treated as a block (1.2 m x 6.1 m). Each of the five fertilizer treatments was replicated four times and plots were arranged in a randomized, complete-block design. The plot size was 0.61 mx 0.61 m for a total of twenty plots per canopy coverage and a total of forty plots in the experiment.
- Temperature (soil, air, and canopy) and soil moisture were recorded weekly synchronously with greenhouse gas collection during the growing season using a HM digital TM-1 industrial grade digital thermometer, infrared temperature meter (Spectrum Technologies, Inc.), and a Dynamax TH300 TDR soil moisture probe which takes the average soil moisture in the top 60 mm of soil.
- Turfgrass color was determined using a chlorophyll meter that measured the normalized difference vegetation index (NDVI) of the turfgrass stand (FieldScout CM 1000 NDVI from Spectrum Technologies, Inc.). Turfgrass quality was visually rated (per plot) weekly throughout the growing season using a 1 to 9 scale, where 1 = completely brown dead turf, 6 = minimally acceptable turf, and 9 = optimum uniformity, density, and greenness.
- Gas samples were taken weekly following the protocols of the GRACEnet USDA ARS sampling protocols (Mosier, 2001). A polyvinyl chloride pipe (0.152m diameter x 0.114m height) was tamped into the ground until it was flush with the soil surface. Gas samples were taken by tamping a vented close gas chamber covered in reflective tape (no light penetration) over the base in the ground. Gas samples were analyzed using a gas chromatograph (Varian 350) to determine the concentration of CO2, CH4, and N2O in each sample.

EXPERIMENTAL SITES

Figure 1. Shade (a) and sun (b) putting greens used in this study. The percent shade covered was determined by quantifying the area shaded in this image vs. the area that was not shaded (Google Earth). The shaded green was 98.8% shaded by trees (bottom right: Colorado Blue Spruce; upper left: Japanese Lilac, and 2 American Elms) surrounding the green and the sun green was in 100% sun.

RESULTS-GREENHOUSE GASES

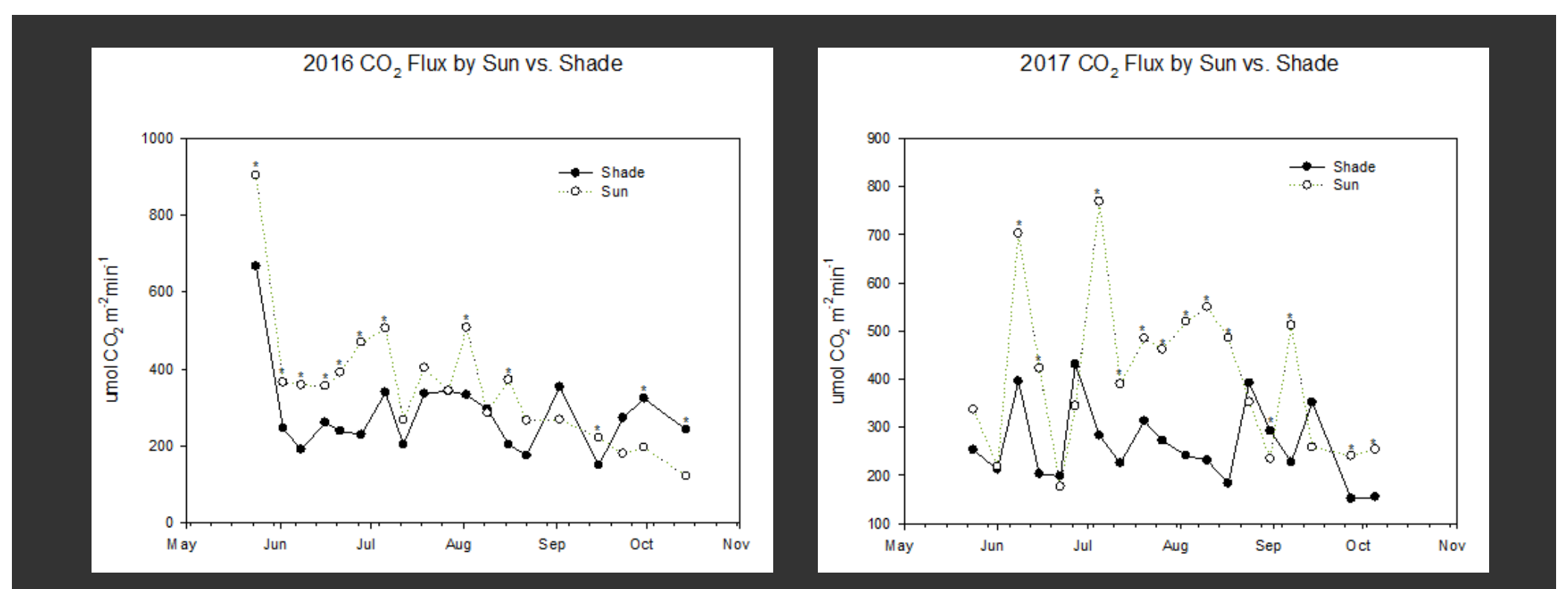

*Figure 2. Canopy coverage (shade vs. sun) on carbon dioxide (CO2) emissions in 2016 and 2017. *Means are significantly different at the 0.05 level according to LSD. All cases of significant differences are Sun>Shade except September 30, 2016, October 14, 2016 and October 5, 2017.*

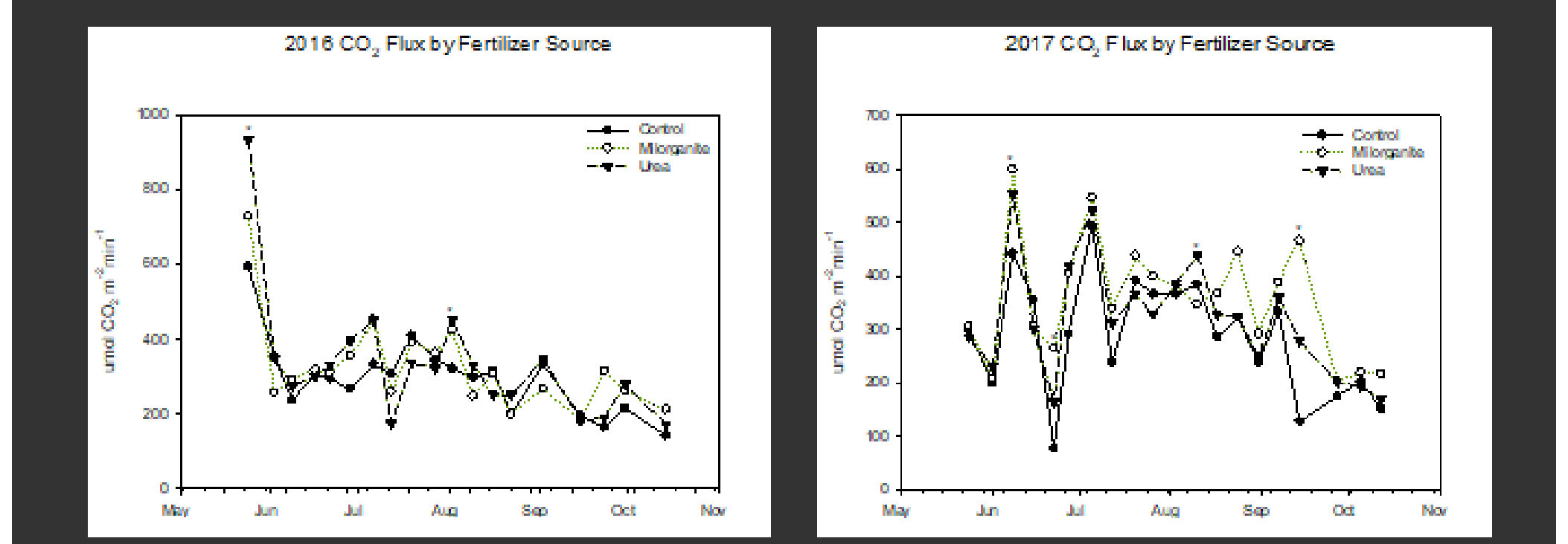

*Figure 3. Fertilizer Source (control, milorganite, urea) on carbon dioxide (CO2) emissions for 2016 and 2017. *Means are significantly different at the 0.05 level according to LSD.*

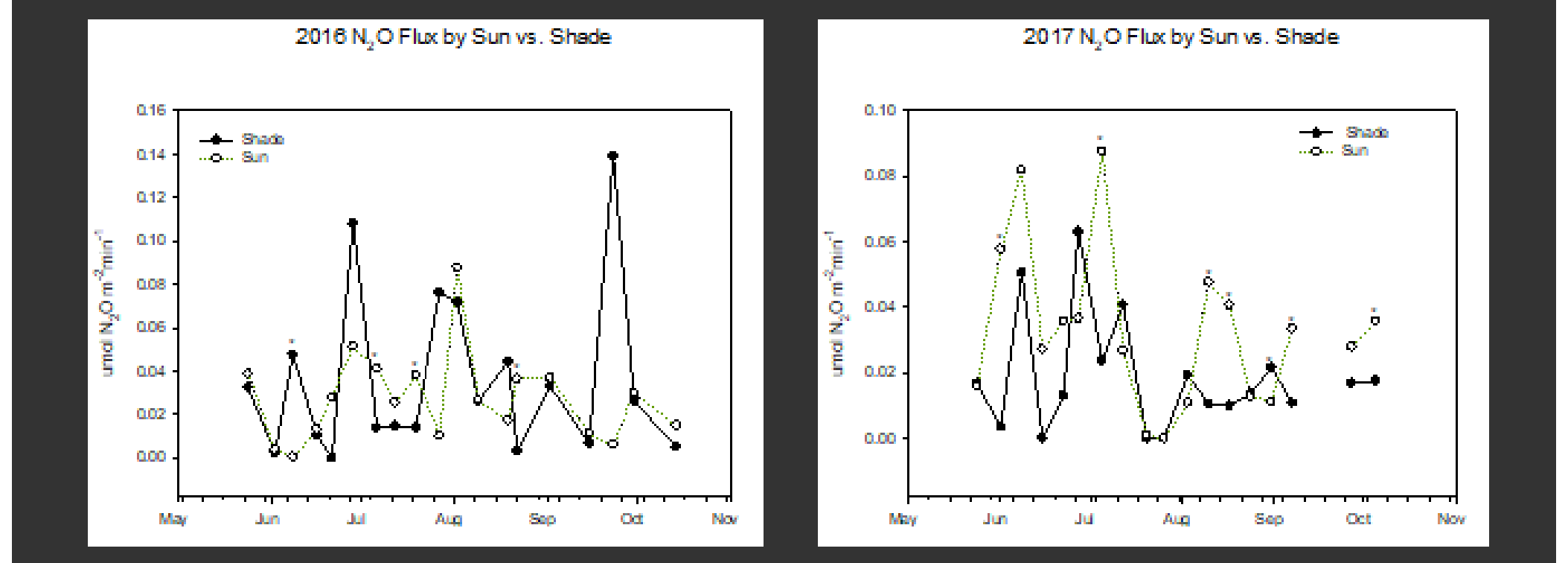

*Figure 4. Canopy coverage (shade vs. sun) on nitrous oxide (N2O) emissions for 2016 and 2017. *Means are significantly different at the 0.05 level according to LSD. All cases of significant differences are Sun>Shade except June 8, 2016 and August 31, 2017.*

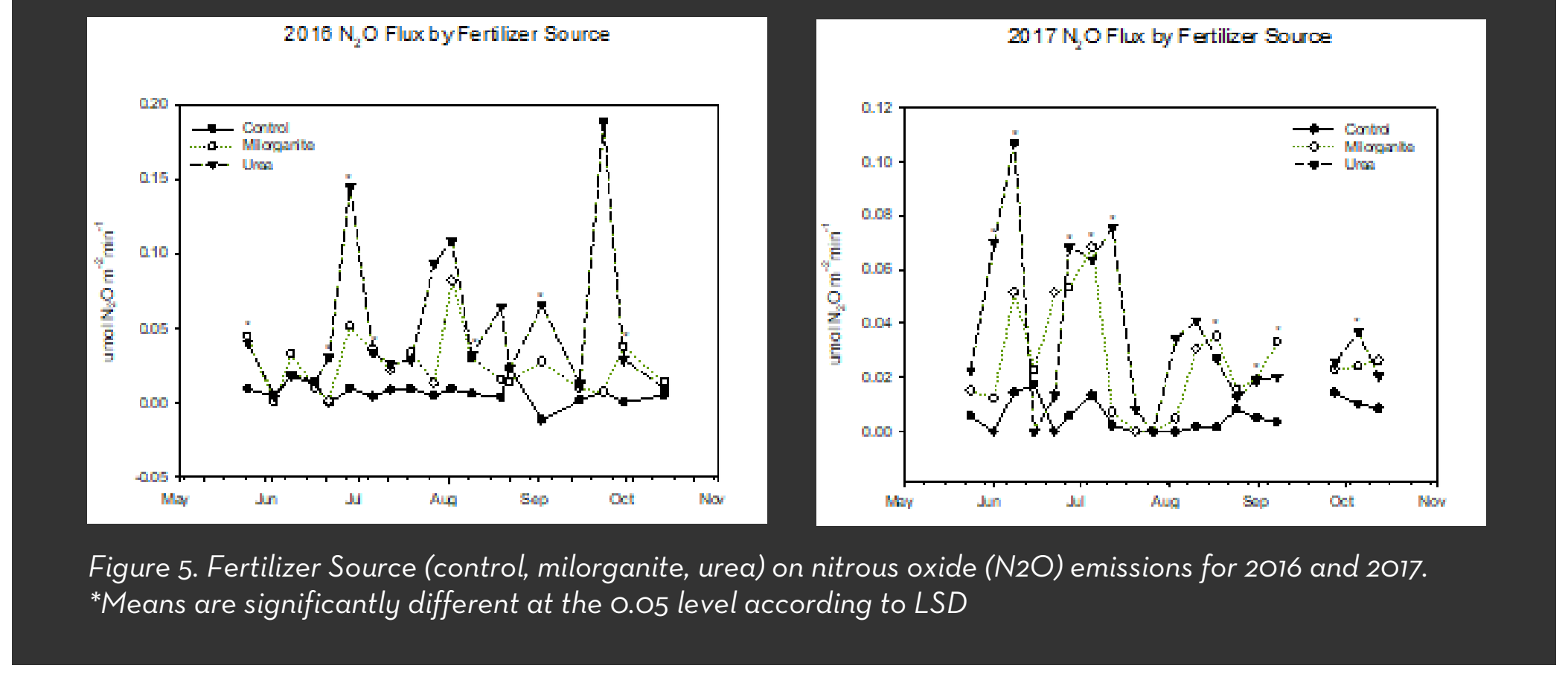

*Figure 5. Fertilizer Source (control, milorganite, urea) on nitrous oxide (N2O) emissions for 2016 and 2017. *Means are significantly different at the 0.05 level according to LSD*

TABLES OF RESULTS

Table 1. Mean and Median Canopy Temperature, Soil Temperature and Soil Moisture by Year, Canopy Coverage.

		Canopy Temperature		Soil Temperature		Soil Moisture	
Year	Treatment	Mean	Median	Mean	Median	Mean	Median
		°C		°C		VWC %	
2016							
	Canopy Coverage						
	Shade	17.0b	16.75	17.3b	18.5	30.1a	30.7
	Sun	23.2a	23.20	22.0a	24.4	21.7b	20.8
Source of Variation		df		df		df	
Shade vs. Sun		1	***	1	***	1	***
Fertilizer		2	NS	2	NS	2	NS
Shade*Fertilizer		2	NS	2	NS	2	NS
2017							
	Canopy Coverage						
	Shade	16.8b	16.75	20.0b	18.6	26.1a	27.9
	Sun	21.2a	21.20	21.5a	21.7	19.6b	19.0
Source of Variation		df		df		df	
Shade vs. Sun		1	***	1	***	1	***
Fertilizer		2	NS	2	NS	2	NS
Shade*Fertilizer		2	NS	2	NS	2	NS

Shade=turf is shaded majority of day; Sun=turf is never shaded; VWC %= volumetric water content.
Within columns, means followed by a different letter are significantly different according to LSD (0.05). No letter means no significance.
*Significant at the 0.05 probability level; **Significant at the 0.01 probability level; *** Significant at the 0.001 probability level. NS, nonsignificant.

Table 2. Mean and Median Soil CO$_2$, N$_2$O, CH$_4$ flux by Year, Canopy Coverage, and Fertilizer.

		CO$_2$		N$_2$O		CH$_4$	
Year	Treatment	Mean	Median	Mean	Median	Mean	Median
		g CO$_2$-C m^{-2} h^{-1}		µg N$_2$O-N m^{-2} h^{-1}		µg CH$_4$-C m^{-2} h^{-1}	
2016							
	Canopy Coverage						
	Shade	0.32B	0.28	43.5	10.9	14.27A	0.35
	Sun	0.40A	0.36	36.9	18.7	-17.92B	-2.08
	Fertilizer						
	Milorganite	0.36ab	0.32	34.5b	22.0	3.10	0.11
	Urea	0.37a	0.32	67.2a	17.3	4.28	-1.40
	Control	0.32b	0.28	0c	5.4	-24.67	-0.37
Source of Variation		df		df		df	
Shade vs. Sun		1	***	1	NS	1	*
Fertilizer		2	*	2	***	2	NS
Shade*Fertilizer		2	NS	2	NS	2	NS
2017							
	Canopy Coverage						
	Shade	0.30B	0.27	13.0B	12.3	83.3	5.8
	Sun	0.45A	0.45	43.6A	21.2	-57.4	-7.6
	Fertilizer						
	Milorganite	0.41a	0.36	34.7	19.3	-5.3	2.7
	Urea	0.37b	0.32	32.9	20.3	86.7	1.3
	Control	0.34b	0.30	5.6	5.4	-87.7	-1.3
Source of Variation		df		df		df	
Shade vs. Sun		1	***	1	*	1	NS
Fertilizer		2	**	2	NS	2	NS
Shade*Fertilizer		2	NS	2	NS	2	NS

Control=no fertilization; Urea=urea fertilizer; Milorganite=milorganite fertilizer; Shade=turf is shaded majority of day; Sun=turf is never shaded.
Means in the same column for each canopy coverage (Shade and Sun) followed by a different uppercase letter are significantly different according to Fisher's protected LSD t-test (p = 0.05). Means in the same column for each fertilizer treatment followed by a different lowercase letter are significantly different according to Fisher's protected LSD t-test (p = 0.05). No letter means no significance.
*Significant at the 0.05 probability level; **Significant at the 0.01 probability level; *** Significant at the 0.001 probability level. NS, nonsignificant.

Table 3. Percent Global Warming Potential Contributions of CO$_2$, N$_2$O, CH$_4$ flux by Year, Canopy Coverage, and Fertilizer.

		CO$_2$	N$_2$O	CH$_4$
Year	Treatment	GWP	Mean	Mean
2016				
	Canopy Coverage			
	Shade	97%	3%	0
	Sun	98%	2%	0
	Fertilizer			
	Milorganite	98%	2%	0
	Urea	96%	4%	0
	Control	100%	0	0
2017				
	Canopy Coverage			
	Shade	98%	1%	1%
	Sun	97%	2%	1%
	Fertilizer			
	Milorganite	98%	2%	0%
	Urea	97%	2%	1%
	Control	100%	0	0

Control=no fertilization; Urea=urea fertilizer; Milorganite=milorganite fertilizer; Shade=turf is shaded majority of day; Sun=turf is never shaded.

Table 4. Turfgrass Color and Turfgrass Quality Yearly Means for 2016 and 2017.

	Turfgrass Color		Turfgrass Quality	
	NDVI		1-9 Visual Scale	
Canopy Coverage	2016	2017	2016	2017
Shade	0.81B	0.86	7.6A	7.6A
Sun	0.83A	0.86	7.3B	7.2B
Fertilizer				
MILH	0.82bc	0.87a	7.6a	7.9a
MILL	0.81cd	0.85b	7.4b	7.6b
UREH	0.83a	0.86ab	7.5ab	7.3b
UREL	0.82ab	0.86ab	7.5ab	7.4b
UNT	0.80d	0.84c	7.3b	6.9c
Source of Variation				
Shade vs. Sun	***	NS	**	***
Fertilizer	***	***	NS	***
Shade*Fertilizer	NS	NS	NS	NS

Turfgrass color, the Normalized Difference Vegetation Index (NDVI) measurements can range from -1 to 1, with higher values indicating greater plant health.

Turfgrass quality is a visual rating of 1-9; where 1= completely brown dead turf, 6= minimally acceptable turf, and 9= optimum uniformity, density, and greenness.

Means in the same column for each canopy coverage (Shade and Sun) followed by a different uppercase letter are significantly different according to Fisher's protected LSD t-test (p = .05). Means in the same column for each fertilizer treatment (MILH=Milorganite, 294 kg N ha^{-1} yr^{-1}, MILL= Milorganite, 147 kg N ha^{-1} yr^{-1}, UREH=Urea, 294 kg N ha^{-1} yr^{-1}, UREL=Urea, 147 kg N ha^{-1} yr^{-1}, UNT=Unfertilized Control, 0 kg N ha^{-1} yr^{-1}) followed by a different lowercase letter are significantly different according to Fisher's protected LSD t-test (p = 0.05). No letter means no significance.

*, **, *** and NS refer to significance at 0.05, 0.01, 0.001, and nonsignificant, respectively.

References and Published Paper can be found by following QRCode or Z-Link below:

MTGF
minnesota turf and grounds foundation

z.umn.edu/chapmanwalker

RESULTS - TURFGRASS COLOR AND QUALITY

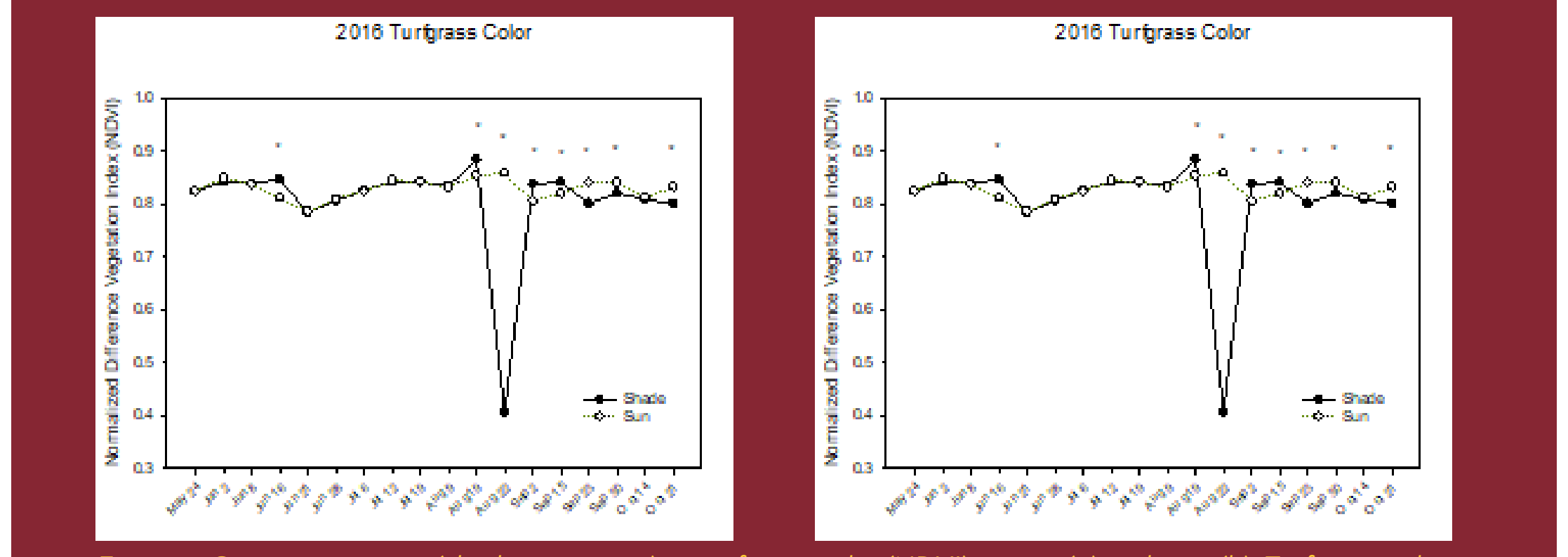

*Figure 6. Canopy coverage (shade versus sun) on turfgrass color (NDVI) in 2016 (a) and 2017 (b). Turfgrass color, the Normalized Difference Vegetation Index (NDVI) measurements can range from -1 to 1, with higher values indicating greater plant health. *Means are significantly different at the 0.05 level according to LSD.*

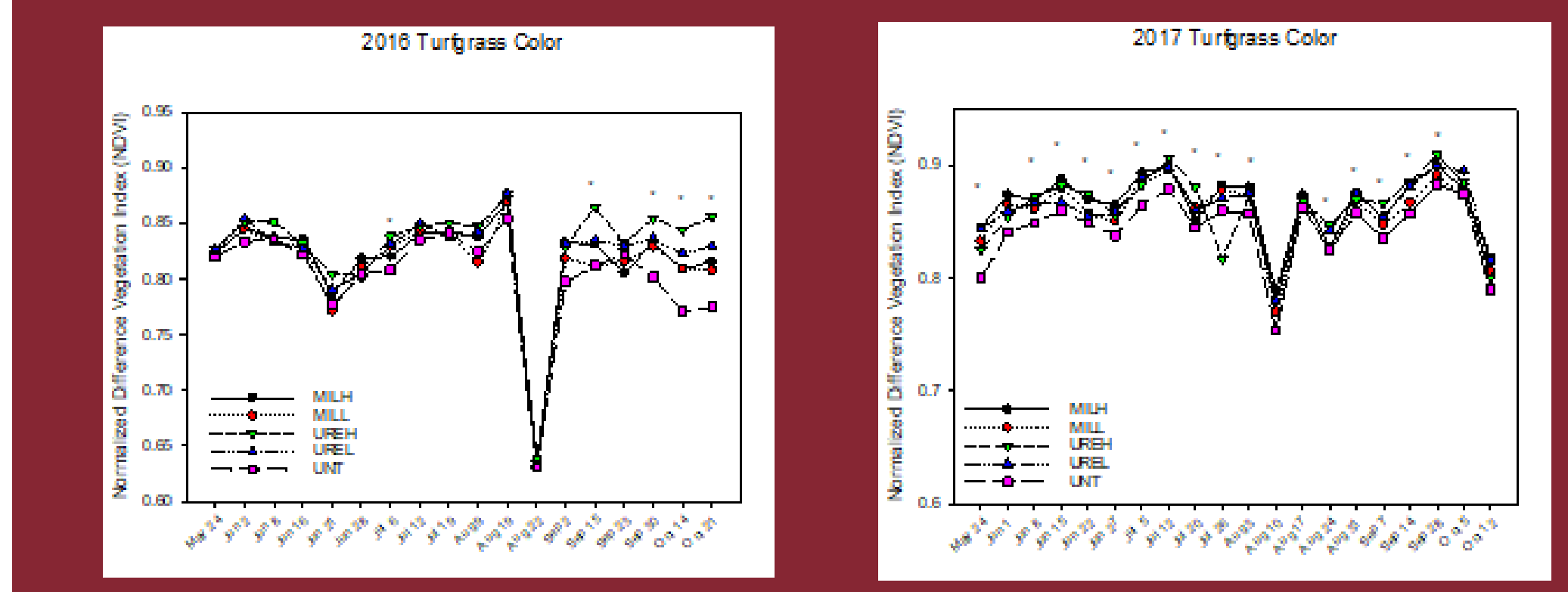

*Figure 6. Canopy coverage (shade versus sun) on turfgrass color (NDVI) in 2016 and 2017. Turfgrass color, the Normalized Difference Vegetation Index (NDVI) measurements can range from -1 to 1, with higher values indicating greater plant health. *Means are significantly different at the 0.05 level according to LSD.*

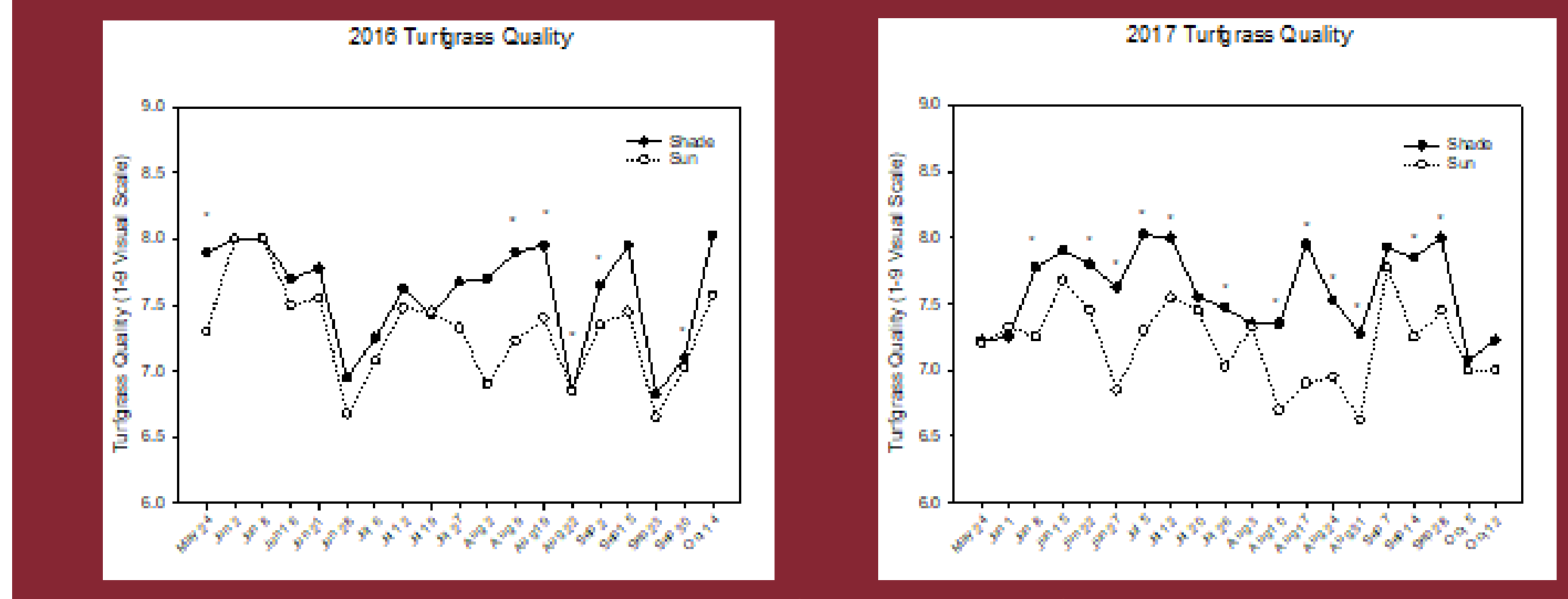

*Figure 7. Canopy coverage (shade versus sun) on turfgrass quality on turfgrass quality (1-9 visual scale) in 2016 and 2017. Turfgrass quality is a visual scale (1-9); where 1= completely brown dead turf, 6= minimally acceptable turf, and 9= optimum uniformity, density, and greenness. *Means are significantly different at the 0.05 level according to LSD.*

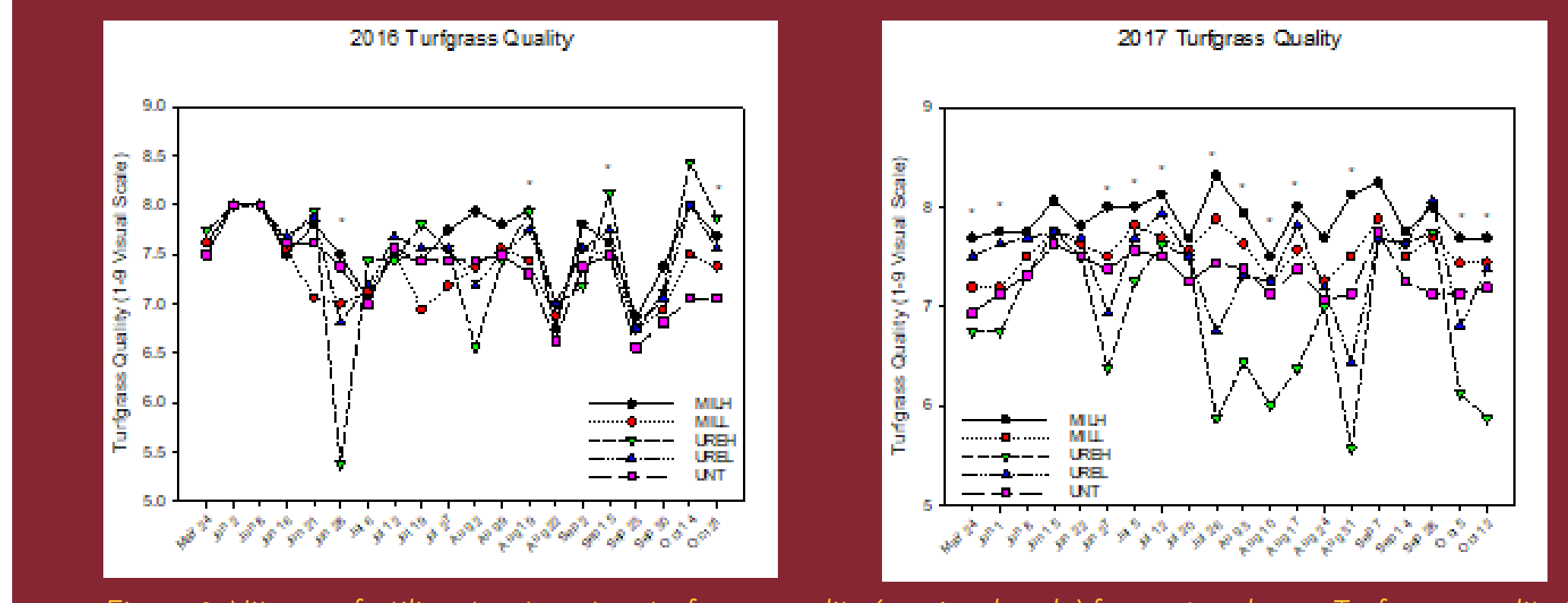

*Figure 8. Nitrogen fertilizer treatment on turfgrass quality (1-9 visual scale) for 2016 and 2017. Turfgrass quality is a visual scale (1-9); where 1= completely brown dead turf, 6= minimally acceptable turf, and 9= optimum uniformity, density, and greenness. There were 5 fertilizers treatments: MILH=Milorganite, 294 kg N ha-1 yr-1, MILL= Milorganite, 147 kg N ha-1 yr-1, UREH=Urea, 294 kg N ha-1 yr-1, UREL=Urea, 147 kg N ha-1 yr-1, UNT=Unfertilized Control, 0 kg N ha-1 yr-1. *Means are significantly different at the 0.05 level according to LSD.*

RESULTS

- The regression analysis showed that soil temperature and soil moisture were significant predictors of soil CO2 flux.
  - Soil temperature was affected (p<0.001) in both 2016 and 2017 and was positively associated with soil respiration with a parameter estimate of 15.04 (2016) and 5.15 (2017) whereas in 2016 soil moisture was also significantly (p<0.05) correlated with soil respiration with a negative parameter estimate (-2.3) in 2016 and was not significant in 2017.
- Both CO2 and N2O fertilized plots fluxed more than the unfertilized plots.
  - Urea fluxed more soil N2O than the milorganite fertilizer treatment across both years of the study.
- Higher flux of soil CH4 in the tree-shaded plots in 2016 which was associated with high soil moisture content thus the sun plots served as a net sink for soil CH4.
- Temperature benefits provided by the trees outweighed the additional moisture content and resulted in reduced soil N2O flux in the shaded plots.
- Turfgrass color was higher on the green located in the sun except in late summer where the shade from trees provided relief from the higher air and canopy temperatures.
  - The urea treatments produced the greenest turf in 2016 whereas in 2017 both urea and milorganite (high rate) produced the greenest turf compared to the untreated control.
- Fertilizer applications of both urea and milorganite greatly improved turfgrass color.
- Milorganite fertilizer applications improved turfgrass quality whereas urea applications (294 kg ha-1 yr-1) decreased turfgrass quality over the 2017 growing season where on several occasions the overall quality of turf fell below acceptable ratings (<6.0).
  - Urea applications at the high rate (294 kg ha-1 yr-1) caused fertilizer burn on the greens.

CONCLUSIONS

- The environmental impacts of tree shade on greens was reduced soil CO2 and N2O flux.
- When N is needed to improve turfgrass color and quality, slow-release N sources like milorganite should be part of any BMP for shaded putting greens.
- Carbon dioxide drives the overall global warming potential of these management techniques suggesting that tree shade on turfgrass could reduce the global warming potential of turfgrass systems.

ACKNOWLEDGEMENTS

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