

**WARM-SEASON TURFGRASS N RATES
& IRRIGATION BMP VERIFICATION**

DEP WM 869

COMPLETED STUDIES REPORT

Principal Investigators

Dr. Laurie E. Trenholm

University of Florida, Institute of Food and Agricultural Sciences
P.O. Box 110675
Gainesville, Florida 32611-0675
(352) 273-4524, letr@ufl.edu

Dr. John L. Cisar

University of Florida, Institute of Food and Agricultural Sciences
Ft. Lauderdale Research and Education Center (FLREC)
3205 College Ave.
Ft. Lauderdale, FL 33314
(954) 577-6336, jlc@ufl.edu

Dr. J. Bryan Unruh

University of Florida, Institute of Food and Agricultural Sciences
West Florida Research and Education Center (WREC)
Jay Research Farm
4253 Experiment Drive, Hwy. 182
Jay, FL 32565
(850) 995-3720 x108, jbu@ufl.edu

Dr. Jerry B. Sartain

University of Florida, Institute of Food and Agricultural Sciences
P.O. Box 110510
Gainesville, Florida 32611-0675
352-392-7271 ext 330, sartain@ufl.edu

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EXECUTIVE SUMMARIES

Fort Lauderdale - Dr. John L. Cisar

Nitrate Leaching From Newly Sodded Grass

- Regardless of soil type, nitrogen mineralization from sod resulted in considerable nitrate-N leaching during the first 30 DAI. For example, for all trials, sod type influenced clipping yields during the first 30 DAI although fertilizer treatments did not.
- The amount of nitrate-N leached due to fertilization directly after sod installation mitigated the benefit in quality.
- Seasonality may have influenced results:
 - Trials 1 and 3 bracketed an active growth period. During this time, less leaching occurred in general. Although not significant, a trend for less nitrate-N leaching coupled with significantly better quality was determined for turfgrass fertilized 30 DAI.
 - Trial 2 corresponds to a less active growth period. Perhaps at this time, the turfgrass is less resource efficient. This would explain the higher nitrate-N concentrations and greater leaching due to fertilizer treatments documented during the 31-60 DAI.
- Variations in results between trials may also be due to the organic soil-based sod originating from different sod farms. For example, while Trials 1 and 3 were during the same time of year, there was no difference in quality scores for sod type in Trial 3 when there was in Trial 1. In Trial 3, the organic soil based sod had 27% less organic matter than the organic soil based sod used in Trial 1.

Nitrate Leaching From Established Grass

Both irrigation regimes produced acceptable quality in both St. Augustinegrass and bahiagrass over the 2 year study even though the low irrigation applied $\frac{1}{2}$ the amount of water as the high irrigation regime.

For both years, N rate significantly affected quality, color, and density in both St. Augustinegrass and bahiagrass. In both studies, quality, color and density increased with increasing N rate. For St. Augustinegrass, fertilization of $196 \text{ kg N ha}^{-1} \text{ yr}^{-1}$ was required to sustain at least minimally acceptable adequate turf quality throughout the duration of a fertilization cycle. For bahiagrass $49 \text{ kg N ha}^{-1} \text{ yr}^{-1}$ was capable of sustaining adequate turf quality for the duration of a cycle during the experiment. Turfgrass density was significantly different on more dates in Year 2 with ratings dipping below the acceptable level of 6 on several dates for both grasses—more notably in St. Augustinegrass

Turfgrass growth increased with increasing N rate for both bahiagrass and St. Augustinegrass over the 2 year test period.

Irrigation regime had no effect on N (nitrate) leaching in both St. Augustinegrass and bahiagrass.

In both for years 1 and 2, St. Augustinegrass and bahiagrass no significant differences were observed between the rate of N applied and the amount of N leached.

Nitrate Leaching Due to N Source and Timing

Nitrate-N leaching was significantly-affected by N treatment, with the urea treatment having the most cumulative leaching, followed by the 70:30 soluble/slow combination treatment and other treatments. The 3 slow or controlled release N products had nitrate-N leaching totals that were statistically equal to control plots and to the 70:30 combination treatment and were lower than the urea treatment. Most of the leaching occurred during the first month after application. Thereafter, there were no significant differences in leaching.

Phosphorus Soil Test

In the field P test, there was a general year to year decline in soil-test P values so that the values observed were in some cases less than the range for that particular soil-test level. For example, a very high P soil-test would be above 60 ppm, and by 10/10/09, the observed value of samples taken from the very high soil-test P treatment at year's end was much below that threshold value.

However, leaching of P in the field test was significantly affected by soil-test P throughout the reporting period with more leaching from higher soil-test P treatments.

In the greenhouse P trials, the very low soil-test P treatment generally had significantly lower turf quality ratings and clipping growth. Increasing the soil-test above medium did not increase ratings or growth.

Concentration of P in percolate was also affected by soil-test P treatment with P leaching increased by soil-test P level. Phosphorus leaching was increased in very low P soil-test treatments that did not have healthy turf to assimilate the P compared to very low P soil-test grassed treatment. Nevertheless, P concentrations in the greenhouse trials were rarely at the threshold level for water quality standards.

Gainesville – Dr. Jerry Sartain

Phosphorus Requirements and Leaching

Information on critical phosphorus (P) concentration in tissue of *Stenotaphrum secundatum* (Walt) Kuntze cultivar 'Floritam' (St. Augustinegrass) and *Zoysia japonica* cultivar 'Empire' (Zoysiagrass) is limited. Knowledge of critical leaf tissue P concentrations for these turfgrass species can help to avoid unnecessary P fertilization and reduce the risks of negative consequences to the environment. A hydroponic study was established to determine the critical P concentration in leaf tissue of 'Floritam' St. Augustinegrass and 'Empire' zoysiagrass. Six levels of P (0, 90, 135, 203, 304, and 456 mg P m⁻³) were used. Plant growth rate, P concentration in leaf tissue, visual ratings of turfgrass quality, percent green turf cover and chlorophyll index (CI) were evaluated biweekly for 140 days.

Turfgrass visual quality rating increased with increasing P supply. Maximum zoysiagrass growth rate and percent green cover were reached at 1.67 g P kg⁻¹ and 1.35 g P kg⁻¹, respectively. Maximum St. Augustinegrass growth rate and percent green cover were reached at 1.73 g P kg⁻¹ and 1.48 g P kg⁻¹, respectively. Consequently, a P concentration in leaf tissue of 1.35 g P kg⁻¹ and 1.67 g P kg⁻¹ for zoysiagrass and 1.48 g P kg⁻¹ and 1.73 g P kg⁻¹ for St. Augustinegrass could be used as the threshold concentrations for maintenance of maximum green turf density and maximum growth and recovery rates, respectively. Phosphorus fertilization in low P retention soils can result in P leaching to ground water.

Another study was conducted to evaluate the effect of P application rate on orthophosphate (P_i) leaching. St. Augustinegrass and zoysiagrass were grown in a “clean” sand with very low extractable P and negligible P soil storage capacity. Five rates of P were supplied (from 0 to 5 g m⁻² year⁻¹). Phosphorus uptake, plant dry matter accumulation, and Mehlich I extractable P (M1-P) were determined biweekly for 140 days (May to September) during 2008 and 2009.

Orthophosphate leaching rate and P_i concentration in leachate from zoysiagrass were greater than from St. Augustinegrass. Phosphorus uptake rate over time in St. Augustinegrass was greater than in zoysiagrass. The root system of St. Augustinegrass was more extensive and deeper than in zoysiagrass. Rate of P_i leaching was positively related to amount of rainfall plus irrigation received by the turf. Phosphorus fertilization over time increased M1-P, phosphorus saturation ratio (PSR) and reduced of the soil phosphorus storage capacity (SPSC). Greater volume-weighted P_i concentrations in leachates were measured in soils with greater M1-P and PSR values and lower SPSC values. Orthophosphate concentrations in compliance with the U.S. Environmental Protection Agency (USEPA) water quality criteria for Florida were measured in soils with a PSR as high as 0.6. Total estimated amount of P leached from fertilizer application was below 5% and 0.25% in zoysiagrass and St. Augustinegrass, respectively. The results of this research indicate that if P fertilization is required based on tissue analysis and the SPSC is positive, it would be environmentally safe to supply P at a maximum rate of 0.54 g P m⁻² per application (1.07 g P m⁻² per year) to St. Augustinegrass and 0.2 g P m⁻² per application (0.8 g P m⁻² per year) to zoysiagrass.

Gainesville – Dr. Laurie Trenholm

Nitrate Leaching From Newly Sodded Grass

This research was conducted to determine extent of NO₃-N leached from newly sodded lawn grasses due to applied N rate and irrigation. Grasses tested were Floratam St. Augustinegrass (*Stenotaphrum secundatum* Walt. Kuntze) and Empire zoysiagrass (*Zoysia japonica* Steud.) Nitrogen was applied at various rates on day of sodding and half of the plots received additional treatments 30 days after planting. There were few differences in NO₃-N leached due to N rate over the 4 year period, but NO₃-N loads ranged from 20.3 to 64.8% of applied N from St. Augustinegrass and 21.3 to 74.9 from zoysiagrass. It is recommended that no nitrogen be applied to these species following sodding for a minimum of 30 and up to 60 days after planting.

Nitrate Leaching From Established Grass

The objectives of this research were to evaluate nitrate N (NO₃-N) leaching and turf response to nitrogen rate (NR) and irrigation regime (IR) in ‘Floratam’ St. Augustinegrass (*Stenotaphrum secundatum* [Walt.] Kuntze.) and ‘Empire’ zoysiagrass (*Zoysia japonica* Steud.). The research was conducted in Citra, FL from 2005-2007. Nitrogen (N) was applied at annual rates of 32, 64, 128, and 196 kg ha⁻¹ in 2005 and at 49, 196, 343, or 490 kg ha⁻¹ in 2006 and 2007. Irrigation treatments consisted of 1.3 cm applied twice weekly or 2.6 cm applied once weekly. In general, NO₃-N leaching was greater from zoysiagrass. In 2007, annual NO₃-N leached varied due to the interaction of NR, IR, and grass. There was little association between NR and increased NO₃-N leaching in St. Augustinegrass in any year. While St. Augustinegrass had no differences in NO₃-N leached within NR due to IR, there were some differences in NO₃-N leached from zoysiagrass at some N levels, with greater NO₃-N leached from the more frequent irrigation regime. Turf quality (TQ) was generally above an acceptable level in St. Augustinegrass at all but the lowest NRs and at all NRs in zoysiagrass with the exception of the Spring Fertilizer Cycle (SFC) in 2007, when high NR treatments resulted in disease. Maintenance of a healthy turfgrass cover is an

important strategy for reducing potential nutrient movement from fertilizer application. The currently recommended rates for St. Augustinegrass provide good turf cover and health and result in minimal NO₃-N leaching. Zoysiagrass N rates may need to be revised downward to reduce disease, improve turf cover and reduce NO₃-N leaching.

Nitrate Leaching During Winter Months Due to N Rate

This research was undertaken to observe how NO₃-N loading was impacted by N fertilization in north central Florida throughout the winter months. Nitrogen was applied monthly throughout the winter to Floratam St. Augustinegrass (*Stenotaphrum secundatum* Walt. Kuntze) and UltimateFlora® zoysiagrass (*Zoysia japonica* Steud.). There were differences in NO₃-N loading due to the interaction of grass and nitrogen rate (NR) in 2 out of 3 years. Application of low rates (< 24.5 kg N ha⁻¹) of N during winter months to St. Augustinegrass or zoysiagrass did not result in NO₃-N fluxes greater than those of control plots, but also did not enhance TQ or TC. Turf visual ratings were consistently below acceptable regardless of NR. Higher loading rates occurred from zoysiagrass than from St. Augustinegrass when there were differences due to grass. When comparing NO₃-N loading between months, higher loading occurred in winter and spring months compared to fall. From results of this research, there is no benefit from applying fertilizer in the winter in north central Florida. If an application needs to be made to meet contractual obligations where summer fertilizer bans exist, this research suggests that it would be better for additional N to be applied in Nov or Dec rather than from Jan-Mar to reduce potential NO₃-N loading.

Nitrate Leaching Due to N Source

This research was undertaken to determine the NO₃-N loading from established lawn grasses due to nitrogen source. Established Floratam St. Augustinegrass (*Stenotaphrum secundatum* Walt. Kuntze) and Empire zoysiagrass (*Zoysia japonica* Steud.) were used for this research. In one cycle in 2008 and the winter cycle of 2009, there were differences in NO₃-N loading due to the interaction of grass and N source. Where these differences existed, no differences in loading occurred in response to N in St. Augustinegrass, while zoysiagrass had greater loading from ammonium nitrate. These data suggest that consideration could be given to allow application of up to 49 kg of water soluble N ha⁻¹ on an established, healthy turf. In 3 of 4 years of research, there was no increased loading from 98 kg N ha⁻¹ of a polymer sulfur coated product applied every 120 days, however, in 2011, that treatment produced greater NO₃-N loading.

Statewide Analysis of Effect of N Rate on Nitrate-N Leaching in Established Grasses

This analysis was done to compare NO₃-N loading in St. Augustinegrass (*Stenotaphrum secundatum* Walt. Kuntze) between the 3 locations in the project. Nitrate-N leaching varied due to location in 2 out of 3 years and in the total of the 3-yr period. In these cases, differences appeared not to be related to soil type or season, but primarily to abundant rainfall, including a hurricane that hit northwest Florida in year 1. In year 3, following an extremely cold winter, there was extensive winterkill injury on the Jay plots. There were differences in one year only due to nitrogen rate (NR), with higher NO₃-N loading from 490 kg applied N ha⁻¹ than from other rates, including the higher rate applied in Ft. Lauderdale. There were no differences due to irrigation. Increased percent of applied N leached was attributed to a number of high rainfall events in Jay in yr 1. Excluding these data from Jay, percent of applied nitrogen (N) leached ranged from 0.2 to 4.4%, with higher percentages at the low NRs, which is typical of published reports. From the results of this statewide NO₃-N loading analysis, it appears that the currently recommended N rates for St. Augustinegrass are valid for each location. Maintaining a dense, healthy turf is an important

factor in reducing NO₃-N leaching and it is important that proper turf management practices are followed to maintain a healthy stand of turf.

Jay – Dr. J. Bryan Unruh

Nitrogen Effects on Centipedegrass Establishment after Seeding and Sodding

- Seeded Centipedegrass quality was unaffected by fertilizer application timing in both runs of the experiment with the exception of the initial rating where fertilizer applied 30 days after seeding resulted in slightly better quality.
 - Rate of applied nitrogen had no effect on centipedegrass density.
- There were no significant effects of application date or rate on nitrate leaching from seeded centipedegrass across both studies.
- Centipedegrass established from sod showed a slight improvement in turf quality when fertilized 30 days after sodding versus at the time of sodding during the first run of the experiment.
 - This effect was not noted during the second run of the experiment.
- Trial 2 had significantly more leaching of nitrate versus Trial 1 in all sampling dates following sodding.
 - During 31-60 days following sodding and application across both trials the 30 DAS showed lower levels of nitrate and is likely attributed to the longer time period in which the fertilizer had been on the ground.
 - This time period also showed differences in nitrogen rate with the highest leaching occurring at the 49.0 kg/ha rate, this is again evident for the total accumulated.
 - The 49.0 kg/ha rate resulted in the highest leaching, with the 24.0 kg/ha rate with 24.5% less and the 12.5 kg/ha rate with 45% less when combined across both trials in 2007.

Effects of Irrigation & Nitrogen Application Rates on Nitrogen Leaching from Established Centipedegrass and St. Augustinegrass

- On only one rating date over the three year study did irrigation influence a visual St. Augustinegrass turf rating.
- In 2005 and 2006, increasing nitrogen rate produced better St. Augustinegrass quality, color, and density.
 - By the end of the 2006 growing season, good St. Augustinegrass quality was obtained with single application rates $\leq 98.00 \text{ kg ha}^{-1}$.
 - Plots receiving 16.17 kg ha^{-1} had quality slightly below an acceptable level.
 - Winter 2006 through spring 2007 produced an appreciable level of winter injury.
- The effect of irrigation frequency on nitrate leaching from St. Augustinegrass was significant on seven sampling dates in 2006.
 - In general, the 2X week irrigation regime resulted in greater nitrate leaching.
- Nitrogen applied at 98 kg ha^{-1} (single application) yielded greater nitrate leaching from ST. Augustinegrass compared to rates $\leq 65.17 \text{ kg ha}^{-1}$ (single application).
 - This increased level of nitrate leaching was evident in all three fertilization cycles in 2005 and 2007.

- Centipedegrass quality, color, and density were not influenced by irrigation frequency in 2005 and 2006; however, a single, weekly irrigation event yielded a slight improvement in color and quality in May 2007.
- A notable quality, color, and density response in centipedegrass was observed in all three years of the study.
 - All rates of applied nitrogen produced acceptable centipedegrass turf quality.
- The effect of irrigation frequency on nitrate leaching from centipedegrass was not significant at any time.
- During 2005 and 2007, no differences in nitrate leaching from centipedegrass due to nitrogen rate were observed.

Influence of Nitrogen Source and Timing on NO₃-N Leaching When Applied to Centipedegrass and St. Augustinegrass

- Nutrient import appears to negate treatment differences in the inaugural year.
- Throughout 2009, centipedegrass exhibited better turf quality, color, and density than St. Augustinegrass
 - As expected, soluble N sources yielded rapid improvements in green-up and turf quality following each application.
- The winter of 2009/2010 was colder than normal resulting in significant deterioration of the St. Augustinegrass.
 - Spring ratings showed that plots treated with soluble N sources and the PCU @ 2.0 lbs had quality comparable to the untreated control
 - The 30% SRN, 50% SRN, PCU @ 1.0 lb, and biosolid treatments all had minimally acceptable turf quality – all other treatments were unacceptable.
- St. Augustinegrass turf quality in 2011 was largely below acceptable quality.
 - Only the 30% SRN, 50% SRN, and biosolid treatments had acceptable quality at the beginning of the season through 30 June
 - By 14 July, one month following the second fertilizer application, all treatments except ammonium sulfate and urea had acceptable quality.
- Fertilizer sources had no effect on St. Augustinegrass shoot mass in 2008, however, centipedegrass, was influenced by fertilizer source.
 - All sources containing soluble N increased shoot mass 20 DAA.
- In 2009, differences in St. Augustinegrass shoot mass due to fertilizer treatments were observed on 10 of the 14 collection dates
 - In general, centipedegrass produced 8 – 10 times the quantity of shoots compared to St. Augustinegrass.
- In general, however, centipedegrass produced ~30% more roots than St. Augustinegrass on 3 of the 4 sampling dates.
- In 2008, centipedegrass leached 53% less nitrogen than St. Augustinegrass following the initial application of fertilizer.
- Leaching in 2009 was considerably less than in 2008.
 - Throughout the four 60-day sampling periods, no differences due to turf species or fertilizer source were noted.

- o Over the 49 week study period (21 Apr 2009 – 30 Mar 2010), centipedegrass leached 67% less N than St. Augustinegrass (1.86 vs. 5.65 kg N ha⁻¹).
 - After subtracting the leached quantity detected in the untreated control from the fertilizer source treatments, 49 week leaching totals ranged from 0.0 kg N ha⁻¹ (PCU @ 1.0 lb) to 3.8 kg N ha⁻¹ (ammonium nitrate and urea); however, leaching differences among treatments were not different from each other.
 - These leaching amounts equate to 0.25 – 1.9% of applied nitrogen.
- The winter of 2009/2010 was colder than normal resulting in significant deterioration of the St. Augustinegrass.
 - o Consequently, St. Augustinegrass leached more NO₃⁻-N than centipedegrass on all 60 day cycles, 120 day totals, post 60 day periods, and seasonal totals.
 - The four 60-day treatment cycles averaged 4.87 kg N ha⁻¹ for St. Augustinegrass and 0.22 kg N ha⁻¹ for centipedegrass.
 - The 49 week (20 Apr 2009 – 29 Mar 2010) seasonal leaching total was 23.16 kg N ha⁻¹ for St. Augustinegrass and 1.27 kg N ha⁻¹ for centipedegrass.
 - o Several of the 60-day cycles in 2010 showed a significant Species X Treatment interaction.
 - In all cases, the centipedegrass X fertilizer source treatment interaction was not significant.
 - There were differences in leaching from St. Augustinegrass due to fertilizer source treatment.
 - Leaching from St. Augustinegrass ranged from 1.5 (PCU @ 1.0 lb) to 22.9 (urea) kg N ha⁻¹.
 - On a % of applied basis calculated over the 49 weeks study, urea leached the most (23.6%) followed by ammonium nitrate (20.3%); PCU @ 2.0 lbs (18.5%); 30% SRN (15.4%); 50% SRN (6.6%); biosolid (5.4%); and PCU @ 1.0 lb (3.9%).
- In 2011, leaching from St. Augustinegrass continued to be greater than leaching from centipedegrass.
 - o For the first time in the four year study, centipedegrass was influenced by fertilizer source but from a positive perspective – all plots treated with fertilizer leached *less* than the untreated control plots but the quantity of NO₃⁻-N that was leached was negligible (< 0.029% of applied).

Impact of Fertilizer Applications to Semi-Dormant and Dormant Lawn Grasses on Environmental Quality

- Centipedegrass produced greater biomass (shoot clippings) than St. Augustinegrass.
- Nitrogen rates ≥ 24.0 kg ha⁻¹ improved St. Augustinegrass turf color following the August 2008 application prior to the onset of dormancy and then continued to improve color once the turf greened up in March 2009.
- Higher rates of applied N yielded improved St. Augustinegrass quality and color by enhancing spring green-up. The threshold between acceptable quality was generally around 24 kg ha⁻¹
- Acceptable centipedegrass turf quality was achieved with N rates above 12.5 kg ha⁻¹. Nitrogen rates ≥ 12.5 kg ha⁻¹ promoted a more rapid spring green-up.

- Centipedegrass density during the winter months was not affected by N rate.
- In 2008-09 there were no differences between St. Augustinegrass and centipedegrass in the amount of $\text{NO}_3\text{-N}$ leached or the % of applied N.
- No significant differences in $\text{NO}_3\text{-N}$ leaching between N application rates were detected until sampling periods T5 and T6 (March 2009 through June 2009).
 - During this time period N applied at 49 kg ha^{-1} had the highest leaching (10.9 kg ha^{-1}); more than the other rates applied.
- Leaching events consistently follow major rain events and lead to the total $\text{NO}_3\text{-N}$ leaching being highest with the 49 kg ha^{-1} .
- Over the three year study, leaching was highest during 2006 and is likely attributed to nutrient import from the sod production farm
- Over the three years, centipedegrass leached more $\text{NO}_3\text{-N}$ than St. Augustinegrass during the T3 and T4 time periods.
- Differences in N application rate occurred only at the end of each winter season where the 49 kg N ha^{-1} rate had the highest level of $\text{NO}_3\text{-N}$ leaching.

Influence of Slow Release Nitrogen Source on $\text{NO}_3\text{-N}$ Leaching When Applied to Centipedegrass

- From 2008 – 2010, turf quality differences were minimal.
 - PCU – 120 Day and Corn Gluten Meal generally produced acceptable results but lagged behind all other SRN sources.
- The consequence of providing a cumulative rate of $196 \text{ kg N } 1,000^{-2}$ per year on centipedegrass was fully realized in 2011. The rate of nitrogen exceeds the annual N rate by 200 to 400% depending on the level of maintenance given.
 - No differences in turf quality and turf density were observed in 2011; however, all ratings were significantly below an acceptable level.
- Consisted with the delayed response observed with the turf visual ratings, PCU – 120 Day and Corn Gluten Meal yielded fewer clippings throughout most of the study.
- No differences in rooting due to SRN fertilizer sources were observed at any time throughout the duration of the study.
- In 2008 and 2009, No differences in $\text{NO}_3\text{-N}$ leaching occurred between the six SRN sources.
- In 2010, The PCU – 120 Day and Florikan fertilizers sources leached the greatest quantity (5.5 and $4.5 \text{ kg N } 1,000^{-2}$, respectively), during treatment cycle 4. XCU, methylene urea, and PCU + SCU leached the least (0.17 , 0.56 , and $0.70 \text{ kg N } 1,000^{-2}$ respectively).
- The effects of the deterioration of the turf on $\text{NO}_3\text{-N}$ leaching were evident in 2011.
 - During the first 60 day cycle, PCU – 120 Day leaching the greatest amount (9.5 kg N ha^{-1}) and Corn Gluten Meal leached the least (0.5 kg N ha^{-1}).
 - During the second 60 day cycle of 2011, vast quantities of the applied nitrogen leaching from the treated turf.
 - Leaching values ranged from 6.0 kg N ha^{-1} (Corn Gluten Meal) to $59.7 \text{ kg N ha}^{-1}$ (PCU – 120 Day).
 - Over the 120 day total, the leaching as a percent of applied nitrogen ranged from 7% (Corn Gluten Meal) to 70% (PCU – 120 Day).

INTRODUCTION

There is increasing concern about the effects that lawn and landscape management practices may have on natural water resources, particularly in a state with abundant water resources, encroaching urbanization, shallow water tables, karst soils, and other fragile ecosystems and habitats. Like other agricultural industries in Florida, Best Management Practices (BMPs) have been developed for the Green Industries in Florida in an attempt to mitigate any potential nonpoint source pollution of water resources from fertilization and other lawnglass maintenance practices. With the development and ensuing regulation of the BMPs, there was a need to quantify nutrient loading from these practices under different conditions and sites and to verify the currently recommended rates of nitrogen (N) and phosphorus (P) for use on lawnglass species throughout the state. This research was undertaken by the University of Florida Institute of Food and Agricultural Sciences (UF-IFAS) with funding from the Florida Department of Environmental Protection (FDEP). The research was conducted in 3 locations statewide; at the Ft. Lauderdale Research and Education Center, the Plant Science Research and Education Unit in Citra and at the West Florida Research and Education Center in Jay. The research consisted of multiple projects, some of which were common to all locations. The research ran from 2005-2011.

PROJECTS BY LOCATION

Location	Project Title	Grasses	Start Date	Completion Date
Ft. Lauderdale	Nitrate Leaching From Newly Sodded Grass	St. Augustinegrass	Spring 2005	2006
	Nitrate Leaching From Established Grass	St. Augustinegrass Bahia grass	2006	2008
	Nitrate Leaching Due to N Source and Timing	St. Augustinegrass	2007	2009
	Soil Test Phosphorus	St. Augustinegrass	2008	2009
Gainesville	Nitrate Leaching From Newly Sodded Grass	St. Augustinegrass Zoysiagrass	2005	2008
	Nitrate Leaching From Established Grass	St. Augustinegrass Zoysiagrass	2005	2007
	Nitrate Leaching In Winter Months	St. Augustinegrass Zoysiagrass	Fall 2006	Winter 2009
	Nitrate Leaching Due to N Source	St. Augustinegrass Zoysiagrass	Summer 20008	2011
	Phosphorus Requirements and Leaching	St. Augustinegrass Zoysiagrass	2007	2009
	Phosphorus Leaching	St. Augustinegrass Zoysiagrass	2007	2009
Jay	Nitrate Leaching From Newly Seeded/Sodded Grass	St. Augustinegrass Centipedegrass	2005	2007
	Nitrate Leaching From Established Grass	St. Augustinegrass Centipedegrass	2005	2007
	Nitrate Leaching In Winter Months	St. Augustinegrass Centipedegrass	2006	2009
	Nitrate Leaching Due to SRN and N Source	Centipedegrass	2008	2011

FT. LAUDERDALE PROJECTS – DR. JOHN CISAR

NITRATE LEACHING FROM NEWLY SODDED GRASS

MATERIALS AND METHODS:

Project initiation began in November 2004 with the selection of the experimental site, suitable sands and gravel mixes, and appropriate lysimeter containers. An approximate 400 cubic meters of soil was removed from the experimental site and an underlying fill base foundation was leveled for the elevated experiment. This fill base will allow for gravity flow percolate collection. The experimental design of 36 plots was constructed over the foundation. The candidate landscape soil was a mason sand that best matched the fine native sand found at the Fort Lauderdale site (Landscape sand 62.9% Fine Sand vs. Native sand at 68.7% FINE SAND) and was backfilled into the 36 plots installed with plastic containers (lysimeters). The lysimeters were constructed from 55 gallon plastic drums (36.25 inch high, 23.5 inch diameter, 0.5 inch thick wall, US Plastics Corporation) with a flat bottom which had a threaded opening already manufactured into the container for easy drainage pipe installations. The lysimeters were fitted with 0.75 inch PVC drainage pipe, spliced to allow for lysimeter drainage and individually installed on the foundation. The drainage pipe system was individually tested for outflow prior to backfilling. Each drainage orifice was fitted with a stainless steel screen to avoid clogging. The lysimeters were individually leveled and backfilled with approximately 4 inches of 0.24 inch 'river gravel'. A 2.0 inch layer of coarse sand was backfilled on top of the gravel and then the landscape sand was backfilled by hand into the lysimeter and uniformly compacted throughout the backfilling process. Upon completion of the backfilling of lysimeters, the surrounding plot area was backfilled in a similar manner to match the construction of the lysimeter. Thereafter, the surrounding field site was filled in, and graded for final installation of the turfgrass. An irrigation system with individually controlled zones for each plot was installed. Sampling stations were excavated to allow access to drainage pipes and were fitted with [36] 5 gallon containers to collect percolate from each lysimeter.

The experimental design consisted of eighteen main irrigation plots (4m x 4m) that were split in half (plot size 4m x 2m) with each half containing either muck or mineral sod making 36 subplots with installed lysimeters. There were 3 replications each containing 3 fertilizer treatments: 1.) no fertilizer, 2.) 1.0 lb. N/M of 6-6-6 [United Industries Corporation; total N: 6.00%, 2.35% ammoniacal nitrogen and 3.65% urea nitrogen] at trial initiation, and 3.) 1.0 lb. N/M of 6-6-6 at 30 days after initiation, and 2 irrigation treatments: 1.) 0.25 inch twice daily for 30 days, then 0.50 inch every other day for 30 days (ALT), and 2.) 0.25 inch twice daily for 30 days, then 0.50 inch at sign of visual wilt for 30 days (WO). Experiment trial duration was approximately 2 months, sod was then removed and plots left fallow for 2 months. New sod was installed at the beginning of each of three trials. Turfgrass quality scores (scale of 1-10 with 10=dark green turf, 1=dead/brown turf, and 6=minimally acceptable turf) and percent wilt (when visible) were taken throughout the experimental period. Turfgrass clipping samples for shoot growth were taken at a 3.0 inch height of cut approximately monthly or more frequently when necessary. Clipping dry weights were obtained after oven dried at 60 degrees C. Percolate water samples were taken twice weekly and more frequently when a rain event occurred. Percolate samples were taken and processed following DEP QA/QC protocol and were shipped to the Gainesville analytical laboratory for nitrate and ortho-P analysis. Flow weighted mean concentration (total leached/ total percolate) and total leached were determined from analyses for 0-30 days after initiation (0-30DAI) and for 31-60 days after initiation (31-60 DAI). A pre-trial fertilization of minors (AFEC Major Minors #1070: Cl: 2%; Mg: 9.4%; Mn: 3.0%; Cu: 0.2%; Zn: 0.7%; Fe: 6.25%) was applied to and incorporated into the soil at 20lbs/M/plot. Additionally incorporated into the soil was 0.5lbs/M/plot of triple super phosphate (0-46-0). This was done before each of the three trials began. Trials 1& 2 received organic soil based sod from King Ranch

and mineral soil based sod from A. Duda & Sons. Trial 3 received organic soil based sod from TJ Farms and mineral soil based sod from A. Duda & Sons. Samples of each sod type were analyzed for percent organic matter and N content (See Appendix A for %OM within each sod for all three Trials). Rooting samples were taken twice (after trial 2 and trial 3) by removing 4 inch diameter cup cutter cores at 2 depths: 0-15cm and 15-30cm. Root ash weights were determined (see Appendix B) All data was subject to statistical analysis and significant means were identified.

RESULTS AND DISCUSSION

TRIAL 1: March 29th - May 25th, 2005

CLIMATE AND HYDROLOGY:

Trial 1 encompassed a dry period with a mean temperature of 24.8 °C (ranging from 16 – 34 °C) and humidity averaging 67 % (ranging from 53-86 %). During Trial 1, seven separate rainfall events occurred, with a cumulative total of 108 mm. Nitrate-N and orthophosphate concentrations within the rainfall for five of the rain events ranged from 0.05-0.15 and 0.05-0.80 mg l⁻¹ respectively, with means of 0.11 and 0.35 mg l⁻¹ for nitrate-N and orthophosphate respectively. Rainfall contributed a total of 11.9 and 38.3 mg m⁻² of nitrate-N and orthophosphate over the Trial. The average volume of percolate collected over the period was 293 mm. Over twice as much percolate occurred during the first 30 DAI (mean = 210 mm) than occurred in the last 30 days of the experiment (mean=83 mm, P<0.01). Irrigation influenced volumes during the second half of the trial, with greater percolate volumes from the ALT irrigation schedule (mean=117 mm, st. dev. = 64 mm) compared to the WO irrigation schedule (mean=49 mm, std. dev. = 36 mm, Table 1).

Table 1. Significant differences for observations and measurements over the first 30 days and the second 30 days for Trial 1.

Days after initiation	Volumes		NO ₃ -N concentration		NO ₃ -N leached		PO ₄ -P concentration		PO ₄ -P leached		Quality Scores		Clipping Yields	
	0-30†‡	31-60	0-30	31-60	0-30	31-60	0-30	31-60	0-30	31-60	0-30	31-60	0-30	31-60
IRR	---	**	---	ns	---	ns	---	ns	---	**	---	ns	---	ns
FERT	ns‡	ns	ns	ns	ns	ns	ns	ns	ns	*	*	**	ns	ns
IRR*FERT	---	ns	---	ns	---	ns	---	ns	---	*	---	ns	---	ns
SOD	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	**	**	**	**
SOD*IRR	---	ns	---	ns	---	ns	---	ns	---	ns	---	ns	---	ns
SOD*FERT	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	**	ns	ns	**
SOD*FERT*IRR	---	ns	---	ns	---	ns	---	ns	---	ns	---	ns	---	ns

† Irrigation and other factor interaction with irrigation were not tested for 0-30 DAI since irrigation treatments were not initiated until 31 DAI.

‡ Fertilizer treatments tested were: no fertilizer applied (NONE), and fertilizer applied at the time of sodding (0 DAI) or 30 days after sodding (30DAI).

‡ ns, * and ** = P>0.05, P<0.05, and P<0.01 respectively.

NITRATE-N CONCENTRATIONS AND LEACHING:

Nitrate-N concentrations during the first half of the experiment ranged from 0.88 to 40.7 mg l⁻¹ (mean = 13.3 mg l⁻¹), the latter being above the EPA maximum contaminant level of 10 mg l⁻¹ for drinking water (USEPA, 2005). Concentrations were considerably lower over the second half of the trial, ranging from

0.22 to 6.02 mg l⁻¹ (mean = 1.07 mg l⁻¹, P<0.01). Variations in nitrate-N concentrations and leaching appeared to be random events, since they were not influenced by any treatment factor or interaction during Trial 1 (Tables 1, 2 and 3).

Table 2. Flow weighted nitrate-N concentrations (mean ± std. dev.) for each factor and interaction during Trial 1.

		Nitrate-N concentration (mg l ⁻¹)			
		0-30DAI		31-60DAI	
(a)					
Fertilizer					
None		10.5 ± 6.7		1.5 ± 2.1	
0DAI		21.7 ± 11.7		0.8 ± 0.8	
30DAI		n/a		0.5 ± 0.3	
(b)					
Irrigation					
ALT		n/a		0.8 ± 1.4	
WO		n/a		1.0 ± 1.4	
(c) Sod					
Organic		14.5 ± 10.2		1.0 ± 1.5	
Mineral		13.6 ± 9.9		0.8 ± 1.3	
(d) SOD					
X FERT					
	Organic	Mineral	Organic	Mineral	
None	10.7 ± 5.7	10.4 ± 7.9	1.6 ± 2.2	1.3 ± 2.2	
0DAI	22.8 ± 13.5	20.6 ± 11.1	0.8 ± 1.0	0.7 ± 0.7	
30DAI	n/a	n/a	0.5 ± 0.3	0.5 ± 0.3	
(e) IRR					
X FERT					
	ALT	WO	ALT	WO	
None	n/a	n/a	1.5 ± 2.2	1.4 ± 2.3	
0DAI	n/a	n/a	0.3 ± 0.1	1.7 ± 1.0	
30DAI	n/a	n/a	0.6 ± 0.3	0.4 ± 0.3	
(f) SOD					
X IRR					
	Organic	Mineral	Organic	Mineral	
ALT	n/a	n/a	1.2 ± 2.0	0.4 ± 0.3	
WO	n/a	n/a	0.8 ± 0.8	1.3 ± 1.9	
(g) SOD					
X IRR X					
FERT					
	Organic		Mineral		
	ALT	WO	ALT	WO	
None	n/a	n/a	n/a	n/a	2.7 ± 2.9
0DAI	n/a	n/a	n/a	n/a	0.3 ± 0.2
30DAI	n/a	n/a	n/a	n/a	0.4 ± 0.2
	Organic		Mineral		
	ALT	WO	ALT	WO	
None	n/a	n/a	n/a	n/a	0.5 ± 0.5
0DAI	n/a	n/a	n/a	n/a	1.6 ± 1.5
30DAI	n/a	n/a	n/a	n/a	0.5 ± 0.4
	Organic		Mineral		
	ALT	WO	ALT	WO	
None	n/a	n/a	n/a	n/a	0.4 ± 0.2
0DAI	n/a	n/a	n/a	n/a	0.2 ± 0.0
30DAI	n/a	n/a	n/a	n/a	0.6 ± 0.3
	Organic		Mineral		
	ALT	WO	ALT	WO	
None	n/a	n/a	n/a	n/a	2.8 ± 3.6
0DAI	n/a	n/a	n/a	n/a	1.4 ± 0.8
30DAI	n/a	n/a	n/a	n/a	0.3 ± 0.1

Table 3. Nitrate-N leaching (mean $\pm$ std. dev.) for each factor and interaction during Trial 1.

		Nitrate leaching (mg m ⁻²)							
		0-30DAI				31-60DAI			
(a)									
Fertilizer									
None		581 ± 442				48 ± 80			
0DAI		1040 ± 732				10 ± 5			
30DAI		n/a				7 ± 9			
(b)									
Irrigation									
ALT		n/a				24 ± 50			
WO		n/a				20 ± 51			
(c) Sod									
Organic		678 ± 511				23 ± 52			
Mineral		772 ± 653				22 ± 49			
(d) SOD									
X FERT		Organic		Mineral		Organic		Mineral	
None		620 ± 426		544 ± 476		49 ± 82		79 ± 87	
0DAI		807 ± 704		1274 ± 758		9.0 ± 5.6		11 ± 4.4	
30DAI		n/a		n/a		5.5 ± 4.0		9.1 ± 11	
(e) IRR									
X FERT		ALT		WO		ALT		WO	
None		n/a		n/a		51 ± 81		45 ± 88	
0DAI		n/a		n/a		7.2 ± 2.4		14 ± 4.5	
30DAI		n/a		n/a		13 ± 10		2.8 ± 1.1	
(f) SOD									
X IRR		Organic		Mineral		Organic		Mineral	
ALT		n/a		n/a		39 ± 72		11 ± 8.8	
WO		n/a		n/a		7.0 ± 7.0		35 ± 74	
(g) SOD									
X IRR X									
FERT									
		Organic		Mineral		Organic		Mineral	
		ALT	WO	ALT	WO	ALT	WO	ALT	WO
None		n/a	n/a	n/a	n/a	91 ± 106	7.0 ± 8.8	11 ± 8.4	103 ± 142
0DAI		n/a	n/a	n/a	n/a	6.1 ± 2.1	13 ± 7.2	8.2 ± 2.5	15 ± 1.9
30DAI		n/a	n/a	n/a	n/a	9.6 ± 2.1	2.7 ± 0.8	15 ± 14	2.8 ± 1.3

ORTHOPHOSPHATE CONCENTRATIONS AND LEACHING:

Orthophosphate concentrations during the first half of the experiment ranged from 0.02 to 7.46 mg l⁻¹ (mean = 2.26 mg l⁻¹), which exceeds the EPA criteria of 0.05 mg l⁻¹ for streams discharge into lakes or reservoirs (USEPA, 1986). Concentrations were lower over the second half of the trial, ranging from 0.02 to 4.65 mg l⁻¹ (mean = 1.33 mg l⁻¹, P=0.05). Orthophosphate concentrations were not influenced by any factor or interaction during the study.

Orthophosphate leaching was greater during the first half of the trial in comparison to the second half (115 and 31.6 mg m⁻² respectively, P<0.01). While no factor or interaction influenced orthophosphate leaching during the initial 30 days, the interaction of IRR*FERT influenced orthophosphate leaching during the second half of the trial (Tables 1 and 6). During this time, less orthophosphate leaching was determined from the St. Augustinegrass maintained with the ALT irrigation schedule and fertilized at 30DAI compared to the St. Augustinegrass not fertilized, or fertilized at 0DAI (Table 6, P<0.01). In comparison, orthophosphate leaching from the WO irrigation schedule was similar regardless of fertilization treatment (Table 6, P>0.05). For the no fertilizer and 0DAI fertilizer treatments, applying irrigation only when wilt was apparent reduced orthophosphate leaching (Table 6).

Table 4. Flow weighted orthophosphate concentrations (mean $\pm$ std. dev.) for each factor and interaction during Trial 1.

		Orthophosphate concentration (mg l ⁻¹)			
		0-30DAI		31-60DAI	
(a)					
Fertilizer					
None		1.7 ± 2.4		1.4 ± 1.4	
0DAI		3.6 ± 2.3		2.3 ± 1.3	
30DAI		n/a		0.6 ± 0.5	
(b)					
Irrigation					
ALT		n/a		1.8 ± 1.1	
WO		n/a		1.0 ± 1.4	
(c) Sod					
Organic		2.3 ± 2.2		1.6 ± 1.1	
Mineral		2.2 ± 2.8		1.2 ± 1.5	
(d) SOD					
X FERT					
	Organic	Mineral	Organic	Mineral	
None	2.1 ± 2.4	1.3 ± 2.4	1.7 ± 1.3	1.2 ± 1.6	
0DAI	2.9 ± 2.1	4.2 ± 2.7	2.3 ± 0.8	2.2 ± 1.7	
30DAI	n/a	n/a	0.9 ± 0.5	0.3 ± 0.4	
(e) IRR					
X FERT					
	ALT	WO	ALT	WO	
None	n/a	n/a	2.4 ± 1.2	0.3 ± 0.2	
0DAI	n/a	n/a	2.1 ± 0.7	2.5 ± 2.0	
30DAI	n/a	n/a	0.7 ± 0.6	0.5 ± 0.4	
(f) SOD					
X IRR					
	Organic	Mineral	Organic	Mineral	
ALT	n/a	n/a	2.2 ± 0.7	1.4 ± 1.3	
WO	n/a	n/a	1.1 ± 1.1	0.9 ± 1.7	
(g) SOD					
X IRR X					
FERT					
	Organic		Mineral		
	ALT	WO	ALT	WO	
None	n/a	n/a	n/a	n/a	2.8 ± 0.08
0DAI	n/a	n/a	n/a	n/a	2.0 ± 0.7
30DAI	n/a	n/a	n/a	n/a	1.4 ± 0.1
					0.5 ± 0.08
					2.7 ± 1.1
					0.2 ± 0.2
					0.4 ± 0.6
					1.9 ± 1.8
					2.1 ± 0.8
					2.4 ± 3.2
					0.08 ± 0.07

Table 5. Orthophosphate leaching (mean $\pm$ std. dev.) for each factor and interaction during Trial 1.

		Orthophosphate leaching (mg m ⁻²)			
		0-30DAI		31-60DAI	
(a)					
Fertilizer					
None		89 ± 132		48 ± 60	
0DAI		205 ± 185		46 ± 29	
30DAI		n/a		11 ± 15	
(b)					
Irrigation					
ALT		n/a		56 ± 47	
WO		n/a		10 ± 13	
(c) Sod					
Organic		123 ± 138		37 ± 39	
Mineral		128 ± 179		32 ± 45	
(d) SOD					
X FERT					
	Organic	Mineral		Organic	Mineral
None	122 ± 143	57 ± 118		52 ± 56	42 ± 69
0DAI	124 ± 142	286 ± 201		39 ± 25	53 ± 33
30DAI	n/a	n/a		17 ± 20	5.8 ± 6.6
(e) IRR					
X FERT					
	ALT	WO		ALT	WO
None	n/a	n/a		83 ± 61	4.5 ± 3.4
0DAI	n/a	n/a		60 ± 27	25 ± 175
30DAI	n/a	n/a		18 ± 20	4.9 ± 5.3
(f) SOD					
X IRR					
	Organic	Mineral		Organic	Mineral
ALT	n/a	n/a		63 ± 41	50 ± 53
WO	n/a	n/a		11 ± 11	8.6 ± 15
(g) SOD					
X IRR X					
FERT					
	Organic		Mineral		
	ALT	WO	ALT	WO	
None	n/a	n/a	n/a	n/a	98 ± 39
0DAI	n/a	n/a	n/a	n/a	45 ± 33
30DAI	n/a	n/a	n/a	n/a	36 ± 22
	Organic		Mineral		
	ALT	WO	ALT	WO	
None	n/a	n/a	n/a	n/a	5.8 ± 3.4
0DAI	n/a	n/a	n/a	n/a	29 ± 5.9
30DAI	n/a	n/a	n/a	n/a	5.2 ± 5.2
	Organic		Mineral		
	ALT	WO	ALT	WO	
None	n/a	n/a	n/a	n/a	68 ± 84
0DAI	n/a	n/a	n/a	n/a	2.6 ± 3.2
30DAI	n/a	n/a	n/a	n/a	21 ± 28
	Organic		Mineral		
	ALT	WO	ALT	WO	
None	n/a	n/a	n/a	n/a	6.9 ± 7.8
0DAI	n/a	n/a	n/a	n/a	4.6 ± 6.5
30DAI	n/a	n/a	n/a	n/a	4.6 ± 6.5

Table 6. Interaction of IRR*FERT on orthophosphate leaching (mg m⁻²) during the second half of Trial 1.

FERT / IRR	ALT	WO	Within FERT Significance
None	83 a†	4.5 a	<0.0001
0DAI	60 a	25 a	0.0111
30 DAI	18 b	4.9 a	0.4083

†Means with the same letter within a column are not significantly different at the 0.05 significance level.

TURFGRASS VISUAL QUALITY:

Mean turfgrass quality was rated at 7.1 during the first 30 days of the trial, which was similar to the mean quality ratings during the second half of the trial (6.7, $P>0.05$). With the exception on $[\text{NO}_3\text{-N}]$, fertilizer did not influence N and P losses during the first half of the trial. However fertilizer did influence quality scores with greater quality from turf fertilized at 0 DAI compared to non-fertilized turf (mean = 7.6 and 6.8 respectively, $P<0.01$, Table 1). For the second half of the trial, visual quality decreased for St. Augustinegrass receiving no fertilizer or fertilizer at 0DAI, and while they were similar in value, both were lower than quality on St. Augustinegrass fertilized at 30DAI (Tables 1 and 7). For both halves of the trial, organic soil grown sod had better visual quality than mineral soil grown sod (Table 1, Figure 1).

Table 7. Visual quality‡ was affected by FERT during the second half of Trial 1.

FERT	Mean	Std. dev.
None	6.2 a†	1.0
0DAI	6.5 a	0.8
30 DAI	7.4 b	0.7
Significance	<0.0001	

‡ Visual quality rated on a scale from 1 to 10 with 1=dead turf, 6= minimally acceptable, and 10= dark green healthy turfgrass.

†Means with the same letter within a column are not significantly different at the 0.05 significance level.

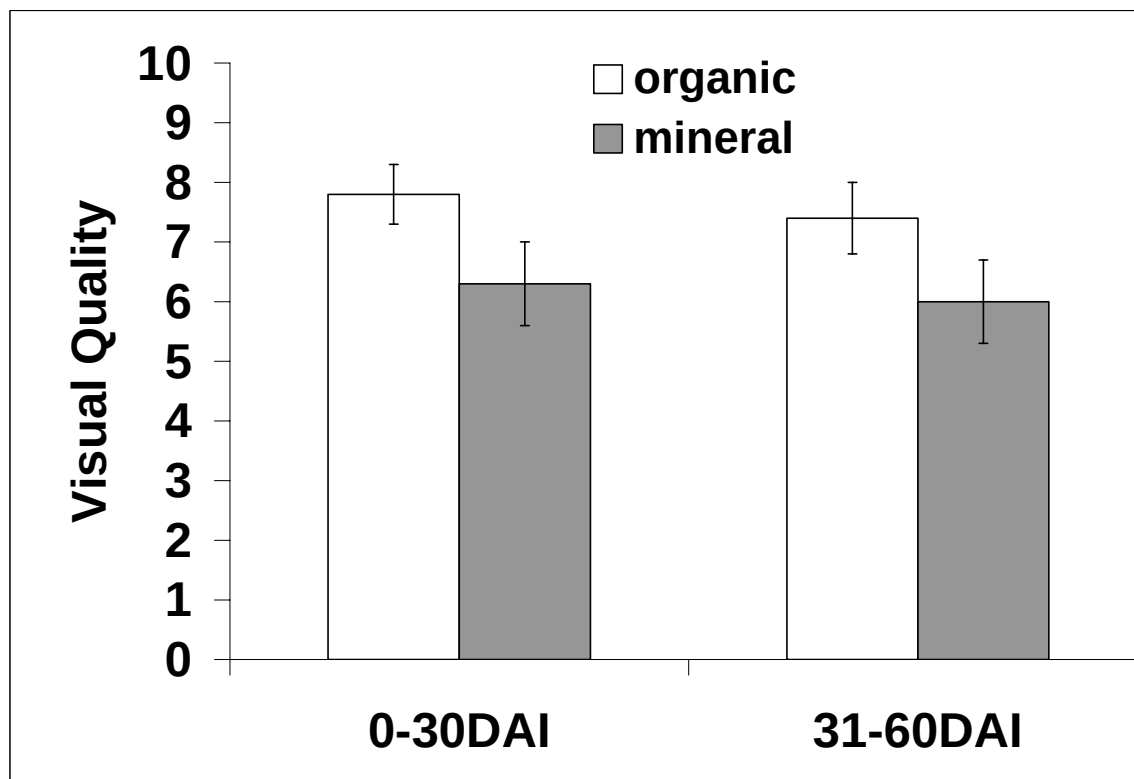


Figure 1. Comparison of visual quality scores (mean $\pm$ one standard deviation) from the two sod types for each half of Trial 1.

GROWTH:

Dry clipping yields from the first half of the trial were greater than yields from the second half of the trial (means= 15.0 and 8.0 g m⁻² for 0-30DAI and 31-60DAI respectively, P<0.05). Clipping yields during the both halves of the trial were influenced by sod type with the addition of the interaction of SOD*FERT for the second half of the trial (Table 1). During both halves of the trial, greater dry clipping yields from the organic soil grown sod were collected in comparison to the mineral soil grown sod (Table 1, Figure 2). During the second half of the trial, the SOD*FERT interaction determined that dry clipping yields were greater for organic soil grown sod than mineral soil grown sod at each fertilization level (Table 8). More importantly, the interaction determined that all fertilization levels had the same affect on clipping yields for the mineral soil grown sod, however organic soil grown sod fertilized at 30 DAI resulted in greater growth than the other two treatments (Table 8).

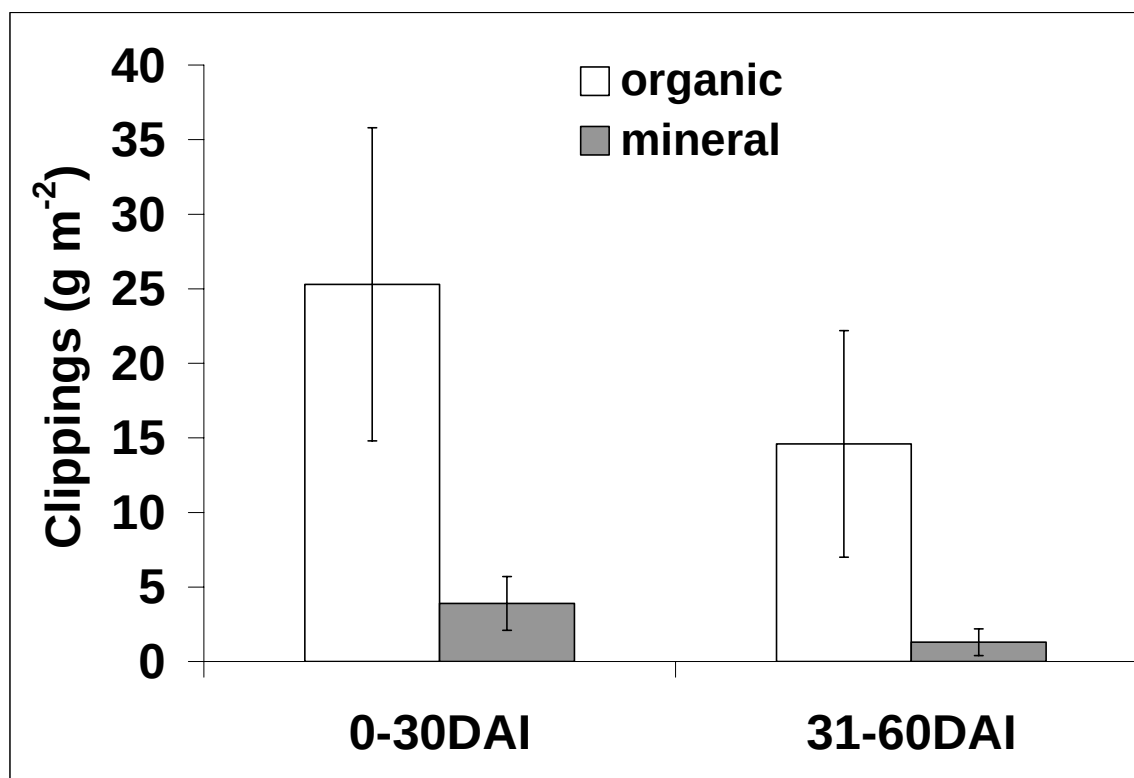


Figure 2. Comparison of mean (and $\pm$ one standard deviation) dry clipping yields (g m⁻²) from the two sod types for each half of Trial 1.

Table 8. Interaction of SOD*FERT on dry clipping yield (g m⁻²) during the second half of Trial 1.

FERT / SOD	Organic	Mineral	Within FERT Significance
None	10.5 b†	0.6 a	0.0091
0DAI	12.3 b	1.2 a	0.0041
30 DAI	21.6 a	1.9 a	<0.0001

†Means with the same letter within a column are not significantly different at the 0.05 significance level.

TRIAL 2: September 14th – November 14th, 2005

CLIMATE AND HYDROLOGY:

Compared to Trial 1, Trial 2 was relatively wet with rain occurring on twenty days for a cumulative total of 262 mm. The mean temperature during Trial 2 was 25.9 °C (ranging from 10 – 34 °C) with humidity averaging 75 % (ranging from 58-87 %). During Trial 2, nitrate-N and orthophosphate concentrations within the rainfall for seven of the rain events ranged from 0.00-0.08 and 0.01-0.12 mg l⁻¹ respectively, with means of 0.01 and 0.05 mg l⁻¹ for nitrate-N and orthophosphate respectively. Rainfall contributed a total of 0.12 and 12.5 mg m⁻² of nitrate-N and orthophosphate over the Trial. On October 22nd, all irrigation was turned off due to Hurricane Wilma. After the Hurricane, there was no electrical power for irrigation until October 26th, at which time all turfgrass received 12.7 mm of irrigation water. Thereafter, normal 30DAI irrigation treatments were resumed.

Percolate volumes collected over the period ranged from 441 to 1084 mm (mean = 891 mm). Over twice as much percolate was collected during the first 30 DAI (mean = 607 mm) than what occurred in the last 30 days of the experiment (mean=288 mm, P<0.01). Compared to Trial 1, in which percolate volumes during the second half of the trial were influenced by irrigation scheduling, no factor or interaction influenced percolate volumes during Trial 2 (Table 9).

Table 9. Significant differences for observations and measurements over the first 30 days and the second 30 days for Trial 2.

	Volumes		NO ₃ -N concentration		NO ₃ -N leached		PO ₄ -P concentration		PO ₄ -P leached		Quality Scores		Clipping Yields	
Days after initiation	0-30†‡	31-60	0-30	31-60	0-30	31-60	0-30	31-60	0-30	31-60	0-30	31-60	0-30	31-60
IRR	---	ns	---	ns	---	ns	---	ns	---	ns	---	ns	---	ns
FERT	ns	ns	ns	*	ns	*	ns	ns	ns	ns	**	**	ns	**
IRR*FERT	---	ns	---	ns	---	ns	---	ns	---	ns	---	ns	---	ns
SOD	ns	ns	ns	ns	ns	ns	ns	*	ns	ns	**	**	**	**
SOD*IRR	---	ns	---	ns	---	ns	---	ns	---	ns	---	ns	---	ns
SOD*FERT	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	**	ns	ns	*
SOD*FERT*IRR	---	ns	---	ns	---	ns	---	ns	---	ns	---	ns	---	ns

† Irrigation and other factor interaction with irrigation was not tested for 0-30 DAI since irrigation treatments were not initiated until 31 DAI.

‡ Fertilizer treatments tested were no fertilizer applied (NONE and 30DAI) and 0 DAI.

‡ ns, * and ** = P>0.05, P<0.05, and P<0.01 respectively.

NITRATE-N CONCENTRATIONS AND LEACHING:

Nitrate-N concentrations during the first half of the experiment ranged from 0.24 to 29.5 mg l⁻¹ (mean = 7.71 mg l⁻¹). A larger range of concentrations was observed over the second half of the trial (ranging from 0.21 to 51.0 mg l⁻¹), with a mean value of 6.00 mg l⁻¹ being similar to concentrations during the first half of the trial (P=0.48). Nitrate-N concentrations were influenced by fertilizer treatments during the second half of Trial 2 (Tables 9 and 10). For the most part, nitrate-N concentrations were similar except for shortly after a large rain event occurring on 29 September resulting in 46 mm of rainfall (Figure 3). For the remainder of Trial 2, nitrate-N concentrations were highest in percolate collected from St. Augustinegrass fertilized at 30DAI (mean = 14.7 mg l⁻¹, Figure 3). These concentrations were similar to concentrations from St. Augustinegrass fertilized 0DAI (mean = 2.68 mg l⁻¹), but higher than

concentrations from St. Augustinegrass not fertilized (mean = 0.60 mg l⁻¹, P=0.03). Again, the difference in means was driven by rainfall events (Figures 3 and 4).

Nitrate leaching was greater during the first half of the trial in comparison to the second half (1,089 and 406 mg m⁻² respectively, P<0.01). Nitrate leaching was influenced by fertilizer application during the second half of Trial 2 (Table 9 and 11, Figure 5). Similar to nitrate-N concentrations, peaks in nitrate leaching followed rainfall events (Figures 4 and 5).

Table 10. Flow weighted nitrate-N concentrations (mean ± std. dev.) for each factor and interaction during Trial 2.

		Nitrate-N concentration (mg l ⁻¹)			
		0-30DAI		31-60DAI	
(a)					
Fertilizer					
None		3.8 ± 4.0		0.6 ± 1.1	
0DAI		15.5 ± 11.2		2.7 ± 4.7	
30DAI		n/a		14.7 ± 15.8	
(b)					
Irrigation					
ALT		n/a		7.3 ± 13.7	
WO		n/a		4.6 ± 8.2	
(c) Sod					
Organic		7.9 ± 8.9		4.1 ± 6.7	
Mineral		7.5 ± 9.4		7.9 ± 14.4	
(d) SOD					
X FERT		Organic	Mineral	Organic	Mineral
None		3.7 ± 3.4	3.9 ± 4.8	0.3 ± 0.3	0.9 ± 1.6
0DAI		16.3 ± 10.8	14.6 ± 12.6	2.7 ± 5.0	2.7 ± 4.8
30DAI		n/a	n/a	9.3 ± 8.7	20.2 ± 20.1
(e) IRR					
X FERT		ALT	WO	ALT	WO
None		n/a	n/a	0.3 ± 0.3	0.9 ± 1.6
0DAI		n/a	n/a	4.3 ± 6.3	1.1 ± 1.3
30DAI		n/a	n/a	17.7 ± 19.9	11.8 ± 11.5
(f) SOD					
X IRR		Organic	Mineral	Organic	Mineral
ALT		n/a	n/a	5.0 ± 8.7	9.9 ± 17.5
WO		n/a	n/a	3.2 ± 4.2	5.9 ± 11.0
(g) SOD					
X IRR X					
FERT					
		Organic	Mineral	Organic	Mineral
		ALT	WO	ALT	WO
None		n/a	n/a	0.5 ± 0.4	0.2 ± 0.0
0DAI		n/a	n/a	4.4 ± 7.3	1.0 ± 1.3
30DAI		n/a	n/a	10.2 ± 13.4	8.4 ± 2.8
				0.2 ± 0.0	1.5 ± 2.2
				4.2 ± 6.9	1.1 ± 1.5
				25.2 ± 25.4	15.2 ± 16.9

Table 11. Nitrate-N leaching (mean $\pm$ std. dev.) for each factor and interaction during Trial 2.

		Nitrate-N leaching (mg m ⁻²)			
		0-30DAI		31-60DAI	
(a)					
Fertilizer					
None		543 ± 592		36 ± 56	
0DAI		2179 ± 1664		196 ± 361	
30DAI		n/a		985 ± 1098	
(b)					
Irrigation					
ALT		n/a		519 ± 537	
WO		n/a		292 ± 566	
(c) Sod					
Organic		1123 ± 1269		276 ± 443	
Mineral		1055 ± 1382		236 ± 999	
(d) SOD					
X FERT					
	Organic	Mineral		Organic	Mineral
None	529 ± 517	559 ± 681		25 ± 19	48 ± 79
0DAI	2311 ± 1530	2048 ± 1926		205 ± 396	188 ± 360
30DAI	n/a	n/a		598 ± 551	1372 ± 1410
(e) IRR					
X FERT					
	ALT	WO		ALT	WO
None	n/a	n/a		25 ± 19	48 ± 80
0DAI	n/a	n/a		329 ± 489	65 ± 79
30DAI	n/a	n/a		1205 ± 1365	765 ± 821
(f) SOD					
X IRR					
	Organic	Mineral		Organic	Mineral
ALT	n/a	n/a		345 ± 577	693 ± 1215
WO	n/a	n/a		207 ± 272	378 ± 768
(g) SOD					
X IRR X					
FERT					
	Organic		Mineral		
	ALT	WO	ALT	WO	
None	n/a	n/a	n/a	n/a	34 ± 25
0DAI	n/a	n/a	n/a	n/a	15 ± 1.4
30DAI	n/a	n/a	n/a	n/a	15 ± 0.9
	Organic		Mineral		
	ALT	WO	ALT	WO	
None	n/a	n/a	n/a	n/a	81 ± 112
0DAI	n/a	n/a	n/a	n/a	64 ± 91
30DAI	n/a	n/a	n/a	n/a	991 ± 1224

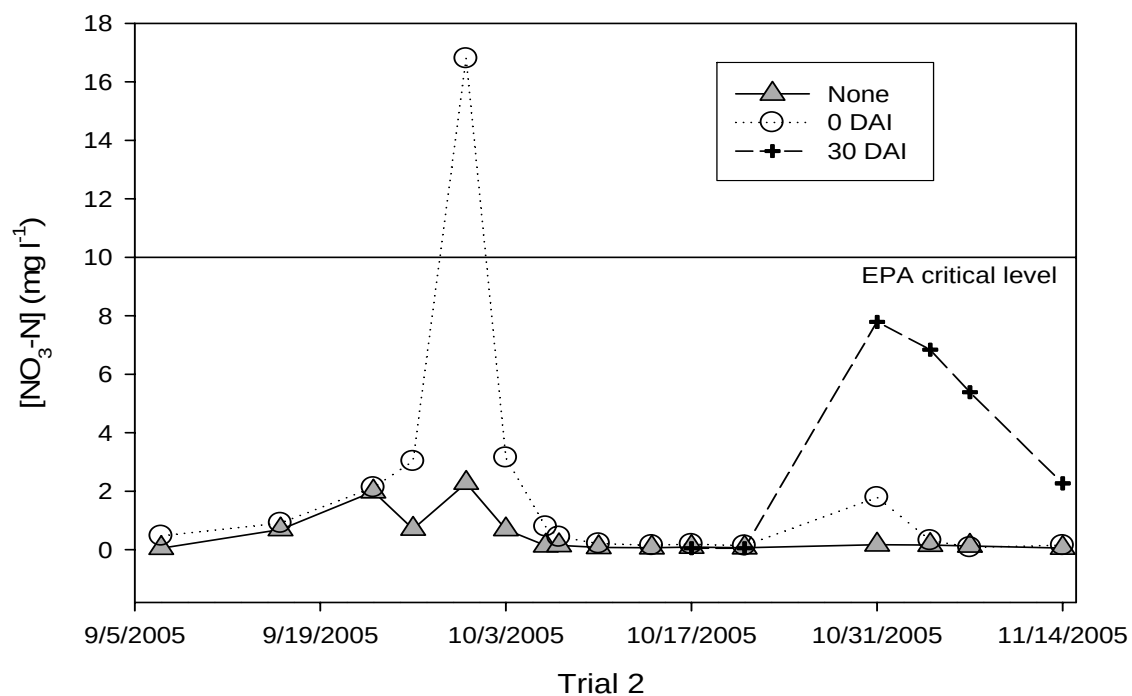


Figure 3. Nitrate-N concentrations during Trial 2 were influenced by fertilizer level.

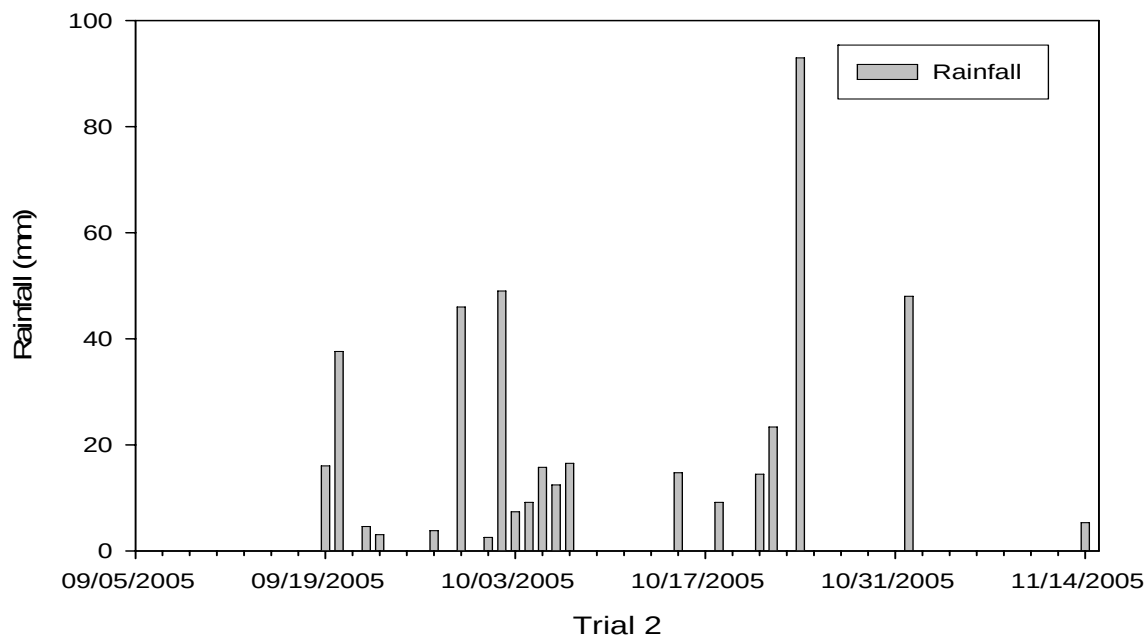


Figure 4. Daily rainfall during Trial 2.

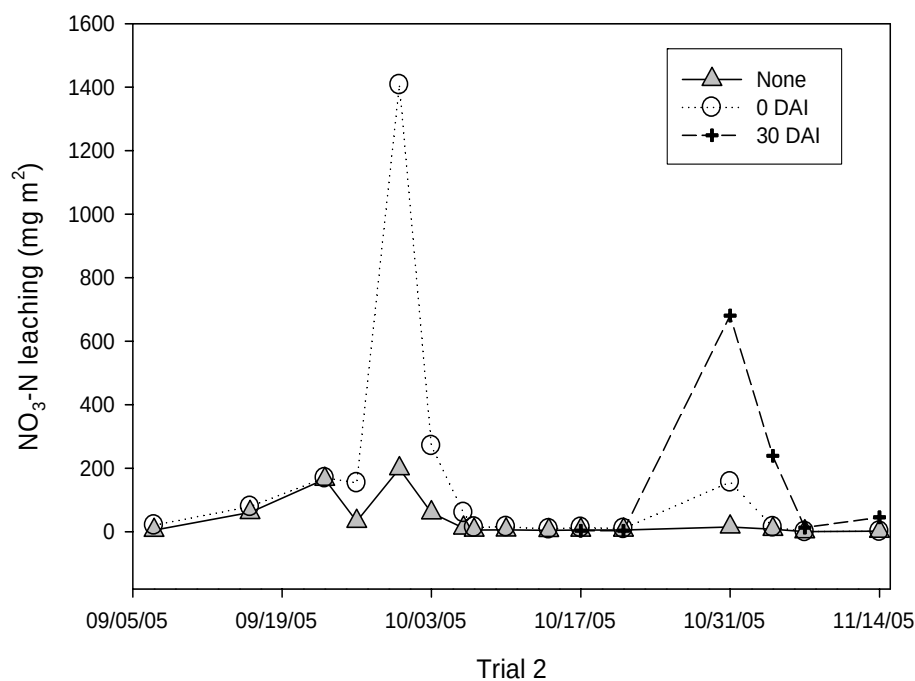


Figure 5. Nitrate-N leaching during Trial 2 was influenced by fertilizer level.

ORTHOPHOSPHATE CONCENTRATIONS AND LEACHING:

Orthophosphate concentrations during the first half of the trial ranged from 0.15 to 6.41 mg l^{-1} (mean = 2.05 mg l^{-1}), which exceeds the EPA criteria of 0.05 mg l^{-1} for stream discharge into lakes or reservoirs (USEPA, 1986). Concentrations were lower over the second half of the trial, ranging from 0.27 to 3.37 mg l^{-1} (mean = 1.58 mg l^{-1} , $P=0.03$) however still above the EPA critical value. With the exception of sod type influencing orthophosphate concentrations during the second half of Trial 2, no other factor or interactions influenced orthophosphate concentrations during the trial (Tables 9 and 12). Organic soil grown sod had lower orthophosphate concentrations than mineral soil grown sod during the last half of the trial (means = 1.39 and 1.77 mg l^{-1} , $P=0.02$).

Orthophosphate leaching was greater during the first half of the trial in comparison to the second half (290 and 102 mg m^{-2} respectively, $P<0.01$). No factor or interaction influenced orthophosphate leaching during Trial 2 (Tables 9 and 13).

Table 12. Flow weighted orthophosphate concentrations (mean $\pm$ std. dev.) for each factor and interaction during Trial 2.

		Orthophosphate concentration (mg l ⁻¹)						
		0-30DAI	31-60DAI					
(a)								
Fertilizer								
None		1.7 ± 0.6	1.4 ± 0.4					
0DAI		2.7 ±1.7	1.8 ± 0.7					
30DAI		n/a	1.5 ± 0.7					
(b)								
Irrigation								
ALT		n/a	1.7 ± 0.6					
WO		n/a	1.5 ± 0.7					
(c) Sod								
Organic		1.9 ± 1.0	1.4 ± 0.5					
Mineral		2.2 ±1.3	1.8 ± 0.7					
(d) SOD								
X FERT								
	Organic	Mineral	Organic	Mineral				
None	1.5 ± 0.7	1.9 ± 0.4	1.2 ± 0.3	1.6 ± 0.4				
0DAI	2.6 ± 1.2	2.9 ± 2.2	1.8 ± 0.5	1.8 ± 0.9				
30DAI	n/a	n/a	1.2 ± 0.6	1.9 ± 0.6				
(e) IRR								
X FERT								
	ALT	WO	ALT	WO				
None	n/a	n/a	1.5 ± 0.3	1.3 ± 0.4				
0DAI	n/a	n/a	1.8 ± 0.3	1.8 ± 1.0				
30DAI	n/a	n/a	1.7 ± 0.9	1.4 ± 0.3				
(f) SOD								
X IRR								
	Organic	Mineral	Organic	Mineral				
ALT	n/a	n/a	1.3 ± 0.6	2.0 ± 0.4				
WO	n/a	n/a	1.5 ± 0.5	1.6 ± 0.8				
(g) SOD								
X IRR X								
FERT								
	Organic		Mineral		Organic		Mineral	
	ALT	WO	ALT	WO	ALT	WO	ALT	WO
None	n/a	n/a	n/a	n/a	1.3 ± 0.3	1.1 ± 0.4	1.7 ± 0.3	1.5 ± 0.5
0DAI	n/a	n/a	n/a	n/a	1.7 ± 0.3	1.9 ± 0.6	1.9 ± 0.4	1.8 ± 1.4
30DAI	n/a	n/a	n/a	n/a	1.0 ± 0.9	1.3 ± 0.2	2.3 ± 0.2	1.4 ± 0.5

Table 13. Orthophosphate leaching (mean $\pm$ std. dev.) for each factor and interaction during Trial 2.

		Orthophosphate leaching (mg m ⁻²)					
		0-30DAI				31-60DAI	
(a)							
Fertilizer							
None		244 ± 92				98 ± 21	
0DAI		382 ± 263				113 ± 44	
30DAI		n/a				96 ± 48	
(b)							
Irrigation							
ALT		n/a				114 ± 43	
WO		n/a				90 ± 30	
(c) Sod							
Organic		264 ± 143				95 ± 35	
Mineral		316 ± 209				109 ± 42	
(d) SOD							
X FERT		Organic	Mineral		Organic	Mineral	
None		217 ± 112	271 ± 61		89 ± 20	105 ± 20	
0DAI		360± 160	405 ± 355		120 ± 30	105 ± 56	
30DAI		n/a	n/a		74 ± 39	117 ± 49	
(e) IRR							
X FERT		ALT	WO		ALT	WO	
None		n/a	n/a		108 ± 17	87 ± 20	
0DAI		n/a	n/a		124 ± 43	101 ± 45	
30DAI		n/a	n/a		108 ± 64	83 ± 23	
(f) SOD							
X IRR		Organic	Mineral		Organic	Mineral	
ALT		n/a	n/a		96 ± 42	131 ± 39	
WO		n/a	n/a		93 ± 28	88 ± 34	
(g) SOD							
X IRR X							
FERT							
		Organic		Mineral			
		ALT	WO	ALT	WO	ALT	WO
None		n/a	n/a	n/a	n/a	101 ± 5.6	78 ± 24
0DAI		n/a	n/a	n/a	n/a	116 ± 24	95 ± 012
30DAI		n/a	n/a	n/a	n/a	124 ± 58	87 ± 59
		n/a	n/a	n/a	n/a	153 ± 33	80 ± 30
		Organic		Mineral			
		ALT	WO	ALT	WO	ALT	WO
None		n/a	n/a	n/a	n/a	101 ± 5.6	78 ± 24
0DAI		n/a	n/a	n/a	n/a	116 ± 24	95 ± 012
30DAI		n/a	n/a	n/a	n/a	124 ± 58	87 ± 59
		n/a	n/a	n/a	n/a	153 ± 33	80 ± 30

TURFGRASS VISUAL QUALITY:

Mean turfgrass quality was rated at 7.0 during the first 30 days of the trial, which was similar to the mean quality ratings during the second half of the trial (6.7, $P > 0.05$). Fertilizer application and sod type influenced quality scores during Trial 2 with an interaction of the two factors also influencing quality during the first half of the trial (Table 9).

During the first 30DAI, the mean quality rating for the organic soil grown sod was 8.3. In comparison, the mean quality rating for the mineral soil grown sod was 6.0. Turfgrass not fertilized had a mean quality of

6.8, which was significantly lower than the quality of the turfgrass fertilized directly after sodding (7.5). During the first half of Trial 2, organic soil grown sod continually had greater quality than mineral soil grown sod (Table 14). While fertilization 0DAI increased turf quality in organic soil grown sod, it did not significantly increase quality for mineral grown soil sod (Table 14).

Table 14. Interaction of SOD*FERT on visual quality scores during the first half of Trial 2.

FERT / SOD	Organic	Mineral	Within FERT Significance
None	7.9	5.7	<0.0001
0DAI	8.7	6.2	<0.0001
Significance	0.0016	0.0675	

†Means with the same letter within a column are not significantly different at the 0.05 significance level.

Visual quality rated on a scale from 1 to 10 with 1=dead, brown turfgrass, 6=minimally acceptable, and 10=dark green healthy looking turfgrass.

GROWTH:

In Trial 2, less dry clipping yields were collected during the first half of the trial in comparison to the last half of the trial (means= 10.5 and 15.5 g m⁻², P<0.05). Clipping yields during both halves of the trial were influenced by sod type (Table 9). In addition, fertilizer application and the interaction of SOD*FERT influenced clipping yields for the second half of the trial (Table 9). During both halves of the trial, greater dry clipping yields from the organic soil grown sod were collected in comparison to the mineral soil grown sod (Table 9, Figure 6).

During the second half of the trial, St. Augustinegrass fertilized 0DAI and 30DAI had similar mean dry clipping yields (20.2 and 17.0 g m⁻², respectively), both of which were greater than yields from non-fertilized St. Augustinegrass (mean = 9.5 g m⁻², P<0.01).

During this time, the SOD*FERT interaction determined that regardless of Fertilization, similar dry clipping yields were collected from mineral soil grown sod (Table 13). Greater clipping yields were collected from organic soil grown sod in comparison to mineral grown sod only when sod was fertilized at (Table 13).

Table 13. Interaction of SOD*FERT on dry clipping yields (g m⁻²) during the second half of Trial 2.

FERT / SOD	Organic	Mineral	Within FERT Significance
None	12.7 b	6.3 a	0.1480
0DAI	31.3 a	9.1 a	0.0001
30DAI	22.0 ab	12.0 a	0.1075

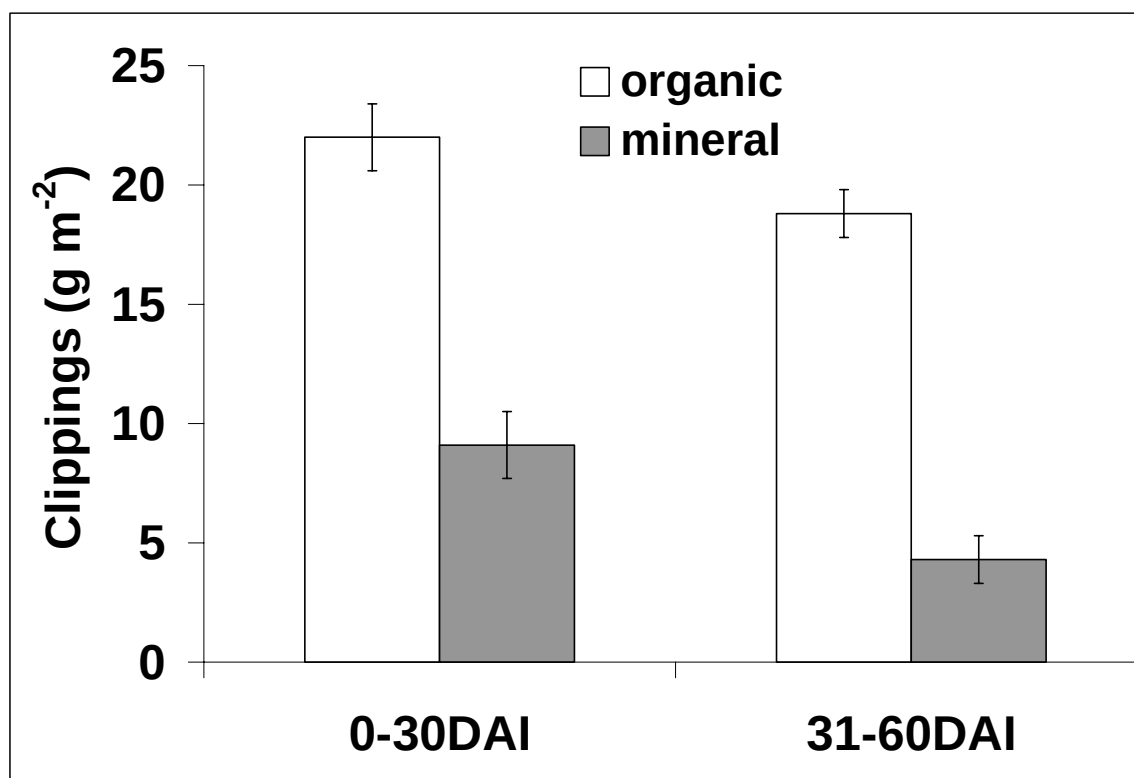


Figure 6. Comparison of mean dry clipping yields (g m^{-2}) from the two sod types for each half of Trial 2.

TRIAL 3: March 28th - May 31st, 2006

CLIMATE AND HYDROLOGY:

Trial 3 encompassed a dry period with a mean temperature of 24.7 °C (ranging from 11.6 – 36.1 °C) and humidity averaging 68 % (ranging from 52-87 %). During Trial 3, rainfall occurred on seven days, with a cumulative total of 160.5 mm (Figure 7). Nitrate-N and orthophosphate concentrations within the rainfall for two of the rain events ranged from 0.09-0.18 and 0.007-0.32 mg l^{-1} respectively, with means of 0.12 and 0.18 mg l^{-1} for nitrate-N and orthophosphate respectively. Rainfall contributed a total of 19.8 and 29.0 mg m^{-2} of nitrate-N and orthophosphate over the Trial. The average volume of percolate collected over the period was 603 mm with the majority collected during the first half of the trial (420 and 184 mm for the first and second halves of the trial respectively). Percolate was influenced by irrigation schedule and fertilizer during the second half of Trial 3 (Table 14). Percolate volumes were greater from St. Augustinegrass irrigated on alternate days than St. Augustinegrass irrigated only when wilt was observed (437 and 157 mm respectively, $P=0.0053$). Similar percolate volumes were collected for St. Augustinegrass not fertilized and St. Augustinegrass fertilized at 0DAI (214 and 192 mm respectively), both of which were greater than the percolate collected from St. Augustinegrass fertilized 30DAI (144 mm, $P=0.0113$).

Table 14. Significant differences for observations and measurements over the first 30 days and the second 30 days for Trial 3.

	Volumes		NO ₃ -N concentration		NO ₃ -N leached		PO ₄ -P concentration		PO ₄ -P leached		Quality Scores		Clipping Yields	
Days after initiation	0-30†‡	31-60	0-30	31-60	0-30	31-60	0-30	31-60	0-30	31-60	0-30	31-60	0-30	31-60
IRR	---	**	---	ns	---	ns	---	ns	---	ns	---	**	---	ns
FERT	ns	*	ns	ns	ns	ns	ns	ns	ns	*	ns	**	ns	**
IRR*FERT	---	ns	---	ns	---	ns	---	ns	---	ns	---	ns	---	ns
SOD	ns	ns	ns	ns	ns	ns	ns	*	ns	ns	ns	ns	**	*
SOD*IRR	---	ns	---	ns	---	ns	---	ns	---	ns	---	ns	---	ns
SOD*FERT	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
SOD*FERT*IRR	---	ns	---	ns	---	ns	---	ns	---	ns	---		---	

† Irrigation and other factor interaction with irrigation was not tested for 0-30 DAI since irrigation treatments were not initiated until 31 DAI.

‡ Fertilizer treatments tested were no fertilizer applied (NONE and 30DAI) and 0 DAI.

‡ ns, * and ** = $P > 0.05$, $P < 0.05$, and $P < 0.01$ respectively.

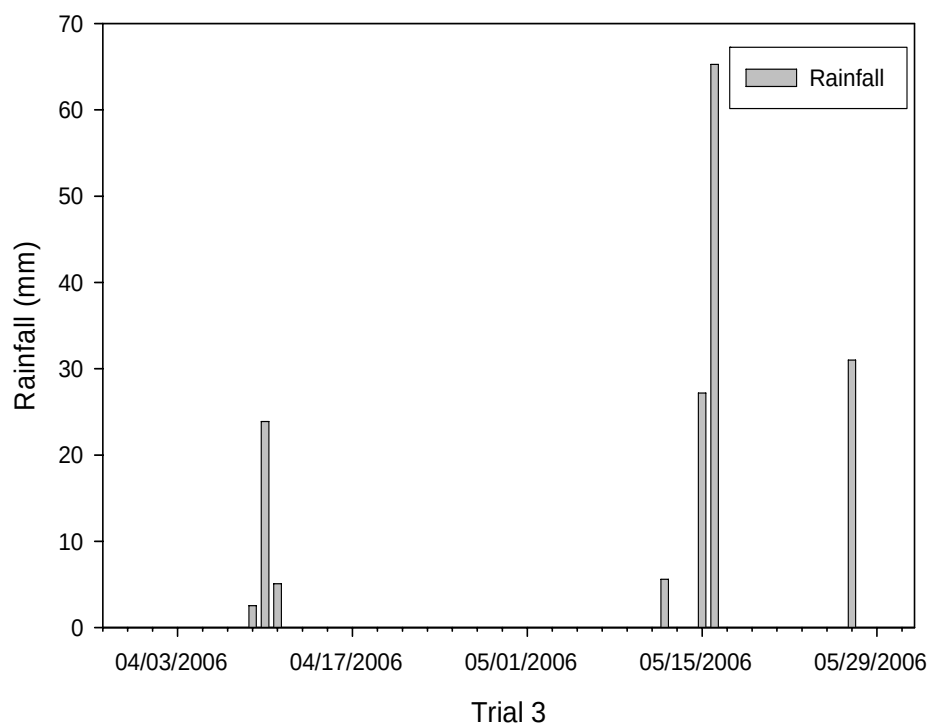


Figure 7. Rainfall over the experimental period for Trial 3.

NITRATE-N CONCENTRATIONS AND LEACHING:

Nitrate-N concentrations during the first half of the experiment ranged from 0.00 to 71.86 mg l⁻¹ (mean = 14.2 mg l⁻¹). The range of concentrations observed over the second half of the trial (0.00 to 1.37 mg l⁻¹, with a mean value of 0.04 mg l⁻¹) was significantly lower than those of the first half of the trial ($P < 0.01$).

Similar to nitrate-N concentrations nitrate-N leaching was greater during the first half of the trial in comparison to the second half (means = 1,285 and 2.11 mg m⁻² respectively, P<0.01). No factor or interaction influenced nitrate-N concentrations and leaching during the Trial 3 (Tables 14, 15 and 16). low nitrate-N concentrations and leaching were documented during the second half of Trial 3, regardless of the large rain event that occurred on May 15 and 16th (Figure 7). From the percolate that was collected following this rain event, nitrate –N was detected from only one plot, which was a mineral soil based sod, not fertilized and under the WO irrigation schedule (Tables 15 and 16).

Table 15. Flow weighted nitrate-N concentrations (mean ± std. dev.) for each factor and interaction during Trial 3.

		Nitrate-N concentration (mg l ⁻¹)							
		0-30DAI		31-60DAI					
(a)									
Fertilizer									
None		11.3 ± 17.1		0.12 ± 0.39					
0DAI		20.1 ± 18.9		0.01 ± 0.04					
30DAI		n/a		0.00 ± 0.00					
(b)									
Irrigation									
ALT		n/a		0.00 ± 0.00					
WO		n/a		0.08 ± 0.32					
(c) Sod									
Organic		12.0 ± 20.9		0.00 ± 0.00					
Mineral		16.4 ± 14.8		0.08 ± 0.32					
(d) SOD									
X FERT									
	Organic	Mineral		Organic	Mineral				
None	9.0 ± 22.3	13.5 ± 10.8		0.003 ± 0.007	0.23 ± 0.56				
0DAI	17.9 ± 18.8	22.3 ± 20.5		0.00 ± 0.00	0.02 ± 0.06				
30DAI	n/a	n/a		0.00 ± 0.00	0.00 ± 0.00				
(e) IRR									
X FERT									
	ALT	WO		ALT	WO				
None	n/a	n/a		0.00 ± 0.00	0.23 ± 0.56				
0DAI	n/a	n/a		0.00 ± 0.00	0.02 ± 0.06				
30DAI	n/a	n/a		0.00 ± 0.00	0.00 ± 0.00				
(f) SOD									
X IRR									
	Organic	Mineral		Organic	Mineral				
ALT	n/a	n/a		0.00 ± 0.00	0.00 ± 0.00				
WO	n/a	n/a		0.00 ± 0.01	0.17 ± 0.45				
(g) SOD									
X IRR X									
FERT									
	Organic		Mineral			Organic		Mineral	
	ALT	WO	ALT	WO	ALT	WO	ALT	WO	
None	n/a	n/a	n/a	n/a	0.00 ± 0.00	0.01 ± 0.01	0.00 ± 0.00	0.46 ± 0.79	
0DAI	n/a	n/a	n/a	n/a	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.05 ± 0.08	
30DAI	n/a	n/a	n/a	n/a	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.01	0.00± 0.00	

Table 16. Nitrate-N leaching (mean $\pm$ std. dev.) for each factor and interaction during Trial 3.

		Nitrate leaching (mg m ⁻²)							
		0-30DAI		31-60DAI					
(a)									
Fertilizer									
None		1018 ± 1468		5.93 ± 20.3					
0DAI		1818 ± 1698		0.37 ± 1.23					
30DAI		n/a		0.02 ± 0.07					
(b)									
Irrigation									
ALT		n/a		0.01 ± 0.06					
WO		n/a		4.20 ± 16.6					
(c) Sod									
Organic		1107 ± 1873		0.03 ± 0.14					
Mineral		162 ± 1229		4.18 ± 16.6					
(d) SOD									
X FERT									
	Organic	Mineral		Organic	Mineral				
None	790 ± 1843	1247 ± 1000		0.10 ± 0.24	11.8 ± 28.8				
0DAI	1744 ± 1928	1892 ± 1615		0.00 ± 0.00	0.75 ± 1.73				
30DAI	n/a	n/a		0.00 ± 0.00	0.04 ± 0.10				
(e) IRR									
X FERT									
	ALT	WO		ALT	WO				
None	n/a	n/a		0.00 ± 0.00	11.9 ± 28.7				
0DAI	n/a	n/a		0.00 ± 0.00	0.75 ± 1.73				
30DAI	n/a	n/a		0.04 ± 0.10	0.00 ± 0.00				
(f) SOD									
X IRR									
	Organic	Mineral		Organic	Mineral				
ALT	n/a	n/a		0.00 ± 0.00	0.03 ± 0.08				
WO	n/a	n/a		0.06 ± 0.19	8.33 ± 23.37				
(g) SOD									
X IRR X									
FERT									
	Organic		Mineral			Organic		Mineral	
	ALT	WO	ALT	WO	ALT	WO	ALT	WO	
None	n/a	n/a	n/a	n/a	0.00 ± 0.00	0.19 ± 0.33	0.00 ± 0.00	23.5 ± 40.7	
0DAI	n/a	n/a	n/a	n/a	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	1.49 ± 2.42	
30DAI	n/a	n/a	n/a	n/a	0.00 ± 0.00	0.00 ± 0.00	0.08 ± 0.14	0.00 ± 0.00	

ORTHOPHOSPHATE CONCENTRATIONS AND LEACHING:

Orthophosphate concentrations during the first half of the experiment ranged from 0.51 to 6.80 mg l⁻¹ (mean = 2.02 mg l⁻¹), which exceeds the EPA criteria of 0.05 mg l⁻¹ for stream discharge into lakes or reservoirs (USEPA, 1986). Orthophosphate concentrations during the second half of the trial ranged from 0.02 to 6.83 mg l⁻¹ (mean = 2.24 mg l⁻¹) and were similar to those of the first half of the trial (P=0.54). Greater orthophosphate leaching occurred during the first half of the trial in comparison to the second half

(204 and 97.7 c, $P < 0.01$). Sod type influenced orthophosphate concentrations during the second half of the study (Tables 14 and 17). During this time, percolate from mineral soil based sod had higher concentrations than organic soil based sod (2.71 and 1.77 mg l⁻¹ respectively). Fertilizer influenced orthophosphate leaching during the second half of the study (Tables 14 and 18). During this time, orthophosphate leaching from St. Augustinegrass not fertilized and St. Augustinegrass fertilized at 0DAI had similar concentrations and leaching, both of which were greater than leaching from St. Augustinegrass fertilized 30DAI (Tables 14 and 18).

Table 17. Flow weighted orthophosphate concentrations (mean $\pm$ std. dev.) for each factor and interaction during Trial 3.

		Orthophosphate concentration (mg l ⁻¹)						
		0-30DAI		31-60DAI				
(a)								
Fertilizer								
None		1.7 ± 1.2		2.7 ± 1.5				
0DAI		2.5 ± 2.2		2.7 ± 1.4				
30DAI		n/a		1.4 ± 0.9				
(b)								
Irrigation								
ALT		n/a		2.2 ± 1.4				
WO		n/a		2.3 ± 1.4				
(c) Sod								
Organic		1.7 ± 1.2		1.7 ± 1.6				
Mineral		2.4 ± 2.0		2.9 ± 2.1				
(d) SOD								
X FERT								
	Organic	Mineral		Organic	Mineral			
None	1.3 ± 0.5	2.2 ± 1.6		2.2 ± 1.9	3.1 ± 1.0			
0DAI	2.4 ±1.91	2.7 ± 2.7		2.2 ± 0.7	3.2 ± 1.7			
30DAI	n/a	n/a		1.0 ± 0.5	1.9 ± 1.0			
(e) IRR								
X FERT								
	ALT	WO		ALT	WO			
None	n/a	n/a		2.4 ± 1.2	2.9 ± 1.9			
0DAI	n/a	n/a		2.9 ± 1.7	2.5 ± 1.0			
30DAI	n/a	n/a		1.3 ± 1.0	1.5 ± 0.9			
(f) SOD								
X IRR								
	Organic	Mineral		Organic	Mineral			
ALT	n/a	n/a		1.4 ± 0.9	3.0 ± 1.4			
WO	n/a	n/a		2.1 ± 1.6	2.4 ± 1.3			
(g) SOD								
X IRR X								
FERT								
	Organic		Mineral		Organic		Mineral	
	ALT	WO	ALT	WO	ALT	WO	ALT	WO
None	n/a	n/a	n/a	n/a	1.6 ± 1.2	2.8 ± 2.6	3.3 ± 0.2	3.0 ± 1.5
0DAI	n/a	n/a	n/a	n/a	1.9 ± 0.7	2.4 ± 0.9	3.9 ± 2.0	2.5 ±12.4
30DAI	n/a	n/a	n/a	n/a	0.8 ± 0.7	1.1 ± 0.4	1.9 ± 1.0	1.9 ± 1.2

Table 18. Orthophosphate leaching (mean $\pm$ std. dev.) for each factor and interaction during Trial 3.

		Orthophosphate leaching (mg m ⁻²)						
		0-30DAI		31-60DAI				
(a)								
Fertilizer								
None		181 ± 170		124 ± 62				
0DAI		250 ± 237		124 ± 96				
30DAI		n/a		46 ± 35				
(b)								
Irrigation								
ALT		n/a		114 ± 92				
WO		n/a		82 ± 54				
(c) Sod								
Organic		166 ± 129		74 ± 54				
Mineral		242 ± 241		122 ± 89				
(d) SOD								
X FERT								
	Organic	Mineral	Organic	Mineral				
None	131 ± 61	230 ± 227	92 ± 65	155 ± 44				
0DAI	234 ± 200	266 ± 289	96 ± 46	152 ± 127				
30DAI	n/a	n/a	33 ± 20	59 ± 43				
(e) IRR								
X FERT								
	ALT	WO	ALT	WO				
None	n/a	n/a	131 ± 62	116 ± 67				
0DAI	n/a	n/a	162 ± 121	85 ± 44				
30DAI	n/a	n/a	48 ± 47	44 ± 22				
(f) SOD								
X IRR								
	Organic	Mineral	Organic	Mineral				
ALT	n/a	n/a	75 ± 54	153 ± 109				
WO	n/a	n/a	72 ± 56	91 ± 54				
(g) SOD								
X IRR X FERT								
	Organic	Mineral	Organic	Mineral				
	ALT	WO	ALT	WO				
None	n/a	n/a	n/a	n/a	89 ± 60	95 ± 83	174 ± 28	136 ± 56
0DAI	n/a	n/a	n/a	n/a	108 ± 43	83 ± 55	216 ± 161	87 ± 44
30DAI	n/a	n/a	n/a	n/a	27 ± 28	38 ± 13	69 ± 58	50 ± 31

TURFGRASS VISUAL QUALITY:

Turfgrass quality during the first 30 days of Trial 3 was rated at 7.0. Quality during this time was significantly greater than quality during the second half of Trial 3 (6.4, $P < 0.01$). Fertilizer application influenced quality scores during the second half of Trial 3 (Table 14). During the second half of the trial, similar quality scores were rated for turfgrass not fertilized and turfgrass fertilized at 0DAI (mean= 5.7 and 6.2 respectively, $P > 0.05$); both of which were rated having lower quality than turfgrass fertilized at 30DAI (mean=7.4, $P < 0.01$). In addition to fertilizer, irrigation schedule influenced quality scores during

the second half of Trial 3 (Table 14). Turfgrass under the ALT schedule had greater quality than turfgrass irrigated only when wilt was present (mean =6.8 and 6.0, $P<0.01$).

GROWTH:

Greater dry clipping yields were collected during the first half of Trial 3 in comparison to the last half of the trial (means= 20.2 and 10.6 g m^{-2} , $P<0.01$). Clipping yields during both halves of the trial were influenced by sod type with the addition of fertilizer influencing yields during the second half of Trial 3 (Table 14).

Greater dry clipping yields were collected from the mineral soil grown sod in comparison to the organic soil grown sod during both halves of Trial 3 (Table 14, Figure 8).

During the second half of the trial, St. Augustinegrass not fertilized and St. Augustinegrass fertilized 0DAI had similar dry clipping yields (5.7 and 7.4 g m^{-2} , respectively), both of which were less than yields from St. Augustinegrass fertilized at 30 DAI (mean = 18.8 g m^{-2} , $P<0.05$).

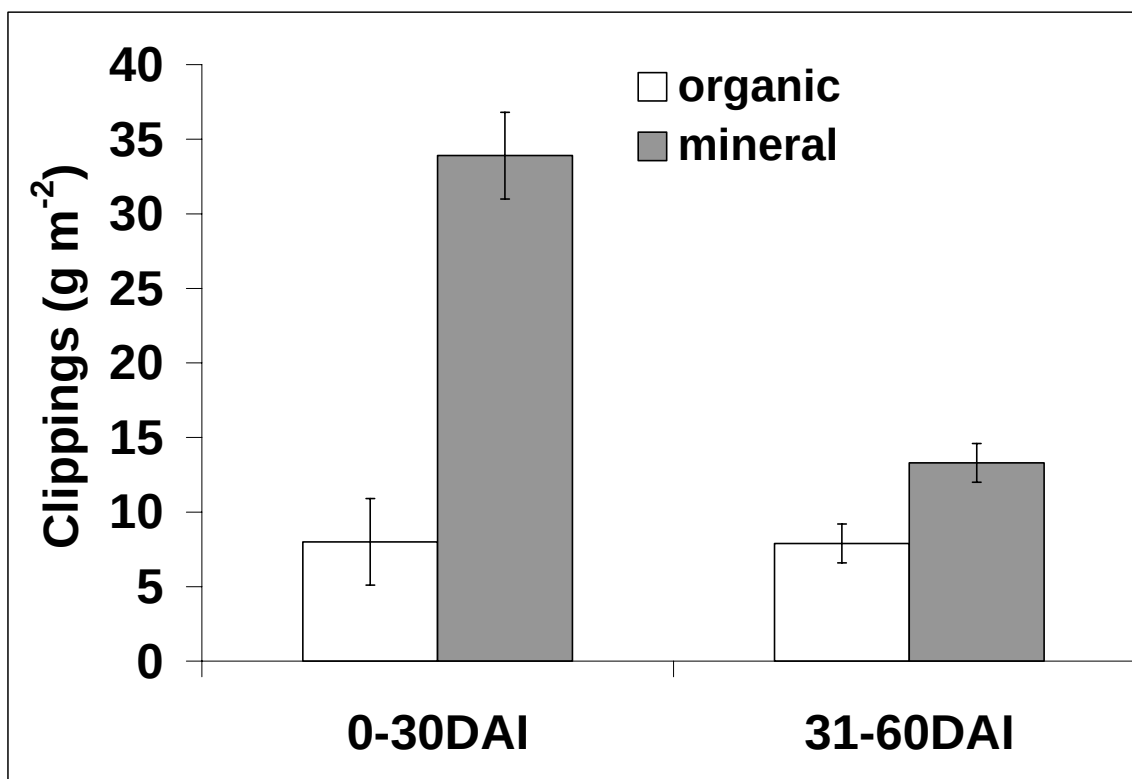


Figure 8. Comparison of mean dry clipping yields (g m^{-2}) from the two sod types for each half of Trial 3.

KEY FINDINGS

- Regardless of soil type, nitrogen mineralization from sod resulted in considerable nitrate-N leaching during the first 30DAI. For example, for all trials, sod type influenced clipping yields during the first 30 DAI although fertilizer treatments did not.
- The amount of nitrate-N leaching due to fertilizing directly after sod installation mitigated the benefit in quality.
- Seasonality may have influenced results:
 - Trials 1 and 3 bracketed an active growth period. During this time less leaching occurred in general. Although not significant, a trend for less nitrate-N leaching coupled with significantly better quality was determined for turfgrass fertilized 30 DAI.
 - Trial 2 corresponds to a less active growth period. Perhaps at this time, the turfgrass is less resource efficient. This would explain the higher nitrate-N concentrations and greater leaching due to fertilizer treatments documented during the 31-60 DAI.
- Variations in results between trials may also be due to the organic soil based sod originating from different sod farms. For example, while Trials 1 and 3 were during the same time of year, there was no difference in quality scores for sod type in Trial 3 when there was in Trial 1. In Trial 3, the organic soil based sod had 27% less organic matter than the organic soil based sod used in Trial 1.

REFERENCES

U.S. EPA. 1986. Quality criteria for water. USEPA Rep. 440/5-86-001. Office of Water Regulations and Standards. U.S. Gov. Print. Office (PB87-226759), Washington, D.C.

U.S.EPA. 2005. List of Drinking Water Contaminants and MCLs.
<http://www.epa.gov/safewater/mcl.html#mcls>

APPENDIX A

Average % organic matter by weight from sod type used in each trial at the Fort Lauderdale site.

	Organic Matter (%)		
	Trial 1	Trial 2	Trial 3
Organic based sod	82.4	79.9	58.5
Mineral based sod	2.4	2.6	2.7

APPENDIX B

Root ash weights (grams) taken November 30, 2005 [Post Trial 2] at Fort Lauderdale Site.

Sod Type	Fertilization	Irrigation	0-15cm depth	15-30cm depth
Organic	None	ALT	0.403 grams	0.141
		WO	0.420	0.363
	0 DAI	ALT	0.527	0.443
		WO	0.587	0.397
	30 DAI	ALT	0.523	0.497
		WO	0.387	0.323
Sand	None	ALT	0.603	0.527
		WO	0.507	0.497
	0 DAI	ALT	0.437	0.527
		WO	0.383	0.567
	30 DAI	ALT	0.417	0.727
		WO	0.583	0.523

SIGNIFICANCE

Irrigation	ns	ns
Fertilization	ns	ns
Fert x Irrigation	ns	ns
Sod Type	ns	**
Sod x Irrigation	ns	ns
Sod x Fert	*	ns
Sod x Fert x Irrig	ns	ns

ns, **, and * = $P > 0.10$, $P < 0.05$, and $P < 0.10$ respectively.

Root ash weights (grams) taken June 6, 2006 [Post Trial 3] at Fort Lauderdale Site.

Sod Type	Fertilization	Irrigation	0-15cm depth	15-30cm depth
Organic	None	ALT	0.553 grams	0.554
		WO	0.812	0.413
	0 DAI	ALT	0.820	0.633
		WO	0.790	0.275
	30 DAI	ALT	1.89	0.370
		WO	0.82	0.260
Sand	None	ALT	0.590	0.297
		WO	0.837	0.390
	0 DAI	ALT	0.616	0.480
		WO	0.710	0.493
	30 DAI	ALT	0.777	0.357
		WO	0.932	0.543

SIGNIFICANCE

Irrigation	ns	ns
Fertilization	ns	ns
Fert x Irrigation	ns	ns
Sod Type	ns	ns
Sod x Irrigation	ns	*
Sod x Fert	ns	ns
Sod x Fert x Irrig	ns	ns

ns and * = $P > 0.10$ and $P < 0.10$ respectively.

NITRATE LEACHING FROM ESTABLISHED ST. AUGUSTINEGRASS AND BAHIA GRASS DUE TO N RATE AND IRRIGATION

INTRODUCTION

Irrigation and nitrogen (N) are essential components for maintenance of turfgrass. At the appropriate rates, N and irrigation have shown to improve turfgrass quality, color and vigor along with many additional benefits. However, excess N and irrigation rates applied to turfgrass can potentially increase $\text{NO}_3\text{-N}$ leaching and degrade water quality. With water becoming a limiting resource due to increasing population in south Florida, great efforts are being made to preserve water quality. One identified source of ground water and surface contamination is from fertilizers applied to home lawns. Thus, homeowners are under increasing scrutiny to ensure that management practices such as fertilization and irrigation do not impact water quality. Measures must be taken to reduce the environmental impact of these practices without forfeiting the quality of the homeowner's lawn. One possible solution would be to reduce N and irrigation inputs. However, there is very little published literature available on the quantity of N or irrigation needed to produce acceptable turfgrass quality for home lawns in south Florida. The objective of this experiment was to determine the effects of irrigation regimes and N rates on turfgrass quality, color, density, clipping yields and N leaching from St. Augustinegrass and bahiagrass in south Florida.

MATERIALS AND METHODS

On 12 October 2006, a study was initiated at University of Florida's Fort Lauderdale Research and Education Center on a mature stand of St. Augustinegrass (*Stenotaphrum secundatum* Walt. Kuntze), cv. 'Floritam' and bahiagrass (*Paspalum notatum* Flugge) grown on mined mason sand (Rymatt Golf, Collier County, Florida). Field plot design was a randomized complete block, split-plot design with four replicates. Main blocks (8 x 4 m) consisted of one of two irrigation regimes: 2.5 mm daily (Low) except when daily precipitation > 6.4 mm (irrigation turned off), and 13.0 mm three times weekly (High). Sub plots (2 x 4 m) consisted of four nitrogen (N) rates (98, 196, 294, and 588 kg N ha⁻¹ yr⁻¹) and (49, 98, 196, and 294 kg N ha⁻¹ yr⁻¹) on the St. Augustinegrass and bahiagrass respectively. A single bucket lysimeter was installed in each sub-plot as previously described.

For both grasses, N rates were split over 6 application dates: 12 Oct., 12 Dec. 2006 and 15 Mar., 17 Apr., 18 June, and 16 Aug. 2007 providing 3 application cycles for each of Florida's wet and dry season. Each application date represented the start of a new fertilizer cycle (C). Spray grade granular urea (46-0-0) was used as the source of N and applied with a backpack CO₂-pressurized (30psi) sprayer equipped with two flat-fan Tee Jet 8010 nozzles on 50 cm spacing. Immediately following urea applications plots received 10 mm of irrigation to reduce volatilization. In addition, to N fertilization, P and K from triple superphosphate and muriate of potash respectively was applied to maintain acceptable soil test values at the rate 196 kg P and 392 kg K ha⁻¹ yr⁻¹, split equally every 3 months. Pesticides were applied according to their label when required.

Visual quality and color ratings based on a scale of 1-9, (9 = dark green uniform turf, 1 = dead brown turf and 6 = minimally acceptable turf) were made bi-weekly. Using a rotary mower set at a height of 75 mm, samples were removed for dry weight determination after 48 hrs in a 60°C oven. Percolate samples were collected weekly or more frequently depending on rainfall, analyzed for

NO₃+NO₂ and calculated as NO₃-N leached (mg m⁻²). Any NO₃ concentration that was lower than the minimum detection limit (MDL) of 0.05 mg L⁻¹ was corrected to the MDL value. All turfgrass clipping yield, visual rating, and NO₃-N leaching data were subject to analysis of variance using with PROC GLM (SAS Institute, 1999) and means were separated by Waller-Duncan Multiple range test, K ratio=100 (*P*<0.05).

RESULTS AND DISCUSSION – YEAR 1

Hydrology

The climate of south Florida is broadly characterized as having an extended wet and dry season period. The first 3 bimonthly cycles bracket the main portion of the dry season period with less than 40% of the total rain over the length of the reporting period and the final 3 cycles bracketing the wet season with over 60% of the total rain (Table 19). The low irrigation rate accounted for approximately 800 mm and the high irrigation rate supplied over 1900 mm of water (Table 19). As a result, there was significantly more percolate for the high irrigation throughout the year for both turfgrasses (Tables 20 and 21). Increasing N rate reduced percolate for 3 of the six cycles in St. Augustinegrass but not in bahiagrass (Tables 20 and 21) presumably due to greater vigor and density as increased amounts of N were applied to plots.

Table 19. Hydrology data for low and high irrigation regimes (mm) for the 6 cycles (C).

Factor	C1	C2	C3	C4	C5	C6	TOTALS
	10/12 – 12/11	12/12 – 03/14	03/15 – 04/16	04/17 – 06/17	06/18 – 08/15	08/15 – 10/16	
Low irrigation	142.2	221.0	78.7	129.5	129.5	104.1	805.0
High irrigation	330.2	508.0	177.8	330.2	330.2	292.1	1968.5
<i>Precipitation</i>	97.3	215.9	86.4	411.7	248.4	452.9	1512.6

Table 20. Effect of irrigation regime and N fertilization on percolate (cm) for St. Augustinegrass averaged by cycle (C) for year 1.

Factor	C1 10/12 – 12/11	C2 12/12 – 03/14	C3 03/15 – 04/16	C4 04/17 – 06/17	C5 06/18 – 08/15	C6 08/15 – 10/16
†Irrigation Regime						
Low	5.2a	4.3a	0.9a	5.4a	9.3a	5.2a
High	6.7b	7.2b	1.3b	7.7b	11.2b	7.1b
ANOVA	**	**	**	**	**	**
N Rate kg ha ⁻¹ yr ⁻¹						
98	6.4	6.3a	1.4	7.2a	11.3	6.5a
196	6.5	6.5a	1.2	6.7a	10.2	6.3ab
294	5.4	4.9b	1.1	6.6a	9.3	5.8b
588	5.5	5.8ab	0.8	5.5b	10.1	5.9b
ANOVA	NS	**	NS	*	NS	*
Irr. x N	NS	NS	NS	NS	NS	NS

**, NS, and * = $P < 0.01$, $P > 0.05$, and $P < 0.05$

†Low irrigation: 2.5mm daily except when daily precipitation > 6.4mm (irrigation turned off)

High irrigation: 13.0 mm three times weekly

Table 21. Effect of irrigation regime and N fertilization on percolate (cm) for bahiagrass averaged by cycle (C) for year 1.

Factor	C1 10/12 – 12/11	C2 12/12 – 03/14	C3 03/15 – 04/16	C4 04/17 – 06/17	C5 06/18 – 08/15	C6 08/15 – 10/16
†Irrigation Regime						
Low	4.2a	3.6a	0.4a	4.6a	8.5a	5.1a
High	6.1b	5.9b	0.9b	6.7b	10.9b	6.7
ANOVA	**	**	**	**	**	**
N Rate kg ha ⁻¹ yr ⁻¹						
49	5.3	4.6	0.8	5.8	10.0	6.1
98	5.3	4.7	0.4	5.0	9.3	5.8
196	4.7	5.2	0.6	6.3	10.2	5.8
294	4.7	4.7	0.9	5.5	9.7	5.9
ANOVA	NS	NS	NS	NS	NS	NS
Irr. x N	NS	NS	NS	NS	NS	NS

** and NS = $P < 0.01$ and $P > 0.05$

†Low irrigation: 2.5mm daily except when daily precipitation > 6.4mm (irrigation turned off)

High irrigation: 13.0 mm three times weekly

Turfgrass Quality, Color, Density and Clipping Yields

For the duration of study, irrigation regime had no significant effect ($p > 0.05$) on turfgrass quality, color, density or clippings for either turfgrass (Tables 22 -29). This may be explained by the total amounts irrigation + precipitation exceeding growing season ET rates in south Florida (Table 19). N rate did significantly ($p < 0.05$) affect turfgrass quality and color for either grass (Tables 22 and 23). For St. Augustinegrass and bahiagrass all N rates averaged over a cycle provided minimally-acceptable turfgrass quality of 6.0 or higher (Tables 22 and 23). However, within a cycle, turfgrass ratings could drop below the minimal acceptable level as observed for St. Augustinegrass at the lower N application rates (Fig. 9). Bahiagrass quality was always above the minimal standard throughout a cycle (Fig. 10). Plots receiving the highest (294 and 588 kg N ha⁻¹ yr⁻¹) and lowest N rate (49 and 98 kg N ha⁻¹ yr⁻¹) continuously ranked highest and lowest for turfgrass quality and color respectively for St. Augustinegrass and bahiagrass (Tables 22 and 23). Although increasing N rate increased turfgrass quality and color (Tables 22 – 25), even at the highest application rate, ratings were not excessively high suggesting that the fertilizer applications were within the range necessary for good quality turf. Nitrogen rate significantly ($p < 0.05$) affected density in St. Augustinegrass and was always highest in the plots receiving highest N rates (Table 26). For bahiagrass, N rate had no significant effect ($p > 0.05$) on density (Table 27). This may be attributed to the natural open growth habitat of bahiagrass. In addition, N rates significantly ($p < 0.05$) affected turfgrass cumulative clipping yields in both St. Augustinegrass and bahiagrass. For St. Augustinegrass cumulative clipping yields were highest and lowest in the plots receiving highest and the lowest N rates in C2, C5, and C6 (Table 28). Bahiagrass cumulative clipping yields also increased with increasing N rate (Table 29). Both grasses produced higher cumulative

clipping yields during wet season cycles (C4, C5, and C6) with longer day length and warmer temperatures.

Table 22. Effect of irrigation regime and N fertilization on turf quality ratings‡ for St. Augustinegrass averaged by cycle (C) for year 1.

Factor	C1 10/12 – 12/11	C2 12/12 – 03/14	C3 03/15 – 04/16	C4 04/17 – 06/17	C5 06/18 – 08/15	C6 08/15 – 10/16
†Irrigation Regime						
Low	6.9	6.9	6.8	7.1	7.1	7.0
High	6.9	7.0	7.0	7.1	7.1	7.1
ANOVA	NS	NS	NS	NS	NS	NS
N Rate kg ha ⁻¹ yr ⁻¹						
98	6.2c	6.0d	6.2c	6.1c	6.4d	6.5c
196	6.8b	6.6c	6.4c	6.7bc	6.8c	6.8bc
294	7.0b	7.2b	7.1b	7.4b	7.3b	7.2b
588	7.5a	7.9a	8.0a	8.3a	7.9a	7.8a
ANOVA	**	**	**	**	**	**
Irr. x N	NS	NS	NS	NS	NS	NS

NS and ** = $P > 0.05$ and $P < 0.01$

‡Turfgrass quality ratings based on a 1-9 scale with 9=dark green turf, 1=dead/brown turf, and 6=minimally acceptable turf

†Low irrigation: 2.5mm daily except when daily precipitation > 6.4mm (irrigation turned off)
High irrigation: 13.0 mm three times weekly

Table 23. Effect of irrigation regime and N fertilization on turf quality ratings‡ for bahiagrass averaged by cycle (C) for year 1.

Factor	C1 10/12 – 12/11	C2 12/12 – 03/14	C3 03/15 – 04/16	C4 04/17 – 06/17	C5 06/18 – 08/15	C6 08/15 – 10/16
†Irrigation Regime						
Low	7.1	6.8	6.8	7.3	7.1	7.0
High	7.1	7.0	6.8	7.1	7.1	7.2
ANOVA	NS	NS	NS	NS	NS	NS
N Rate kg ha ⁻¹ yr ⁻¹						
49	6.9c	6.6c	6.3c	6.9c	6.9c	6.8
98	7.0c	6.8bc	6.7b	7.2bc	7.0bc	7.0
196	7.2b	7.0b	6.8b	7.3b	7.1b	7.3
294	7.4a	7.3a	7.3a	7.6a	7.3a	7.3
ANOVA	**	**	**	**	**	NS
Irr. x N	NS	NS	NS	NS	NS	NS

NS and ** = $P > 0.05$ and $P < 0.01$

‡Turfgrass quality ratings based on a 1-9 scale with 9=dark green turf, 1=dead/brown turf, and 6=minimally acceptable turf.

†Low irrigation: 2.5mm daily except when daily precipitation > 6.4mm (irrigation turned off)
High irrigation: 13.0 mm three times weekly

Table 24. Effect of irrigation regime and N fertilization on turf color ratings‡ for St. Augustinegrass averaged by cycle (C) for year 1.

Factor	C1 10/12 – 12/11	C2 12/12 – 03/14	C3 03/15 – 04/16	C4 04/17 – 06/17	C5 06/18 – 08/15	C6 08/15 – 10/16
†Irrigation Regime						
Low	7.1	7.1	7.1	7.2	7.3	7.2
High	7.7	7.2	7.2	7.3	7.3	7.3
ANOVA	NS	NS	NS	NS	NS	NS
N Rate kg ha ⁻¹ yr ⁻¹						
98	6.5c	6.3c	6.4c	6.2b	6.6c	6.7c
196	7.0b	6.8c	6.7bc	7.0b	7.1b	7.0bc
294	7.2b	7.4b	7.2b	7.4b	7.4b	7.3a
588	7.7a	8.2a	8.4a	8.5a	8.0a	7.9a
ANOVA	**	**	**	**	**	**
Irr. x N	NS	NS	NS	NS	NS	NS

NS and ** = $P > 0.05$ and $P < 0.01$

‡Turfgrass color ratings based on a 1-9 scale with 9=dark green turf, 1=dead/brown turf, and 6=minimally acceptable turf.

†Low irrigation: 2.5mm daily except when daily precipitation > 6.4mm (irrigation turned off)
High irrigation: 13.0 mm three times weekly

Table 25. Effect of irrigation regime and N fertilization on turf color ratings‡ for bahiagrass averaged by cycle (C) for year 1.

Factor	C1 10/12 – 12/11	C2 12/12 – 03/14	C3 03/15 – 04/16	C4 04/17 – 06/17	C5 06/18 – 08/15	C6 08/15 – 10/16
†Irrigation Regime						
Low	7.3	7.2	7.0	7.5	7.1	7.3
High	7.4	7.2	7.2	7.4	7.2	7.4
ANOVA	NS	NS	NS	NS	NS	NS
N Rate kg ha ⁻¹ yr ⁻¹						
49	7.0c	6.8c	6.5d	7.1d	7.0b	7.1b
98	7.3b	7.1bc	6.9c	7.4c	7.1b	7.2ab
196	7.5ab	7.2b	7.3b	7.5b	7.2b	7.5a
294	7.7a	7.5a	7.8a	7.9a	7.4a	7.5a
ANOVA	**	**	**	**	**	**
Irr. x N	NS	NS	NS	NS	NS	NS

NS and = $P > 0.05$ and $P < 0.01$

‡Turfgrass color ratings based on a 1-9 scale with 9=dark green turf, 1=dead/brown turf, and 6=minimally acceptable turf.

†Low irrigation: 2.5mm daily except when daily precipitation > 6.4mm (irrigation turned off)

High irrigation: 13.0 mm three times weekly

Table 26. Effect of irrigation regime and N fertilization on turf density ratings‡ for St. Augustinegrass averaged by cycle (C) for year 1.

Factor	C1 10/12 – 12/11	C2 12/12 – 03/14	C5 06/18 – 08/15
†Irrigation Regime			
Low	6.8	6.3	7.3
High	6.8	6.3	7.3
ANOVA	NS	NS	NS
N Rate kg ha ⁻¹ yr ⁻¹			
98	6.6	5.9b	6.6c
196	6.8	6.2ab	7.1b
294	6.8	6.4a	7.6ab
588	6.9	6.6a	7.9a
ANOVA	NS	**	**
Irr. x N	NS	NS	NS

NS and ** = $P > 0.05$ and $P < 0.01$

‡Turfgrass density ratings based on a 1-9 scale with 9=most dense and uniform turf, 1=least dense turf,

and 6=minimally acceptable turf.

†Low irrigation: 2.5mm daily except when daily precipitation > 6.4mm (irrigation turned off)

High irrigation: 13.0 mm three times weekly

Table 27. Effect of irrigation regime and N fertilization on turf density ratings‡ for bahiagrass averaged by cycle (C) for year 1.

Factor	C1 10/12 – 12/11	C2 12/12 – 03/14	C5 06/18 – 08/15
†Irrigation Regime			
Low	7.0	6.4	6.4
High	6.9	6.4	6.6
ANOVA	NS	NS	NS
N Rate kg ha ⁻¹ yr ⁻¹			
49	6.8	6.4	6.6
98	6.8	6.4	6.4
196	7.1	6.4	6.6
294	7.1	6.5	6.6
ANOVA	NS	NS	NS
Irr. x N Interaction			
ANOVA	NS	NS	NS

NS = $P > 0.05$

‡Turfgrass density ratings based on a 1-9 scale with 9=most dense and uniform turf, 1=least dense turf, and 6=minimally acceptable turf.

†Low irrigation: 2.5mm daily except when daily precipitation > 6.4mm (irrigation turned off)
High irrigation: 13.0 mm three times weekly

Table 28. Effect of irrigation regime and N fertilization on turf clipping yields (g m^{-2}) for St. Augustinegrass averaged by cycle (C) for year 1.

Factor	C1 10/12 – 12/11	C2 12/12 – 03/14	C3 03/15 – 04/16	C4 04/17 – 06/17	C5 06/18 – 08/15	C6 08/15 – 10/16
†Irrigation Regime						
Low	3.9	5.4	12.1	19.5	38.2	37.2
High	4.2	5.2	14.3	20.3	41.1	41.6
ANOVA	NS	NS	NS	NS	NS	NS
N Rate $\text{kg ha}^{-1} \text{yr}^{-1}$						
98	2.0	2.3b	8.4b	6.8c	14.0c	16.1c
196	5.8	4.0b	11.7b	18.5bc	32.3bc	36.2b
294	3.2	5.5a	10.7b	16.6b	35.0b	36.5ab
588	2.1	9.6a	22.1a	37.7a	78.0a	68.7a
ANOVA	NS	**	**	**	**	**
Irr. x N	NS	NS	NS	NS	NS	NS

NS and ** = $P > 0.05$ and $P < 0.01$

†Low irrigation: 2.5mm daily except when daily precipitation > 6.4mm (irrigation turned off)

High irrigation: 13.0 mm three times weekly

Table 29. Effect of irrigation regime and N fertilization on turf clipping yields (g m^{-2}) for bahiagrass averaged by cycle (C) for year 1.

Factor	C1 10/12 – 12/11	C2 12/12 – 03/14	C3 03/15 – 04/16	C4 04/17 – 06/17	C5 06/18 – 08/15	C6 08/15 – 10/16
†Irrigation Regime						
Low	17.1	8.5	35.2	68.7	100.4	110.8
High	15.9	9.1	34.2	71.1	105.8	129.2
ANOVA	NS	NS	NS	NS	NS	NS
N Rate $\text{kg ha}^{-1} \text{yr}^{-1}$						
49	15.2	6.7b	23.5b	53.9c	82.7b	91.2b
98	13.9	7.5b	33.7a	61.4bc	99.4ab	113.8ab
196	17.8	9.9a	38.1a	78.3ab	111.6a	134.3a
294	19.1	11.2a	43.7a	86.2a	118.8a	140.6a
ANOVA	NS	**	**	**	**	**
Irr. x N	NS	NS	NS	NS	NS	NS

NS and ** = $P > 0.05$ and $P < 0.01$

†Low irrigation: 2.5mm daily except when daily precipitation > 6.4mm (irrigation turned off)
High irrigation: 13.0 mm three times weekly

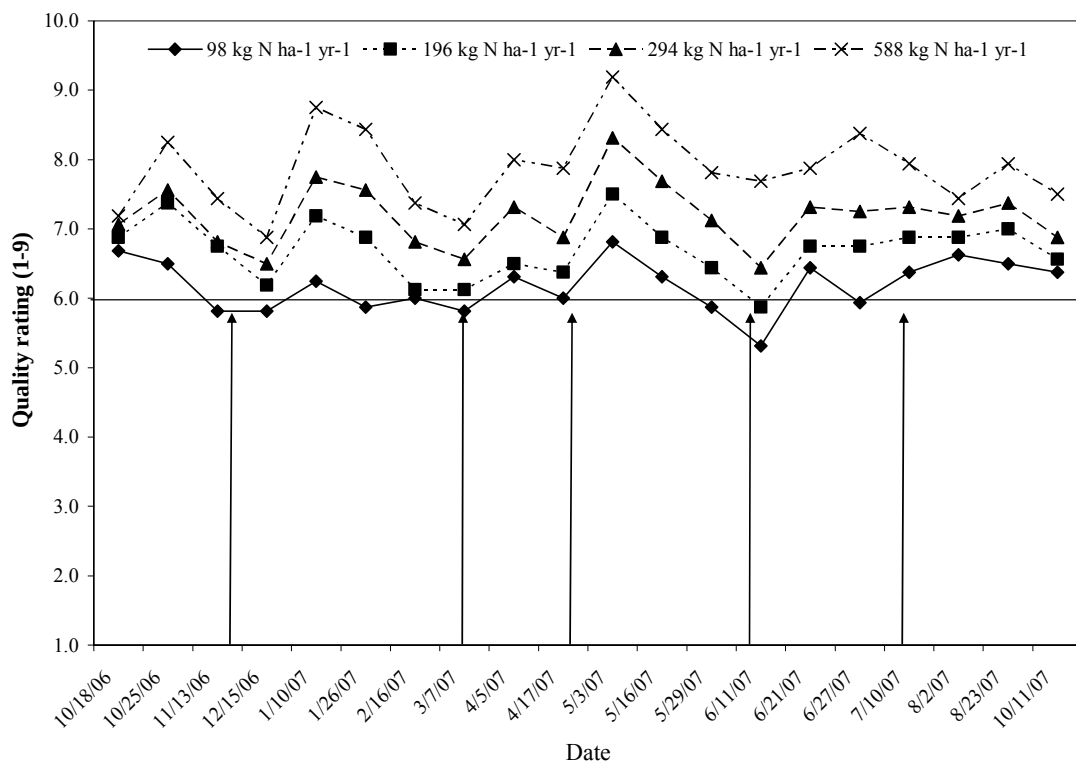


Figure 9. Turfgrass quality ratings for St. Augustinegrass over all cycles (Arrows indicate fertilizer application)

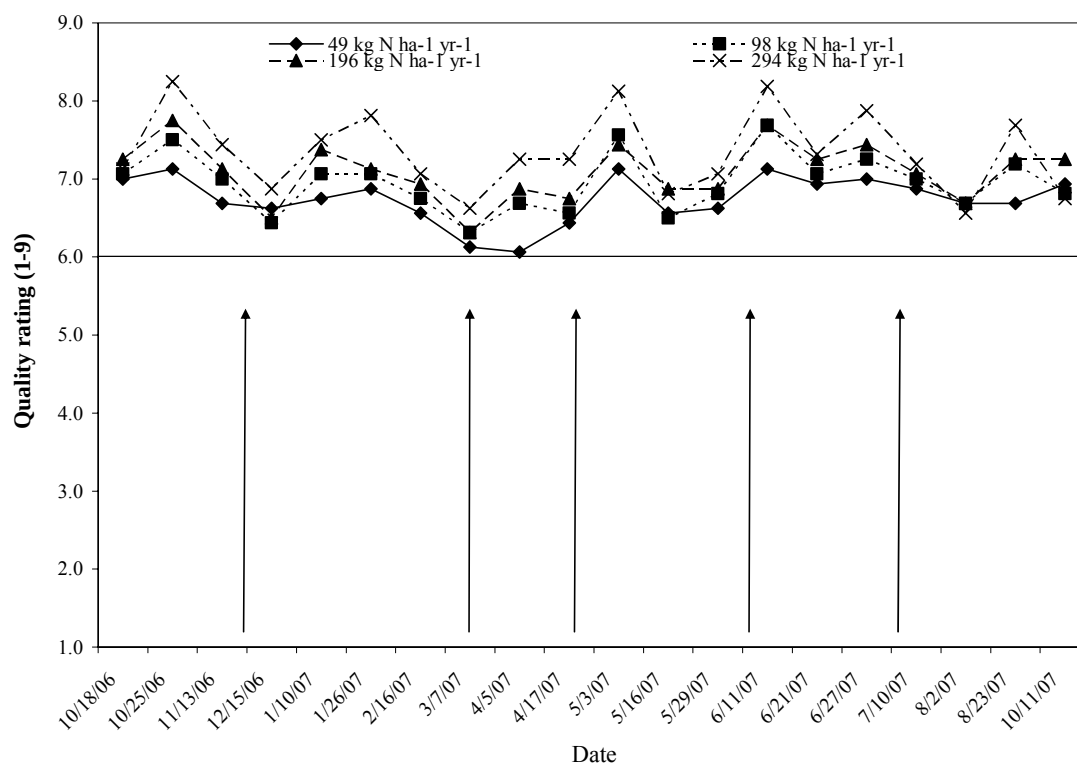


Figure 10. Turfgrass quality ratings for bahiagrass over all cycles (Arrows indicate fertilizer application)

YEAR 2

Turfgrass Quality, Color, Density and Clipping Yields

Year 2 results were similar to trends in Year 1 with irrigation regime having no significant effect ($P>0.05$) on quality, color, density and growth for either grass (Tables 30-37).

N rate was significant as in Year 1 with higher ratings as N rate increased (Tables 30-35). Turfgrass density was significantly different on more dates in Year 2 with ratings dipping below the acceptable level of 6 on several dates for both grasses—more notably in St. Augustinegrass (Tables 34 and 35). Turfgrass growth increased with increasing N rate for both bahiagrass and St. Augustinegrass. During Cycle 2 clipping samples were not collected due to cold weather with little to no growth.

Table 30. Effect of irrigation regime and N fertilization on turf quality ratings‡ for St. Augustinegrass averaged by cycle (C) for year 2.

Factor	C1 10/17 – 12/20	C2 12/24 – 02/15	C3 02/26 – 04/21	C4 04/28 – 06/23	C5 07/02 – 09/01	C6 09/12 – 11/05
†Irrigation Regime						
Low	7.0	6.8	6.8	6.5	6.7	6.7
High	6.9	6.6	6.6	6.5	6.6	6.6
Significance	NS	NS	NS	NS	NS	NS
N Rate kg ha ⁻¹ yr ⁻¹						
98	6.0a	5.4a	5.4a	5.5a	5.9a	6.0a
196	6.8b	6.6b	6.6b	6.3b	6.4ab	6.4ab
294	7.0c	6.7b	6.7b	6.6b	6.8b	6.7bc
588	7.9d	8.2c	8.2c	7.5c	7.5c	7.3c
Significance	**	**	**	**	**	**
Irr. x N Interaction	NS	NS	NS	NS	NS	NS

NS and ** = $P > 0.05$ and $P < 0.01$

‡Turfgrass quality ratings based on a 1-9 scale with 9=dark green turf, 1=dead/brown turf, and 6=minimally acceptable turf.

†Low irrigation: 2.5mm daily except when daily precipitation > 6.4mm (irrigation turned off) and High irrigation: 13.0 mm three times weekly

Table 31. Effect of irrigation regime and N fertilization on turf quality ratings‡ for bahiagrass averaged by cycle (C) for year 2.

Factor	C1 10/17 – 12/20	C2 12/24 – 02/15	C3 02/26 – 04/21	C4 04/28 – 06/23	C5 07/02 – 09/01	C6 09/12 – 11/05
†Irrigation Regime						
Low	7.1	6.9	6.9	7.1	7.1	6.9
High	6.9	7.0	6.6	6.9	6.7	6.2
Significance	NS	NS	NS	NS	NS	NS
N Rate kg ha ⁻¹ yr ⁻¹						
49	6.7	6.4a	6.4a	6.5a	6.6a	6.0a
98	6.9	6.8ab	6.6ab	7.0b	6.9ab	6.4b
196	7.3	7.2bc	6.8b	7.1b	7.0b	6.8bc
294	7.1	7.4c	7.2c	7.3b	7.2c	6.9c
Significance	NS	**	**	**	**	**
Irr. x N Interaction	NS	NS	NS	NS	NS	NS

NS and ** = $P > 0.05$ and $P < 0.01$

‡Turfgrass quality ratings based on a 1-9 scale with 9=dark green turf, 1=dead/brown turf, and 6=minimally acceptable turf.

†Low irrigation: 2.5mm daily except when daily precipitation > 6.4mm (irrigation turned off) and High irrigation: 13.0 mm three times weekly

Table 32. Effect of irrigation regime and N fertilization on turf color ratings‡ for St. Augustinegrass averaged by cycle (C) for year 2.

Factor	C1 10/17 – 12/20	C2 12/24 – 02/15	C3 02/26 – 04/21	C4 04/28 – 06/23	C5 07/02 – 09/01	C6 09/12 – 11/05
†Irrigation Regime						
Low	7.0	6.7	6.5	6.7	7.0	7.0
High	7.0	6.5	6.5	6.5	6.9	6.9
Significance	NS	NS	NS	NS	NS	NS
N Rate kg ha ⁻¹ yr ⁻¹						
98	6.2a	5.4a	5.6a	6.0a	6.4a	6.1a
196	6.8b	6.4b	6.4b	6.4ab	6.8ab	6.8b
294	7.0b	6.6b	6.7b	6.7b	7.0bc	7.2b
588	8.0c	8.1c	7.5c	7.5c	7.5c	7.7c
Significance	**	**	**	**	**	**
Irr. x N Interaction	NS	NS	NS	NS	NS	NS

NS and ** = $P > 0.05$ and $P < 0.01$

‡Turfgrass color ratings based on a 1-9 scale with 9=dark green turf, 1=dead/brown turf, and 6=minimally acceptable turf.

†Low irrigation: 2.5mm daily except when daily precipitation > 6.4mm (irrigation turned off) and High irrigation: 13.0 mm three times weekly

Table 33. Effect of irrigation regime and N fertilization on turf color ratings‡ for bahiagrass averaged by cycle (C) for year 2.

Factor	C1 10/17 – 12/20	C2 12/24 – 02/15	C3 02/26 – 04/21	C4 04/28 – 06/23	C5 07/02 – 09/01	C6 09/12 – 11/05
†Irrigation Regime						
Low	7.1	6.8	7.0	7.2	7.2	7.0
High	6.9	6.9	6.8	6.8	6.9	6.5
Significance	NS	NS	NS	NS	NS	NS
N Rate kg ha ⁻¹ yr ⁻¹						
49	6.7	6.3a	6.6a	6.5a	6.5a	6.1a
98	7.0	6.7ab	6.8ab	6.9b	7.0a	6.6b
196	7.3	7.1bc	7.0bc	7.2bc	7.3a	7.1c
294	7.1	7.4c	7.3c	7.4c	7.4b	7.2c
Significance	NS	**	**	**	**	**
Irr. x N Interaction	NS	NS	NS	NS	NS	NS

NS and = $P > 0.05$ and $P < 0.01$

‡Turfgrass color ratings based on a 1-9 scale with 9=dark green turf, 1=dead/brown turf, and 6=minimally acceptable turf.

†Low irrigation: 2.5mm daily except when daily precipitation > 6.4mm (irrigation turned off) and High irrigation: 13.0 mm three times weekly

Table 34. Effect of irrigation regime and N fertilization on turf density ratings‡ for St. Augustinegrass averaged by cycle (C) for year 2.

Factor	C1 10/17 – 12/20	C2 12/24 – 02/15	C5 07/02 – 09/01
†Irrigation Regime			
Low	6.4	6.6	6.2
High	6.6	6.4	6.2
Significance	NS	NS	NS
N Rate kg ha ⁻¹ yr ⁻¹			
98	5.4a	4.8a	5.6a
196	6.3ab	6.3b	5.9a
294	6.6b	6.4b	6.3ab
588	7.8c	8.6c	6.9b
Significance	**	**	**
Irr. x N Interaction			
Significance	NS	NS	NS

NS and ** = $P > 0.05$ and $P < 0.01$

‡Turfgrass density ratings based on a 1-9 scale with 9=most dense and uniform turf, 1=least dense turf, and 6=minimally acceptable turf.

†Low irrigation: 2.5mm daily except when daily precipitation > 6.4mm (irrigation turned off) and High irrigation: 13.0 mm three times weekly

Table 35. Effect of irrigation regime and N fertilization on turf density ratings‡ for bahiagrass averaged by cycle (C) for year 2.

Factor	C1 10/17 – 12/20	C2 12/24 – 02/15	C5 07/02 – 09/01
†Irrigation Regime			
Low	7.4	6.4	5.8
High	7.4	6.4	6.3
Significance	NS	NS	NS
N Rate kg ha ⁻¹ yr ⁻¹			
49	7.1a	5.6a	5.9
98	7.1a	6.3b	6.1
196	7.7b	6.9b	6.1
294	7.7b	6.9b	6.3
Significance	**	**	NS
Irr. x N Interaction			
Significance	NS	NS	NS

NS and ** = $P > 0.05$ and $P < 0.01$

‡Turfgrass density ratings based on a 1-9 scale with 9=most dense and uniform turf, 1=least dense turf, and 6=minimally acceptable turf.

†Low irrigation: 2.5mm daily except when daily precipitation > 6.4mm (irrigation turned off) and High irrigation: 13.0 mm three times weekly

Table 36. Effect of irrigation regime and N fertilization on turf clipping yields (g m^{-2}) for St. Augustinegrass averaged by cycle (C) for year 2.

Factor	C1 10/17 – 12/20	!C2 12/24 – 02/15	C3 02/26 – 04/21	C4 04/28 – 06/23	C5 07/02 – 09/01	C6 09/12 – 11/05
†Irrigation Regime						
Low	10.6	ND	22.0	20.6	24.8	45.9
High	11.7	ND	22.9	20.1	22.4	43.1
Significance	NS	NS	NS	NS	NS	NS
N Rate $\text{kg ha}^{-1} \text{yr}^{-1}$						
98	3.7a	ND	4.9a	6.2a	11.4a	26.2a
196	9.4b	ND	16.8b	16.2b	19.9a	41.7ab
294	11.7b	ND	18.7c	15.5b	21.0a	47.0bc
588	19.7d	ND	49.5d	43.6c	42.2b	63.0c
Significance	**	NS	**	**	**	**

NS and ** = $P > 0.05$ and $P < 0.01$

†Low irrigation: 2.5mm daily except when daily precipitation > 6.4mm (irrigation turned off) and
High irrigation: 13.0 mm three times weekly

! ND = No data (Not enough growth to take clippings)

Table 37. Effect of irrigation regime and N fertilization on turf clipping yields (g m^{-2}) for bahiagrass averaged by cycle (C) for year 2.

Factor	C1 10/17 – 12/20	C2 12/24 – 02/15	C3 02/26 – 04/21	C4 04/28 – 06/23	C5 07/02 – 09/01	C6 09/12 – 11/05
†Irrigation Regime						
Low	29.8	ND	10.6	37.9	76.5	70.4
High	30.6	ND	11.4	48.1	75.8	65.6
Significance	NS	NS	NS	NS	NS	NS
N Rate $\text{kg ha}^{-1} \text{yr}^{-1}$						
49	21.7a	ND	5.3a	25.5a	54.7a	52.3a
98	26.8ab	ND	7.8a	33.0ab	67.9a	61.3a
196	38.4bc	ND	16.7b	60.0b	89.0b	75.7b
294	33.9c	ND	14.3b	54.6b	92.9b	82.7b
Significance	**	NS	**	**	**	**

NS and ** = $P > 0.05$ and $P < 0.01$

†Low irrigation: 2.5 mm daily except when daily precipitation $> 6.4\text{mm}$ (irrigation turned off) and
High irrigation: 13.0 mm three times weekly

! ND = No data (Not enough growth to take clippings)

THE EFFECT OF SOIL-TEST PHOSPHORUS ON TURFGRASS QUALITY, GROWTH AND P LEACHING

MATERIALS AND METHODS

Using a mined quartz sand initially low in phosphorus, 4 levels of soil-test P were established corresponding to the low, medium, high, and very high categories provided by the University of Florida Extension Soil Testing Lab (ESTL). A preliminary incubation study was conducted to determine the amount of P needed to establish the 4 soil-test P levels in the field and later in the greenhouse. A range of triple super phosphate (0-46-0) amounts were added to the sand and after incubating in plastic containers in a field-moist state for 1 month, samples of the soil mixes were analyzed by the ESTL for P concentration. Using the P application vs. soil-test P curves generated with these data, the low, medium, high and very high levels of P were established in the mixes used in the field. A fifth treatment, very low, containing no added P was also included in the field study. Four treatments were used in the greenhouse trials: very low, medium, very high, and a very low sand-only treatment.

The field experiment was initiated September 28, 2008 at University of Florida's Fort Lauderdale Research and Education Center. Phosphorus treatments (Table 38) were incorporated into 4 replications of randomized plots each having a single lysimeter. After sand mixes were added to each plot, sand-grown St. Augustinegrass sod (courtesy of King Ranch, Belle Glade, FL) with soil washed free from roots was then established over plots. Lysimeters, which were previously installed into each 0.5m x 2m plot, had a 40L capacity, 35.6cm inside diameter, 40.6cm height and were constructed of stainless steel with stainless steel tubing extending to sampling stations for leachate removal via vacuum. Plots were maintained throughout the study with phosphorus-free fertilizers at 1.0 lb. N 1000 ft.⁻² monthly for 3 months then every other month thereafter. Potassium (0-0-62) was also applied at initiation at 3.0 lbs. K 1000 ft.⁻². Soil samples were taken throughout the study and sent to ESTL for P analysis (Table 42).

Table 38. Soil P treatments based on Extension Soil Testing Lab Results

SOIL P TRT.	ppm range
Very Low (no P added)	0-10
Low	10-15
Medium	15-30
High	30-60
Very High	> 60

Turfgrass visual ratings (scale of 1-9 with 9=dark green, dense turf, 1=dead/brown turf, and 6=minimally acceptable turf) were taken throughout the experimental period. Turfgrass clipping samples were taken at a 3.0 inch height of cut approximately every 2 weeks or more when necessary. Tissue was oven dried at 60°C for a minimum of 48 hours before weighing.

Leachate water samples were collected weekly or more frequently following a rain event exceeding 0.25 inch. Samples were acid preserved and shipped to the UF Analytical Research Lab in Gainesville for total-PO₄ analysis.

The greenhouse experiment consisted of 2 trials and initiated on August 20, 2009 with lysimeter and soil preparation. Using the same technique as in the field study, phosphorus treatments were incorporated into 4 replications of PVC lysimeters (6" [14cm] diameter x 18" [40cm] depth). All soil-P treatments in lysimeters were sprigged with 'Floritam' St. Augustinegrass (16 sprigs/lysimeter) removed from a very

low P soil plot in the field study. Using a 15-0-15 liquid fertilizer, 1.0 lb. N 1000 ft.⁻² was applied weekly in the beginning months and then bi-weekly thereafter. Grow-in was essentially complete by November and leaching was initiated on November 11, 2009. The irrigation/water source was city hose water (P level in irrigation sampled throughout the trials averaged 5-6 ug/L). Leachate samples were collected weekly by initially having all lysimeters at field capacity and then leaching 2400 mls (previously determined to be 1 pore volume of the lysimeter) water through the columns. Lysimeters were maintained at field capacity throughout the trials with daily ET water replacement. Turfgrass visual ratings (scale of 1-9 with 9=dark green, dense turf, 1=dead/brown turf, and 6=minimally acceptable turf) were taken throughout the experimental period. Turfgrass clipping samples were taken with hand shears at a 3.0 inch height of cut approximately every 2 weeks or more when necessary. Tissue was oven dried at 60°C for a minimum of 48 hours before weighing. Leachate samples were acid preserved and shipped to the UF Analytical Research Lab in Gainesville for total-PO₄ analysis.

All data was subject to statistical analysis and significant means were identified.

RESULTS –FIELD TESTS

Generally, increasing soil test-P did not have an effect on either turf color, turf quality or clipping growth over time (Tables 39-41). Turfgrass color and quality improved after field establishment presumably since the sod placed on the site was initially washed free of sand to reduce P influence of the sod (Tables 39 and 40).

There was a general year to year decline in soil-test P values so that the values observed were in some cases less than the range for that particular soil-test level (Table 10). For example a very high P soil-test would be above 60 ppm, and by 10/10/09, the observed value of samples taken from the very high soil-test P treatment at year's end was much below that threshold value (Table 42).

Leaching of P was significantly affected by soil-test P throughout the reporting period with more leaching from higher soil-test P treatments (Table 43). Although the greatest amount of leaching occurred initially, significant differences were observed through 2009 (Table 43). The total amounts of P leached were significantly-affected by soil-test P treatment with very high and high soil-test P treatments leaching more P than the medium, low and very low treatments (Table 44).

Although P concentration in percolate was significantly-affected by treatment, P concentration even in the very low P soil-test was above thresholds considered to have an impact on water quality throughout the reporting period (Table 45).

In the greenhouse trials, the very low soil-test P treatment generally had significantly lower turf quality ratings and clipping growth (Tables 46, 47, 49 & 50). Increasing the soil-test above medium did not increase ratings or growth (Tables 46, 47, 49 & 50). Concentration of P in percolate was also affected by soil-test P treatment with P leaching increased by soil-test P level and P leaching was increased in very low P soil-test treatments that did not have turf to uptake P compared to very low P soil-test grassed treatment (Tables 48 and 51). The lower P concentration observed in the greenhouse studies presumably reflect different inputs of P from water and differences in percolate. Nevertheless, P concentrations were rarely at the threshold level for water quality standards (Table 48 and 51).

Table 39a. Field P Test: Turfgrass quality ratings.

SOIL TRT	10/2/08	11/7	12/9	1/12/09	2/5	3/13	3/31
V. LOW	5.6	5.5	5.5b	6.1	6.1	7.0	6.9
LOW	5.6	5.4	5.4b	6.1	6.6	7.5	7.5
MED	5.4	5.4	5.3b	6.3	6.6	7.4	7.6
HIGH	5.8	5.6	6.0a	6.6	6.6	7.5	7.5
V. HIGH	5.5	5.5	5.5b	6.4	6.1	7.5	7.4
Signif.	ns	ns	**	ns	ns	ns	ns

ns and ** = $P > 0.05$ and $P < 0.01$

Means with the same letter within a column are not significantly different according to Duncan's Multiple Range Test.

Turfgrass quality ratings based on a 1-9 scale with 9=dark green turf, 1=dead/brown turf, and 6=minimally acceptable turf.

Table 39b. Field P Test: Turfgrass quality ratings.

SOIL TRT	5/20/09	6/3	7/10	8/6	9/18	10/12
V. LOW	6.0	6.6	6.4	5.9	6.4	5.8
LOW	7.4	7.3	6.5	6.1	6.1	6.0
MED	7.1	7.4	6.3	6.3	6.3	6.5
HIGH	6.6	7.3	6.4	6.1	6.1	6.5
V. HIGH	6.3	7.0	6.3	6.0	6.8	5.8
Signif.	ns	ns	ns	ns	ns	ns

ns = $P > 0.05$

Turfgrass quality ratings based on a 1-9 scale with 9=dark green turf, 1=dead/brown turf, and 6=minimally acceptable turf.

40a. Field P Test: Turfgrass color ratings.

SOIL TRT	10/2/08	11/7	12/9	1/12/09	2/5	3/13	3/31
V. LOW	6.0	6.0	5.9b	6.1	6.4	7.8	7.5
LOW	6.0	5.5	5.6b	6.6	6.8	7.9	7.5
MED	5.9	5.6	5.9b	6.8	6.9	7.8	8.0
HIGH	5.9	6.0	6.4a	6.8	7.0	7.8	7.9
V. HIGH	5.9	5.6	5.9b	6.6	6.6	8.0	7.5
Signif.	ns	ns	*	ns	ns	ns	ns

ns and * = $P > 0.05$ and $P < 0.05$

Means with the same letter within a column are not significantly different according to Duncan's Multiple Range Test.

Turfgrass color ratings based on a 1-9 scale with 9=dark green turf, 1=dead/brown turf, and 6=minimally acceptable turf.

Table 40b. Field P Test: Turfgrass color ratings.

SOIL TRT	5/20/09	6/3	7/10	8/6	9/18	10/12
V. LOW	6.6	7.5	6.5	6.1	6.8	6.1
LOW	7.8	7.6	6.6	6.4	6.5	6.5
MED	7.8	7.4	6.5	6.4	6.3	6.8
HIGH	7.1	7.8	6.6	6.6	6.8	7.0
V. HIGH	6.5	7.4	6.6	6.3	7.1	6.5
Signif.	ns	ns	ns	ns	ns	ns

ns = P>0.05

Turfgrass color ratings based on a 1-9 scale with 9=dark green turf, 1=dead/brown turf, and 6=minimally acceptable turf.

Table 41a. Field P Test: Turfgrass clipping yields

SOIL TRT	10/2/08	11/11	12/22	1/27	3/12	3/31	5/20	6/3
V. LOW	4.0	12.5	3.1	4.9	4.7	1.9	19.2	26.8
LOW	3.0	11.7	4.7	6.3	11.7	8.2	37.8	39.3
MED	2.5	9.8	3.1	6.3	10.9	11.1	33.3	32.8
HIGH	2.9	10.9	4.1	7.5	7.8	5.4	25.0	26.8
V. HIGH	2.8	11.8	2.9	5.6	4.8	3.5	20.0	24.9
Signif.	ns	ns	ns	ns	ns	ns	ns	ns

ns = P>0.05

Table 41b. Field P Test: Turfgrass clipping yields.

SOIL TRT	7/6/09	7/29	8/7	8/14	9/3	9/25	10/12
V. LOW	31.3	56.1	8.3ab	38.7	34.1b	28.2	41.1
LOW	46.5	72.4	13.3a	54.4	52.3a	45.9	50.4
MED	45.6	57.2	10.7ab	47.2	49.8a	42.9	51.4
HIGH	41.2	55.7	10.3ab	54.3	40.6ab	32.1	57.7
V. HIGH	31.9	47.7	6.0b	41.7	36.8b	35.9	48.8
Signif.	ns	ns	*	ns	*	ns	ns

ns and * = P>0.05 and P<0.05

Means with the same letter within a column are not significantly different according to Duncan's Multiple Range Test.

Table 42. Field P Test: Extension Soil Testing Lab soil P (ppm) results

SOIL TRT	8/30/08	4/1/09	10/10/09
V. LOW	7.5d	12.3b	9.3c
LOW	11.3cd	14.3ab	9.5c
MED	19.5c	30.5ab	11.5c
HIGH	33.5b	34.0a	18.5b
V. HIGH	55.5a	33.5a	31.8a
Signif.	**	*	**

** and * = P<0.01 and P<0.05

Means with the same letter within a column are not significantly different according to Duncan's Multiple Range Test.

Table 43a. Field P Test: Phosphorus leached (mg m^{-2})

SOIL TRT	9/27/08	10/6	10/13	10/20	10/27	11/3	11/10
V. LOW	91c	203c	57c	23d	47d	48b	18b
LOW	171c	292c	77c	41d	105cd	46b	32b
MED	920b	764c	205b	92c	158bc	96b	68ab
HIGH	5663b	2406b	313a	162b	234ab	134ab	113a
V. HIGH	15323a	3638a	397a	203a	306a	222a	118a
Signif.	***	***	***	***	***	*	*

*** and * = $P < 0.001$ and $P < 0.05$

Means with the same letter within a column are not significantly different according to Duncan's Multiple Range Test.

Table 43b. Field P Test: Phosphorus leached (mg m^{-2})

SOIL TRT	11/17/08	11/24	12/1	12/15	12/22	12/30	1/5/09
V. LOW	48c	42c	19c	17b	12c	12b	11b
LOW	68c	61bc	33c	30b	18c	12b	11b
MED	123bc	115abc	67b	55a	34b	22ab	18b
HIGH	184ab	140ab	111a	61a	47a	27a	28ab
V. HIGH	267a	200a	104a	63a	56a	27a	13a
Signif.	***	**	***	**	***	*	*

***, **, and * = $P < 0.001$, $P < 0.01$, and $P < 0.05$

Means with the same letter within a column are not significantly different according to Duncan's Multiple Range Test.

Table 43c. Field P Test: Phosphorus leached (mg m^{-2})

SOIL TRT	1/12/09	1/19	1/25	2/2	2/8	2/10	2/23
V. LOW	12b	11b	9b	26	7c	12c	8c
LOW	13b	13b	10b	27	8bc	15c	9bc
MED	24b	28a	20b	42	16abc	27b	20a
HIGH	43a	35a	24b	45	17ab	29b	18ab
V. HIGH	47a	40a	59a	78	23a	41a	28a
Signif.	***	**	+	ns	**	***	**

***, **, *, and ns = $P < 0.001$, $P < 0.01$, $P < 0.05$, and $P > 0.05$

Means with the same letter within a column are not significantly different according to Duncan's Multiple Range Test.

Table 43d. Field P Test: Phosphorus leached (mg m⁻²)

SOIL TRT	3/4/09	3/11	3/20	3/27	5/6	5/19	5/28
V. LOW	11b	10	27d	61	22c	32bc	44b
LOW	13b	9	26d	19	66bc	25c	49b
MED	24ab	16	59c	32	144ab	45bc	76b
HIGH	34a	15	83b	42	202a	60ab	106b
V. HIGH	30a	15	104a	99	156ab	86a	189a
Signif.	**	ns	***	ns	*	**	**

, ns, *, and * = P<0.01, P>0.05, P<0.001, and P<0.05

Means with the same letter within a column are not significantly different according to Duncan's Multiple Range Test.

Table 43e. Field P Test: Phosphorus leached (mg m⁻²)

SOIL TRT	6/10/09	6/17	6/29	7/7	7/17	7/24	7/31
V. LOW	12b	9c	8b	17d	6c	11c	5b
LOW	18b	12c	10b	24cd	9c	20bc	7b
MED	34b	20bc	18b	44c	15bc	31bc	12b
HIGH	54b	35b	32a	82b	26b	68ab	25a
V. HIGH	101a	60a	43a	114a	49a	112a	34a
Signif.	**	***	***	***	***	**	***

** and *** = P<0.01 and P<0.001

Means with the same letter within a column are not significantly different according to Duncan's Multiple Range Test.

Table 43f. Field P Test: Phosphorus leached (mg m⁻²)

SOIL TRT	8/21/09	8/27	9/5	9/13	11/4
V. LOW	17c	1b	13b	15b	24b
LOW	38bc	2b	21b	22b	46b
MED	54b	2b	43b	40b	95b
HIGH	107a	3b	108a	72a	156ab
V. HIGH	135a	7a	119a	93a	293a
Signif.	***	**	***	***	*

***, **, and * = P<0.001, P<0.01, and P<0.05

Means with the same letter within a column are not significantly different according to Duncan's Multiple Range Test.

Table 44. Field P Test: Phosphorus leached (mg m⁻²)

SOIL TRT	TOTAL 9/23/08-11/4/09
V. LOW	1114c
LOW	1542c
MED	3718c
HIGH	11145b
V. HIGH	23087a
Signif.	***

*** = P<0.001

Means with the same letter within a column are not significantly different according to Duncan's Multiple Range Test.

Table 45a. Field P Test: Phosphorus (mg/L)

SOIL TRT	9/27/08	10/6	10/13	10/20	10/27	11/3	11/10
V. LOW	0.4c	1.0c	0.4d	0.3d	0.4d	0.3d	0.3c
LOW	0.9c	1.6c	0.7d	0.6d	1.0cd	0.6cd	0.6bc
MED	4.9c	4.1c	1.7c	1.5c	1.3bc	1.3bc	1.2b
HIGH	28.4b	12.0b	3.2b	2.8b	1.9b	1.9b	1.9a
V. HIGH	78.3a	18.2a	3.9a	3.4a	2.9a	2.9a	2.0a
Signif.	***	***	***	***	***	***	***

*** = P<0.001

Means with the same letter within a column are not significantly different according to Duncan's Multiple Range Test.

Table 45b. Field P Test: Phosphorus (mg/L)

SOIL TRT	11/17	11/24	12/1	12/15	12/22	12/30	1/5/09
V. LOW	0.8d	0.6c	0.3c	0.2c	0.2d	0.3d	0.3c
LOW	1.3cd	1.1c	0.4c	0.4c	0.4d	0.4d	0.3c
MED	2.6bc	1.7bc	0.9b	0.7b	0.7c	0.7c	0.5c
HIGH	3.7b	2.5b	1.5a	1.2a	1.1b	1.0b	0.9b
V. HIGH	5.5a	3.8a	1.5a	1.3a	1.4a	1.3a	1.1a
Signif.	***	***	***	***	***	***	***

*** = P<0.001

Means with the same letter within a column are not significantly different according to Duncan's Multiple Range Test.

Table 45c. Field P Test: Phosphorus (mg/L)

SOIL TRT	1/12/09	1/19	1/25	2/2	2/8	2/10	2/23
V. LOW	0.2d	0.2d	0.2d	0.2d	0.2d	0.2d	0.3c
LOW	0.3d	0.3d	0.3cd	0.3cd	0.3d	0.3d	0.3c
MED	0.5c	0.6c	0.4c	0.5bc	0.5c	0.5c	0.5b
HIGH	0.9b	0.9b	0.6b	0.7ab	0.7b	0.6b	0.7b
V. HIGH	1.0a	1.2a	1.0a	0.9a	1.0a	0.8a	0.9a
Signif.	***	***	***	***	***	***	***

*** = P<0.01

Means with the same letter within a column are not significantly different according to Duncan's Multiple Range Test.

Table 45d. Field P Test: Phosphorus (mg/L)

SOIL TRT	3/4/09	3/11	3/20	3/27	5/6	5/19	5/28
V. LOW	0.3d	0.2c	0.2d	0.2	0.1c	0.2bc	0.3c
LOW	0.3d	0.3abc	0.3d	0.4	0.4bc	0.1c	0.4bc
MED	0.5c	0.3abc	0.5c	0.7	0.9ab	0.3bc	0.5bc
HIGH	0.6b	0.4ab	0.7b	0.9	1.1a	0.4ab	0.9b
V. HIGH	0.8a	0.5a	0.9a	1.4	1.0ab	0.6a	1.5a
Signif.	*	*	*	ns	*	**	***

*, ns, **, and *** = $P < 0.05$, $P > 0.05$, $P < 0.01$ and $P < 0.001$

Means with the same letter within a column are not significantly different according to Duncan's Multiple Range Test.

Table 45e. Field P Test: Phosphorus (mg/L)

SOIL TRT	6/10/09	6/17	6/29	7/7	7/17	7/24	7/31
V. LOW	0.1c	0.2c	0.2c	0.1d	0.1c	0.1c	0.1d
LOW	0.2bc	0.3c	0.3c	0.2cd	0.2c	0.2c	0.2cd
MED	0.3bc	0.4bc	0.4c	0.4c	0.3c	0.3c	0.4bc
HIGH	0.6b	0.8b	0.7b	0.7b	0.5b	0.7b	0.6b
V. HIGH	1.3a	1.3a	1.1a	1.1a	0.8a	0.9a	0.9a
Signif.	***	***	***	***	***	***	***

*** = $P < 0.001$

Means with the same letter within a column are not significantly different according to Duncan's Multiple Range Test.

Table 45f. Field P Test: Phosphorus (mg/L)

SOIL TRT	8/21/09	8/27	9/5	9/13	11/4
V. LOW	0.1c	0.1c	0.09b	0.2c	0.1c
LOW	0.2bc	0.1c	0.2b	0.2c	0.3c
MED	0.4b	0.2bc	0.3b	0.4c	0.5bc
HIGH	0.8a	0.4b	0.7a	0.8b	1.2ab
V. HIGH	0.9a	0.7a	0.9a	1.2a	1.6a
Signif.	***	***	***	***	**

*** and ** = $P < 0.001$ and $P < 0.01$

Means with the same letter within a column are not significantly different according to Duncan's Multiple Range Test.

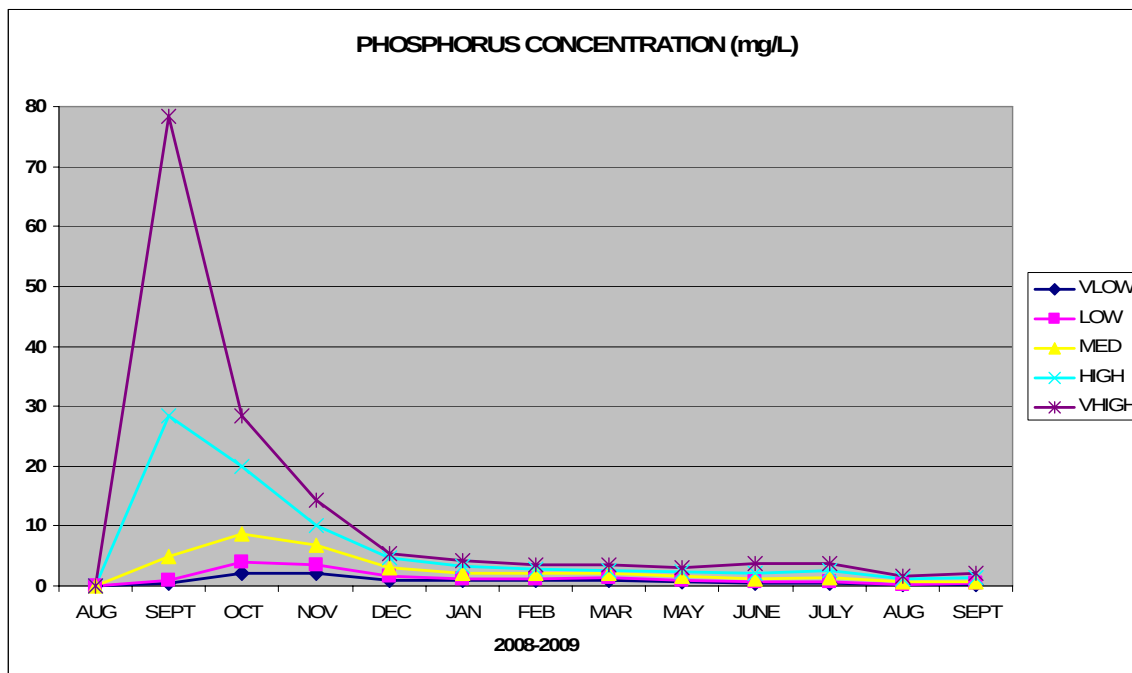


Figure 11. Daily P concentrations from August 2008 – Sept. 2009 for P Availability Field Test at the Fort Lauderdale Research and Education Center.

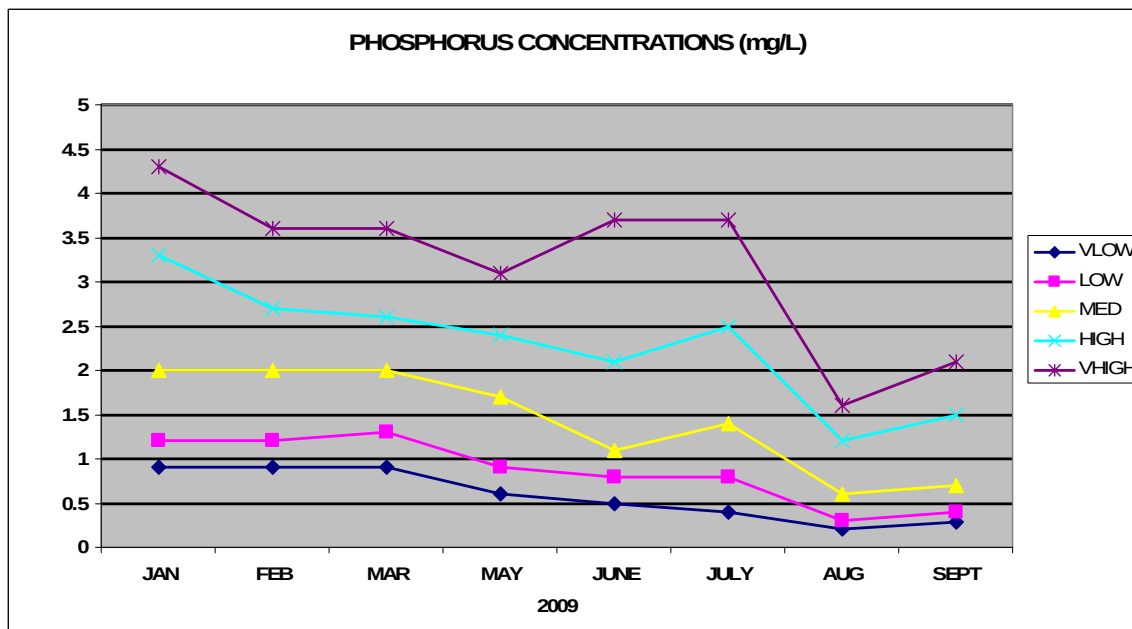


Figure 12. Daily P concentrations from January 2009 – Sept. 2009 for P Availability Field Test at the Fort Lauderdale Research and Education Center.

RESULTS - GREENHOUSE TRIALS

Greenhouse Trial 1

Table 46. Greenhouse P Test Trial 1: Turfgrass quality ratings.

SOIL TRT	2/4/10	2/22	3/15
V. LOW	7.1	6.4	7.6
MED	7.6	6.8	7.9
V. HIGH	7.5	6.8	7.8
Signif.	ns	ns	ns

ns = $P > 0.05$

Turfgrass quality ratings based on a 1-9 scale with 9=dark green turf, 1=dead/brown turf and 6=minimally acceptable turf.

Table 47. Greenhouse P Test Trial 1: Turfgrass clipping yields.

SOIL TRT	9/21/09	9/30	10/8	10/19	11/6	11/16	12/15	12/29
V. LOW	0.8	0.6	0.3b	0.3b	1.0c	0.3b	0.7b	0.4b
MED	0.7	0.8	0.6ab	0.9a	4.6b	1.1a	2.1a	1.2a
V. HIGH	0.8	0.8	0.95a	0.9a	6.6a	1.2a	1.9a	1.0a
Signif.	ns	ns	*	**	**	**	**	**

ns, * and ** = $P > 0.05$, $P < 0.05$ and $P < 0.01$

Means with the same letter within a column are not significantly different according to Duncan's Multiple Range Test.

Table 48. Greenhouse P Test Trial 1: P concentration (mg/L).

SOIL TRT	11/17/09	12/2	12/9	12/16	12/23	12/30
V. LOW	0.6b	0.1b	0.1b	0.1b	0.03c	0.04b
MED	1.8b	0.7b	0.4b	0.5b	0.4b	0.4b
V. HIGH	24.1a	23.9a	6.5a	5.4a	3.2a	3.1a
SAND	0.1b	0.1b	0.1b	0.1b	0.1bc	0.1b
Signif.	**	**	**	**	**	**

** = $P < 0.01$

Means with the same letter within a column are not significantly different according to Duncan's Multiple Range Test.

Greenhouse Trial 2

Table 49. Greenhouse P Test Trial 2: Turfgrass quality ratings.

SOIL TRT	2/4/10	2/22	3/15
V. LOW	7.3c	6.5b	7.3b
MED	7.8b	7.1a	8.0a
V. HIGH	8.3a	7.4a	7.9a
Signif.	**	**	*

** and * = $P < 0.01$ and $P < 0.05$

Turfgrass quality ratings based on a 1-9 scale with 9=dark green turf, 1=dead/brown turf and 6=minimally acceptable turf.

Means with the same letter within a column are not significantly different according to Duncan's Multiple Range Test.

Table 50. Greenhouse P Test Trial 2: Turfgrass clipping yields.

SOIL TRT	9/21/09	9/30	10/8	10/19	11/6	11/16	12/15	12/29
V. LOW	1.0	0.8	0.4b	0.3b	2.6b	0.3b	0.8b	0.5b
MED	0.8	1.9	0.9a	1.3a	4.5ab	1.3a	1.9a	0.9a
V. HIGH	0.9	1.1	0.7ab	1.3a	5.9a	1.2a	1.8a	0.9a
Signif.	ns	ns	*	**	**	**	**	*

ns, *, and ** = $P > 0.05$, $P < 0.05$ and $P < 0.01$

Means with the same letter within a column are not significantly different according to Duncan's Multiple Range Test.

Table 51. Greenhouse P Test Trial 2: P concentration (mg/L).

SOIL TRT	11/17	12/2	12/9	12/16	12/23	12/30
V. LOW	0.3b	0.1b	0.04c	0.1c	0.03c	0.03d
MED	1.5b	0.6b	0.5b	0.5b	0.4b	0.4b
V. HIGH	27.4a	27.2a	4.8a	4.0a	2.7a	2.1a
SAND	0.2b	0.1b	0.1c	0.4b	0.2c	0.1c
Signif.	**	**	**	**	**	**

** = $P < 0.01$

Means with the same letter within a column are not significantly different according to Duncan's Multiple Range Test.

MM/YR	Avg. TEMP. °F	Min. TEMP. °F	Max. TEMP. °F	PPT. inches
SEP 08	81.52	70.93	92.03	6.31
OCT 08	76.67	49.17	90.19	8.05
NOV 08	68.96	46.71	89.91	1.07
DEC 08	68.9	48.16	84.02	0.42
JAN 09	65.18	37.27	85.96	0.11
FEB 09	66.13	35.3	88.66	0.27
MAR 09	70.42	43.54	87.73	4.83
APR 09	75.13	50.02	90.68	1.12
MAY09	78.1	65.91	92.3	8.65
JUN 09	80.79	69.84	96.78	8.12
JUL 09	82.15	69.48	96.12	9.72
AUG 09	83.6	72.72	94.26	6.01
SEP 09	81.05	72.91	92.73	7.08
OCT 09	80.33	56.41	93.9	2.24
NOV 09	73.11	47.12	90.77	4.08
DEC 09	71.03	45.75	88.99	4.17

Table 52.
Climatology:
September
2008—
December
2009.

NITRATE LEACHING DUE TO N SOURCE AND TIMING ON ST. AUGUSTINEGRASS

1.1 Introduction

Urban landscapes have been implicated as a potential non-point source contributor to N species degradation of surface and ground water. Statewide fertilizer labeling legislation was introduced in response to mounting concerns over the impact of urban fertilization practices. The enactment limits per application nitrogen (N) rates to 49 kg N ha^{-1} , of which, the water-soluble N portion should not exceed 34 kg N ha^{-1} .

Legislative bodies at the county and city level have imposed further restrictions prohibiting N fertilization during the traditional rainy season in south Florida from June 1st through September 30th. Rate regulation has been imposed unilaterally across all N sources and may negate the best features of slow release N sources (SRNS), which may be more effective when applied at infrequent higher per-application rates with reduced potential for N leaching. This legislation may rule out the option to fertilize judiciously with higher rates of SRNS and sustain good turf quality throughout rainy season ‘black out’ periods.

The objectives of this study were (1) To determine if slow-release fertilizers applied under current regulatory control can provide acceptable turf quality, (2) to evaluate St. Augustinegrass quality, color, density and clipping yield response to different N sources applied at various application rates, using urea as a baseline to determine initial and long term response, and (3) to determine if SRNS applied before the summer ‘black out’ period at higher rates than currently permitted, could sustain good St. Augustinegrass quality for the ban duration, (4) to evaluate the N leaching characteristics of the quick release, slow release, and combinations of quick and slow release N sources applied at various rates and application frequency.

1.2 Materials and Methods

The field study was initiated on 30 April 2007 at the University of Florida’s Fort Lauderdale Research and Education Center (FLREC) using St. Augustinegrass [*Stenotaphrum secundatum* Walt. Kuntze] cv. ‘Floritam’. The sand grown sod was established 6-mo prior on mined medium-fine sand (very coarse 0.2%, coarse 5.4 %, medium 29.9%, fine sand 62.9%, very fine sand 1.5%, and silt and clay 0.1%) having similar textural characteristics to the Margate/Hallandale fine sand series (Siliceous, hyperthermic Lythic Psammaquent) found in this coastal plain region. Periodic soil-testing, sampled to a depth of 10 cm, averaged across all plots revealed a pH of 7.0, 2.5% organic matter, very high P (Weak Bray P1 63 mg kg^{-1}), and high K (51 mg kg^{-1}). Due to high K mobility in sandy soil, Muriate of Potash at 49 kg K ha^{-1} was applied every 90-d, but no supplementary P was required. Micro-nutrients were applied as Harrell’s Max Minors[®] containing Mg 1%, S 3.5%, B 0.02%, Cu 0.25%, Fe 4%, Mn 1%, Zn 0.6% and Mo 0.0005% at 12.3 L product in 420 L water ha^{-1} every 90-d to ensure adequate tissue concentrations.

The 2 x 4 m plots were arranged in a randomized complete block design with 3 replicates. A single bucket lysimeter was installed in each plot. The lysimeter has a surface area of 0.264 m^2 (square or round) and is 0.9 m deep. Lysimeters were constructed of a heavy grade plastic with a leachate evacuation port located on the bottom of each. PVC pipe was attached to each lysimeter leading to gravity flow collection points adjacent to the plots.

For N sources, N application rates, and frequencies see Table 53. The 49 kg ha^{-1} applications were on 30 April, 30 June, and 31 August, 2007. Dates for 98 kg ha^{-1} applications were 30 April and 31 August, 2007, while the single 147 kg ha^{-1} application was on 30 April, 2007. The controlled-release liquid

treatment was applied in solution at 181 ml m⁻² using a CO₂ sprayer, equipped with two flat-fan Tee Jet 8010 nozzles on 50 cm spacing. Granular sources were hand sprinkled. The irrigation system configuration (i.e. 2 plots per irrigation zone) permitted all treatments to be watered into the turf immediately following applications to reduce volatile N losses. Irrigation was scheduled 3 times per week delivering approximately 0.6 cm at each event, including post-treatment.

Fertilizer responses were evaluated in terms of St. Augustinegrass quality, color, density and clipping yield. Visual quality ratings (scale of 1-9 with 9=dark green uniform turf, 1=dead/brown turf and 6=minimally acceptable turf) were made every two weeks. Clipping samples were harvested from each plot, removed, and sub-sampled for shoot growth, approximately weekly at a 75 mm height of cut. Samples were oven dried at 60°C for 48 hrs to a constant weight and reported in g m⁻² day⁻¹.

Table 53. N source designation, description, application information used in the study.

Code†	Description	% N	Per app. rate (kg N ha ⁻¹)	App. cycles year ⁻¹	Manufacturer
CRL1	12% Urea; 18% methylene urea and triazone	30	49	6	Georgia-Pacific, Inc. Decatur, GA
CRL2	12% Urea; 18% methylene urea and triazone	30	98	3	Georgia-Pacific, Inc. Decatur, GA
CRL3	12% Urea; 18% methylene urea and triazone	30	147	2	Georgia-Pacific, Inc. Decatur, GA
PCU1	Polymer-coated urea	42	49	6	Pursell Inc. Sylacauga, AL
PCU2	Polymer-coated urea	42	98	3	Pursell Inc. Sylacauga, AL
PCU3	Polymer-coated urea	42	147	2	Pursell Inc. Sylacauga, AL
BS1	Lawn grade activated sewage sludge bio-solid	6	49	6	Milorganite, Miliwaukee, WI
BS2	Lawn grade activated sewage sludge bio-solid	6	98	3	Milorganite, Miliwaukee, WI
BS3	Lawn grade activated sewage sludge bio-solid	6	147	2	Milorganite, Miliwaukee, WI
UPCU1	50:50 N combination urea:polymer-coated urea	44	49	6	Pursell Inc. & PCS Sales, Inc
UPCU2	50:50 N combination urea:polymer-coated urea	44	98	3	Pursell Inc. & PCS Sales, Inc
Urea	Granular	46	49	6	PCS Sales, Inc. Northbrook, IL

† Source code: CRL = Control release liquid; PCU = Polymer-coated urea; BS = Activated sewage sludge biosolid; UPCU = Urea in combination with polymer-coated urea.

Percolate water samples were collected weekly or more frequently following precipitation events exceeding 25 mm. The sample matrix was frozen at -4°C before being analyzed by UF Gainesville laboratory (NO₃-N Colorimetric, EPA Method 353.2). Data reported in mg NO₃-N leached m⁻².

St. Augustinegrass clipping yield, visual ratings, and NO₃-N leaching data were subject to analysis of variance using with PROC GLM (SAS Institute, 1999) and the means were separated by Waller-Duncan Multiple range test, K ratio=100 ($P<0.05$).

Results and Discussion – Year 1

Hydrology

The experiment was run during a period of time bracketing the main south Florida wet season. As such, rainfall quantities were over 2 times greater than irrigation applied and percolation was near 130 cm over the period (Table 54).

Table 54. Hydrology data by cycle for N Source and Frequency Test.

Cycle (C) x rate	Hydrology Factors		
	Precipitation	Irrigation	Percolate
	----- cm ³ -----		
49 kg ha ⁻¹			
C1	58.9	15.7	54.9
C2	30.8	17.7	39.2
C3	54.7	15.2	31.5
98 kg ha ⁻¹			
C1	89.7	33.4	97.4
C2	54.7	15.2	32.4
147 kg ha ⁻¹			
C1	144.4	48.6	129.1

Turfgrass Quality and Clipping Yields

Comparisons of N sources applied at 49 kg ha-1 at 60-d intervals

Fertilizer treatments were divided into six cycles per year (Table 53). In cycle 1 PCU and BS were slow to induce satisfactory ratings (Table 55). Cumulative turf quality increases during cycle 2 suggest residual N release from preceding applications may be sufficient to sustain adequate turf quality (Table 55).

Compared to other sources at this N rate, CRL plots were of inferior quality ($P<0.05$). When averaged, clipping yields from CRL were 27% of urea during the experimental period (Table 56). Polymer-coated urea resulted in higher numerical ratings than BS, although differences ($P<0.05$) were only noted 33 days after treatments (DAT) in cycle 2 (Table 55). However, when averaged, clipping yields relative to urea in the cycles 1 through 3 were 70% from the BS treatment and only 48% from PCU. Slower initial N release from PCU, together with higher yields following BS fertilization in cycle 1 and 2, presumably due to the soluble-N component in BS may explain higher clipping yields but lower actual turf quality (Tables 55 and 56).

Urea maintained good turf quality throughout each application cycle. However, UPCU1 provided more consistent turf quality relative to urea, which induced higher ratings immediately following applications but had lower quality in the last quarter of several cycles. Based on these data for a 6-month period of time, under urban fertilizer restrictions, UPCU1 may offer a legitimate alternative to frequent urea applications. However, it bears emphasizing that the use of other soluble and SRN sources and timing may provide different results and interpretations.

Comparisons of N sources applied at 98 kg ha⁻¹ at 120-d intervals

The SRNS evaluated performed best under this 3 cycle per year regime for the 6-month reporting period. PCU delivered higher quality ratings than BS, although statistical differences were only noted 95 and 7 DAT in cycle 1 and 2, respectively. Furthermore, PCU was statistically superior to CRL following a relatively slow initial response in cycle 1 (Tables 55).

Comparisons of clipping yield 32 DAT in experiment 1 may elucidate initial release patterns; CRL, BS, and PCU induced yields of 93, 74, and 41%, respectively, compared to urea (Table 56). These differences were less apparent in subsequent cycles where yields dropped considerably for CRL plots perhaps in part due to lower shoot density (data not included). In contrast, BS generated yields $\geq$ to urea 32 DAT in cycle 2 with PCU plots showing yields of 83% that of urea, conceivably implicating residual N carry-over or simply healthier turf prior to applications (Table 56).

UPCU2 outperformed SRNS in terms of quality ratings and had mean quality ratings per cycle almost identical to that of urea. Clipping yields from UPCU2 were for the most part undistinguishable from urea ($P < 0.05$), however a peak of N release between 30 and 60 DAT produced numerically higher yields and during cycle 2 statistically elevated yields. More importantly, both yield and turf quality did not differ significantly ($P > 0.95$) between UPCU2 and urea in the latter stage of each 120-d cycle (Table 55 and 56), indicating a good overall agronomic performance.

Comparisons within N Sources applied at 147 kg ha⁻¹ at 180-d intervals

The SRNS evaluated were unable to provide N release through the entire 180 d window, although differences in initial and long-term response were observed. CRL gave acceptable St. Augustinegrass quality for approximately 120 d with acceptable turf quality apparent 9 DAT (Table 18). Initial turf quality and clipping yield responses from BS were similar to CRL, although BS maintained initial responses with gradual yield increases from 166% at 32 DAT to a maximum of 200% at 59 DAT compared to urea (Tables 55 and 56).

Both PCU and BS provided acceptable turf quality of comparable 150-d periods. Initial responses were considerably slower, 32 DAT for PCU compared to BS where quality was deemed acceptable 9 DAT, however, weighed against other SRNS, PCU stimulated superior quality ratings ($P < 0.05$) for a large proportion of this cycle (Table 55). The data also indicates that all SRNS tested would be capable of sustaining adequate turf quality for the 120-d fertilizer ‘black out’ period imposed by certain local legislative bodies. Both PCU and BS at this rate provided adequate turf quality for an extra 30-d period, denoting the potential to reduce application rates to provide sufficient turf quality for enforced black outs.

Total cumulative yields for PCU were greater than urea, however, excessive yields concentrated into moderately short periods produced peaks of 2.5 times that of urea (Table 56). Periods of elevated mowing requirements relative to frequent urea applications may prove unacceptable in the lawn care industry where clipping disposal may have financial and environmental implication

Turfgrass Color

Turfgrass color is an important component of overall turfgrass quality and as such ratings were closely linked. Therefore, the discussion will focus only on differences between visual factors. Changes in turfgrass color occur more rapidly in response to N fertilization and may provide additional information on the N release patterns of sources. Our findings suggest that improvements in St. Augustinegrass color

and quality in response to soluble N source occur largely in unison or that the rating scheduling was too infrequent to divulge differences.

Table 55. Turfgrass quality ratings from 30 April through 30 October, 2007 as influenced by N source.

Source§	St. Augustinegrass Quality Rating Dates													Avg.¶
	04/29	05/08	05/31	06/20	06/27	07/27	08/02	08/24	09/07	09/23	10/06	10/19	10/30	
	Ratings (1-9 Scale)													
60-d Cycle	----- Cycle 1 -----				----- Cycle 2 -----				----- Cycle 3 -----					
DAT†	0	9	32	52	59	27	33	55	7	23	36	49	60	
CRL1	5.3‡	5.8ef	5.0d	5.5f	5.5f‡	6.3e	6.7de	6.3d‡	6.2e	6.2gh	5.5f	6.0de	5.3f‡	5.8h
PCU1	5.3‡	5.3f	5.0d	5.8ef	6.3cde	7.3abc	7.8a	7.7a‡	7.0cd	7.2def	7.5abc	7.2ab	7.0bcd	6.9c-f
BS1	5.2‡	6.3c-f	6.0bcd	6.0def	6.3cde	7.2bcd	7.2bc	7.3abc	6.8cde	7.2def	6.8cde	6.8bc	6.2e‡	6.8def
UPCU1	5.3‡	7.0a-d	5.8cd	6.0def	6.0ef‡	7.2bcd	7.8a	7.3abc	8.0ab	7.7bcd	7.5abc	6.8bc	7.2bc‡	7.1bc
Urea	5.7‡	7.8a	7.2ab	6.3c-e	6.8bcd	7.8a	7.5ab	7.5ab‡	8.3a	8.2ab	7.7ab	6.8bc	6.5cde	7.4ab
120-d Cycle	----- Cycle 1 -----				----- Cycle 2 -----				----- Cycle 3 -----					
DAT†	0	9	32	52	59	89	95	117	7	23	36	49	60	
CRL2	5.3‡	7.3abc	6.5abc	6.2def	6.2def	6.3e	6.8cde	6.7cd‡	6.5de	7.0ef	6.3e	6.2de	6.2e	6.6fg
PCU2	5.3‡	5.3f	5.7cd	7.2abc	7.5ab	7.2bcd	7.7a	7.5ab‡	7.5bc	7.5cde	7.8ab	7.5a	8.2a	7.3ab
BS2	5.3‡	6.0def	6.5abc	6.7cde	7.0bc	7.0cd	6.5e	7.0a-d‡	6.7de	7.8bc	7.3bcd	7.3ab	7.0bcd	7.1bc
UPCU2	5.3‡	7.7ab	7.7a	6.8bcd	7.2ab	7.0cd	7.0cd	7.3abc	8.2ab	8.5a	8.2a	7.3ab	7.6ab	7.7a
180-d Cycle	----- Cycle 1 -----				----- Cycle 2 -----				----- Cycle 3 -----					
DAT†	0	9	32	52	59	89	95	117	131	147	160	173	184	
CRL3	5.5‡	7.4abc	7.2ab	6.5cde	6.3cde	6.7de	6.8cde	6.8bcd	6.8cde	5.2i	5.3f	5.7e	5.0f‡	6.2gh
PCU3	5.3‡	5.5f	6.2bcd	7.8a	7.8a	7.7ab	7.8a	7.7a	8.0ab	6.7fg	7.3bcd	6.3cd	6.3de‡	7.0bcd
BS3	5.7‡	6.7b-e	7.7a	7.7ab	7.3ab	7.0cd	7.2bc	7.2abc	7.2cd	5.8h	6.7de	6.2de	5.3f‡	6.7ef
Significance	NS	***	***	***	***	***	***	**	***	***	***	***	***	***

NS, **, and ***, = P>0.05, P<0.01, and P<0.001

Ratings based on a 1-9 scale in increments of 0.5, 9 = dark green turfgrass, 1 = dead turfgrass, 6 = minimally acceptable turfgrass.

Means with the same letter within a column are not significantly different according to Waller-Duncan K-ratio = 100 t-Test.

DAT† = Days after treatments.

‡ Fertilization events followed harvest dates.

¶ Average quality rating for the experimental period.

§ Source code: CRL 1, 2, and 3 = Control release liquid applied at 49 kg N ha⁻¹, 98 kg N ha⁻¹, and 147 kg N ha⁻¹, respectively; PCU 1, 2, and 3 = Polymer-coated urea applied at 49 kg N ha⁻¹, 98 kg N ha⁻¹, and 147 kg N ha⁻¹, respectively; BS 1, 2, and 3 = Activated sewage sludge biosolid applied at 49 kg N ha⁻¹, 98 kg N ha⁻¹, and 147 kg N ha⁻¹, respectively; UPCU 1 and 2 = Urea in equal N combination with polymer-coated urea applied at 49 kg N ha⁻¹ and 98 kg N ha⁻¹, respectively.

When color and quality ratings from SRNS were compared, only PCU at 49 and 98 kg ha⁻¹ demonstrated elevated color prior to improvements in quality ratings. Acceptable color was obtained 52 and 32 DAT for PCU at 49 and 98 kg ha⁻¹, respectively; whereas acceptable quality required 59 and 52 DAT at 49 and 98 kg ha⁻¹, respectively in cycle 1 (Table 55 and 57). Following fertilizer applications in subsequent cycles these differences were less evident, perhaps due to residual N carry over from the previous cycle. For CRL and BS, color and quality improvements occurred at similar rates, which may be explained by the soluble fraction of these sources, 33 and 20% for CRL and BS, respectively.

Table 56. Clipping yields from 29 April through 30 October, 2007 influenced by N source.

Source§	St. Augustinegrass Harvest Dates													Avg. ¶	
	05/31	06/20	06/27	07/10	07/18	07/27	08/09	08/24	09/07	09/17	10/02	10/12	10/26		
----- Growth Rate (g m ⁻² d ⁻¹) -----															

60-d Cycle	----- Cycle 1 -----			----- Cycle 2 -----			----- Cycle 3 -----			-----					
	32	52	59	10	18	27	40	55	7	17	32	42	56		
	CRL1	0.12cde	0.26e	0.04e‡	0.29e	0.83e	0.70cd	0.07f	0.08e‡	0.06d	0.09e	0.06d	0.33e	0.05f‡	0.23e
	PCU1	0.08e	0.33de	0.05de	0.34de	0.91e	0.52d	0.26c-f	0.38b-d‡	0.32bc	0.32b-e	0.27d	1.09bc	0.35de	0.40de
	BS1	0.17cde	0.57de	0.08de	0.68cde	2.1b	0.93bc	0.34bc	0.50bc	0.36bc	0.46bc	0.34cd	0.77cd	0.25def	0.58bc
	UPCU1	0.18cde	0.40de	0.06de	0.75cde	1.75bc	1.22bc	0.32bc	0.46bc	0.45ab	0.60ab	0.72b	1.24b	0.43bc	0.66b
	Urea	0.27bc	0.65cde	0.09cde	1.74ab	1.82bc	1.34b	0.48bc	0.58bc	0.45ab	0.96a	0.77b	1.23b	0.36cde	0.83ab
120-d Cycle	----- Cycle 1 -----			----- Cycle 2 -----			----- Cycle 3 -----			-----					
	32	52	59	72	80	89	102	117	7	17	32	42	56		
	CRL2	0.25bc	0.49de	0.07de	0.55cde	1.12de	0.51d	0.09ef	0.15de	0.13cd	0.24b-e	0.22d	0.60de	0.14f	0.35de
	PCU2	0.11de	0.65cde	0.09cde	1.05bc	2.00bc	1.25bc	0.56b	0.73b‡	0.43abc	0.34b-e	0.64bc	1.48b	0.63ab	0.77ab
	BS2	0.20cde	0.75bc	0.11bc	0.60cde	1.05de	0.80bc	0.18edf	0.21de	0.13cd	0.39b-d	0.78b	1.49b	0.60bc	0.56bc
	UPCU2	0.35ab	1.10abc	0.16abc	1.15bc	1.56b-d	1.03bc	0.28c-f	0.37b-d‡	0.32bc	0.56b	1.16a	1.95a	0.86a	0.83ab
180-d Cycle	----- Cycle 1 -----			----- Cycle 2 -----			----- Cycle 3 -----			-----					
	32	52	59	72	80	89	102	117	131	141	156	166	180		
	CRL3	0.43a	0.80bc	0.11bc	0.83cde	1.27cde	0.71cd	0.13def	0.16de	0.09d	0.14de	0.07d	0.31e	0.06f‡	0.39de
	PCU3	0.13cde	1.14ab	0.16ab	2.27a	3.38a	1.96a	1.14a	1.23a	0.73a	0.51bc	0.34cd	0.71cde	0.15ef‡	1.07a
	BS3	0.45a	1.28a	0.18a	1.07bc	1.94bc	1.18bc	0.30c-f	0.35cde	0.22bc	0.15cde	0.11d	0.40de	0.09f‡	0.58bc
Significance	***	**	**	***	**	***	***	***	**	**	***	**	***	***	

** and *** = P<0.01 and P<0.001

Means with the same letter within a column are not significantly different according to Waller-Duncan K-ratio = 100 t-Test.

DAT† Days after treatments.

‡ Fertilization events followed harvest dates.

¶ Average growth rate for the experimental period.

§ Source code: CRL 1, 2, and 3 = Control release liquid applied at 49 kg N ha⁻¹, 98 kg N ha⁻¹, and 147 kg N ha⁻¹, respectively; PCU 1, 2, and 3 = Polymer-coated urea applied at 49 kg N ha⁻¹, 98 kg N ha⁻¹, and 147 kg N ha⁻¹, respectively; BS 1, 2, and 3 = Activated sewage sludge biosolid applied at 49 kg N ha⁻¹, 98 kg N ha⁻¹, and 147 kg N ha⁻¹, respectively; UPCU 1 and 2 = Urea in equal N combination with polymer-coated urea applied at 49 kg N ha⁻¹ and 98 kg N ha⁻¹, respectively. All treatments totaled 294 kg N ha⁻¹ year⁻¹.

Table 57. Turfgrass color ratings from 29 April through 30 October, 2007 as influenced by N source.

Source§	St. Augustinegrass Color Rating Dates													Avg. ¶
	04/29	05/08	05/31	06/20	06/27	07/27	08/02	08/24	09/07	09/23	10/06	10/19	10/30	
Ratings (1-9 Scale)														
60-d Cycle	Cycle 1					Cycle 2			Cycle 3					
DAT†	0	9	32	52	59	27	33	55	7	23	36	49	60	
CRL1	5.7‡	5.8def	5.0ef	6.0d	5.7e‡	6.5e	7.0e	6.0d‡	6.3de	6.2cd	6.2f	6.2de	5.2gf‡	6.0f
PCU1	5.3‡	5.3f	4.8f	6.5cd	6.7cd‡	7.5c	8.2a	7.3ab‡	7.2b	7.0b	7.5abc	7.3ab	6.8bc‡	6.8cde
BS1	5.3‡	5.8def	6.2b-e	6.5cd	6.8cd‡	7.7bc	7.5cd	6.8abc	7.0bc	7.2b	6.8de	6.8bc	5.8def	6.8e
								‡					‡	
UPCU1	5.5‡	6.8bc	5.7def	6.7cd	6.7cd‡	7.7bc	8.0ab	7.2ab‡	8.0a	7.8a	7.3bcd	7.0bc	6.7c‡	7.1bc
Urea	5.7‡	7.8a	7.3ab	7.2bc	7.0bc‡	8.3a	7.7bc	7.5a‡	8.0a	7.7a	7.5abc	6.8bc	6.3cde	7.4ab
													‡	
120-d Cycle	Cycle 1					Cycle 2								
DAT†	0	9	32	52	59	89	95	117	7	23	36	49	60	
CRL2	5.3‡	7.3ab	6.3bcd	6.5cd	6.7cd	6.7de	7.0e	6.2cd‡	7.2b	6.8b	7.0cd	6.5cd	5.7efg	6.6e
PCU2	5.5‡	5.5ef	6.0c-f	7.7ab	7.8a	7.5c	8.0ab	7.3ab‡	6.8bcd	7.7a	7.8ab	7.8a	7.7a	7.3ab
BS2	5.5‡	6.2cde	7.0abc	7.3bc	7.0bc	7.2cd	7.2de	6.7bcd	6.8bcd	7.7a	7.8ab	7.3ab	6.5cd	7.1bcd
								‡						
UPCU2	5.5‡	7.7a	7.7a	7.7ab	7.5ab	7.2cd	7.5cd	7.0ab‡	8.3a	8.0a	8.0a	7.3ab	7.5ab	7.6a
180-d Cycle	Cycle 1													
DAT†	0	9	32	52	59	89	95	117	131	147	160	173	184	
CRL3	5.5‡	8.0a	7.2abc	6.8bcd	6.3d	6.7de	7.0e	6.8abc	6.2e	5.3e	5.3g	5.7e	5.0g‡	6.2f
PCU3	5.3‡	5.3f	6.0c-f	8.3a	8.0a	8.2ab	8.2a	7.3ab	7.0bc	6.3c	6.3ef	6.7cd	5.8def	6.8de
													‡	
BS3	5.8‡	6.5cd	7.7a	8.3ab	7.7a	7.2cd	7.2bc	6.8abc	6.5cde	5.8d	6.3ef	6.2de	5.3gf‡	6.6e
Significance	NS	***	**	**	***	***	***	**	***	***	***	***	***	***

NS, **, and ***, = P>0.05, P<0.01, and P<0.001

Ratings based on a 1-9 scale in increments of 0.5, 9 = dark green turfgrass, 1 = brown/dead turfgrass, 6 = minimally acceptable turfgrass.

Means with the same letter within a column are not significantly different according to Waller-Duncan K-ratio = 100 t-Test.

DAT† = Days after treatments.

‡ Fertilization events followed rating dates.

¶ Average color rating for the experimental period.

§ Source code: CRL 1, 2, and 3 = Control release liquid applied at 49 kg N ha⁻¹, 98 kg N ha⁻¹, and 147 kg N ha⁻¹, respectively; PCU 1, 2, and 3 = Polymer-coated urea applied at 49 kg N ha⁻¹, 98 kg N ha⁻¹, and 147 kg N ha⁻¹, respectively; BS 1, 2, and 3 = Activated sewage sludge biosolid applied at 49 kg N ha⁻¹, 98 kg N ha⁻¹, and 147 kg N ha⁻¹, respectively; UPCU 1 and 2 = Urea in equal N combination with polymer-coated urea applied at 49 kg N ha⁻¹ and 98 kg N ha⁻¹, respectively.

Table 58. Turfgrass density influenced by N source and application frequency.

Source Code§	Rating Dates			
	05/31/07	08/02/07	10/30/07	Average
	----- † Rating Scale (1-9) -----			
CRL 1	4.8 e	6.5 c	4.0 e	5.1e
CRL 2	6.3 a-d	6.5 c	5.0 cde	5.9cd
CRL 3	7.0 ab	6.7 c	4.2 e	5.9cd
PCU 1	4.5 e	7.5 ab	6.3 b	6.1bcd
PCU 2	5.2 de	7.5 ab	7.5 a	6.7ab
PCU 3	5.7 b-e	7.7 a	5.7 bcd	6.3bcd
UPCU 1	5.3 de	7.5 ab	6.3 b	6.4bcd
UPCU 2	6.8 abc	7.2 ab	7.5 a	7.2a
UREA	6.3 a-d	7.3 ab	6.2 bc	6.6abc
BS 1	5.5 cde	7.0 bc	5.0 cde	5.8d
BS 2	6.8 abc	6.7 c	6.0 bc	6.5a-d
BS 3	7.7 a	7.0 bc	4.7 de	6.4bcd
Significance	***	***	***	**

** and *** = $P < 0.01$ and $P < 0.001$

Ratings based on a 1-9 scale in increments of 0.5, 9 = optimum turfgrass density, 1 = bare soil, 6 = minimally acceptable turfgrass density; Means with the same letter within a column are not significantly different according to Waller-Duncan K-ratio = 100 t-Test; † Mean of 3 replications.

§ Source code: CRL 1, 2, and 3 = Control release liquid applied at 49 kg N ha⁻¹, 98 kg N ha⁻¹, and 147 kg N ha⁻¹, respectively; PCU 1, 2, and 3 = Polymer-coated urea applied at 49 kg N ha⁻¹, 98 kg N ha⁻¹, and 147 kg N ha⁻¹, respectively; BS 1, 2, and 3 = Activated sewage sludge biosolid applied at 49 kg N ha⁻¹, 98 kg N ha⁻¹, and 147 kg N ha⁻¹, respectively; UPCU 1 and 2 = Urea in equal N combination with polymer-coated urea applied at 49 kg N ha⁻¹ and 98 kg N ha⁻¹, respectively.

Turfgrass Density

Turfgrass density was significantly affected by treatments on all rating dates (Table 58). One month after the initiation of the trial, turfgrass density was improved by increasing N with the first application date (Table 58). By the end of the 6 month trial period, turfgrass density declined somewhat compared to the initial rating (Table 58). For example, on 30 October, 2007, the BS 3 treatment had a density rating of 4.7, numerically lower than the BS 1 treatment of 5.0 (although not statistically different). The BS 2 treatment had the significantly greater density, however, its second application had come 2 months prior to the end of the 6-month period so in essence it had received 49 kg N ha⁻¹ more than the other two BS treatments over the time period (Table 58). The best average treatment for density over the entire period was the UPCU2 treatment (Table 58). The UPCU2 treatment was statistically better than all treatments except the BS2, and PCU2 treatments (also quarterly application frequency).

NO₃-N Leaching

Regardless of the application rate or timing frequency the SRNS tested had significantly ($P < 0.05$) lower levels of NO₃-N leaching. Only CRL at 147 kg N ha⁻¹ resulted in NO₃-N losses in excess of 1% applied N (Table 59). In contrast, urea applied solely or in combination at 49 kg soluble N ha⁻¹ produced significantly ($P < 0.05$) greater leaching with total losses of 7.9% from urea and 5.2% UPCU

of applied N (Table 59). When applied according to current BMP guidelines (24.5 kg soluble N ha⁻¹ application⁻¹) for St. Augustinegrass lawns, less than 1% applied N was leached.

Nevertheless, the majority of NO₃-N leaching occurred following initial applications on 30 April and losses from soluble N source declined with subsequent cycles. For instance, following application on 31 August minimal NO₃-N leaching ensued even from soluble N sources applied at 49 kg N ha⁻¹. The St. Augustinegrass was planted in 6 December 2006 and the relatively immature root system may not have developed fully at the initiation of the experiment. Thus, initial N losses may not be indicative of the NO₃-N leaching associated with a mature St. Augustinegrass stand.

The preliminary data suggest that both BS and PCU applied before summer fertilizer “black out” periods at 147 kg N ha⁻¹ may have limited environmental implications. Both sources resulted in less than 0.5% of applied N leached and produced good quality St. Augustinegrass for durations in excess of the 120-d ‘blackout’ period.

Table 59. NO₃-N leaching (mg m⁻²) from established St. Augustinegrass as influenced by N source and application frequency for the summer 2007 experimental period (04/30/07 – 10/20/07).

Source Code§	N Rate Cycle ⁻¹	NO ₃ -N Leached per Application Cycle mg m ⁻²			Total NO ₃ -N Leached	Total N Applied	NO _x -N Leached -- % --
		-- C1 --	-- C2 --	-- C3 --			
CRL1	4900	26.4	35.5	17.0	78.9 b	14700	0.53
PCU1	4900	31.6	20.7	17.5	69.8 b	14700	0.47
BS1	4900	37.8	20.9	17.9	76.5 b	14700	0.52
UPCU1	4900	30.8	88.9	16.0	135.7 b	14700	0.92
Urea	4900	895.9	253.6	16.0	1165.5 a	14700	7.93
		-- C1 --		-- C2 --			
CRL2	9800	99.6		17.0	116.6 b	19600	0.59
PCU2	9800	43.5		23.7	67.2 b	19600	0.34
BS2	9800	54.3		16.3	70.6 b	19600	0.36
UPCU2	9800	998.9		16.2	1015.1 a	19600	5.18
			-- C1 --				
CRL3	14700		173.7 b		173.7 b	14700	1.18
PCU3	14700		64.9 b		64.9 b	14700	0.44
BS3	14700		67.1 b		67.1 b	14700	0.456
Significance		NS	NS	NS	*		

NS and * = P>0.05 and P<0.05

Means with the same letter within a column are not significantly different according to Waller-Duncan K-ratio = 100 t-Test.

§ Source code: CRL 1, 2, and 3 = Control release liquid applied at 49 kg N ha⁻¹, 98 kg N ha⁻¹, and 147 kg N ha⁻¹, respectively; PCU 1, 2, and 3 = Polymer-coated urea applied at 49 kg N ha⁻¹, 98 kg N ha⁻¹, and 147 kg N ha⁻¹, respectively; BS 1, 2, and 3 = Activated sewage sludge biosolid applied at 49 kg N ha⁻¹, 98 kg N ha⁻¹, and 147 kg N ha⁻¹, respectively; UPCU 1 and 2 = Urea in equal N combination with polymer-coated urea applied at 49 kg N ha⁻¹ and 98 kg N ha⁻¹, respectively. All treatments totaled 294 kg N ha⁻¹ year⁻¹.

Conclusion

The preliminary findings of this study suggest that acceptable turf quality is possible with high frequency, low application rates of SRNS; however we found that lower frequency, higher application rates of many SRNS produce better quality turf. Thus, limiting application rates reduce optimal slow release performance with respect to turf quality and clipping yields. The higher per-application rates, which

exceeded current regulated rates, over more extended periods, resulted in better turf quality, particularly for PCU at 98 kg N ha⁻¹ on a 120-d release window. Furthermore, both PCU and BS applied at 2 and 3 times the current regulated rate resulted in the lowest levels of N leaching. Even so, the SRNS evaluated were inadequate in terms of either initial or long term response relative to urea applied at 60-d intervals, although we found that all SRNS applied at 147 kg N ha⁻¹ were capable of delivering acceptable turf quality for the 120-d fertilizer black out period with limited environment consequences in term of N leaching. Our preliminary findings indicated that slow-release N in combination with soluble sources (e.g. UPCU) offered a viable alternative to frequent applications of urea when turf quality was concerned during the period of the present test. However, the soluble fraction in combination sources should be limited to current best management guidelines of 24.5 kg soluble N ha⁻¹ application⁻¹ to limit the potential for NO₃-N leaching. The variable performance of the SRNS tested at high frequency, low rates suggests the need for more extensive evaluations of SRNS on St. Augustinegrass to provide N source recommendations with the least potential for ground and surface water degradation. Moreover, other soluble sources and percent soluble:SRN combinations should be evaluated to ascertain performance of other commercially-available products.

N SOURCE AND TIMING – YEAR 2

Regardless of N source, all treated plots had quality levels above acceptable levels through the last part of the year (Fig. 13 and 14)

Figure 13. St. Augustinegrass quality from September 1, 2008 through January 9, 2009 for slow-release N sources applied at 147 kg N ha⁻¹. Arrow indicates fertilization events.

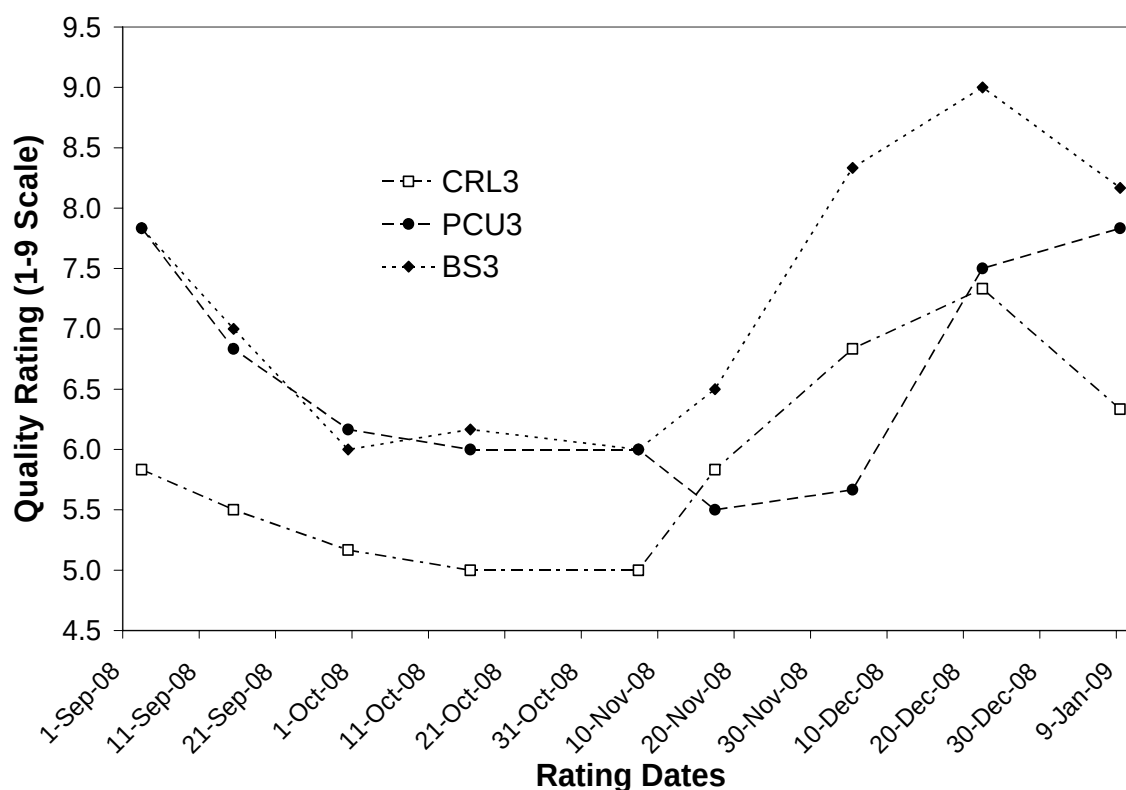
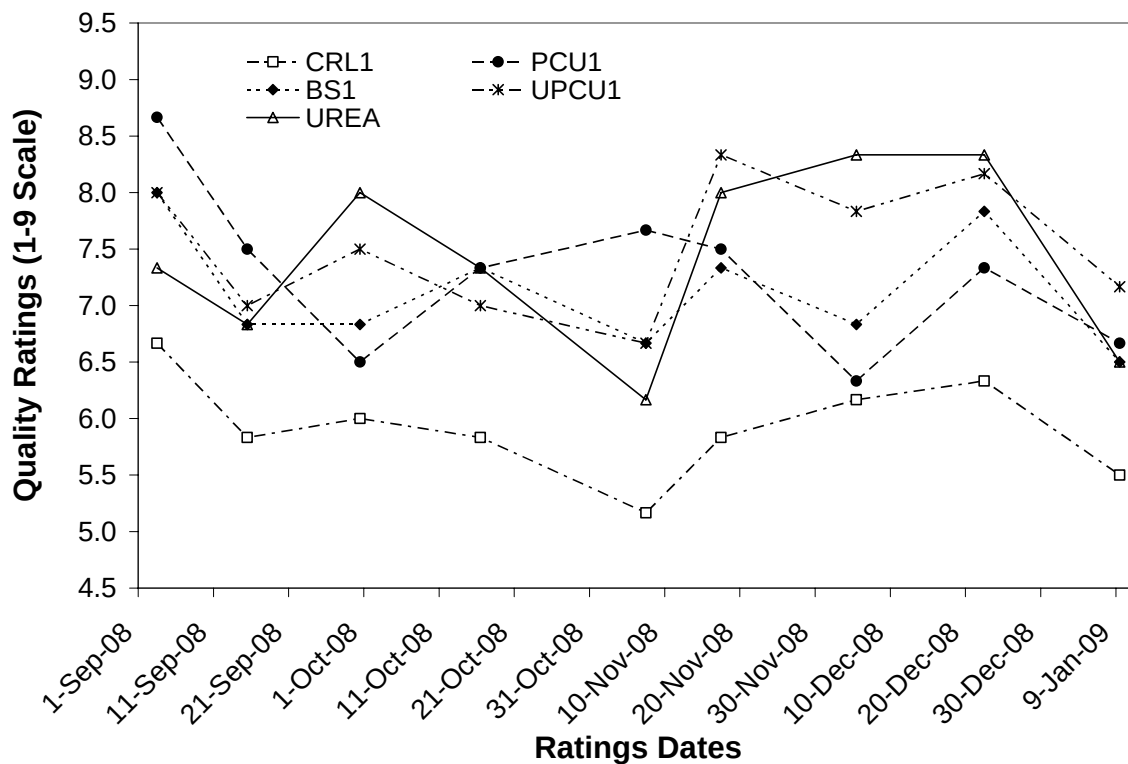


Figure 14. St. Augustinegrass quality from September 1, 2008 through January 9, 2009 for slow-release N sources applied at 49 kg N ha⁻¹. Arrow indicates fertilization events.



Established Turf N Rate Study

St. Augustinegrass did not show any response to irrigation for quality scores or turf growth, but did respond to N rate (Tables 60 - 64). Quality and color scores increased as N increased. Acceptable scores were achieved on all rating dates with 4 lbs. N.

Table 60. Effect of N fertilization on St. Augustinegrass visual quality for Established Turf N Rate Study at Site 2.

lbs N/M	10/19	11/20	12/24	1/18	2/19	3/18	4/8
2.0	6.6c	5.8c	5.7b	5.9b	4.9c	5.1c	6.0b
4.0	7.3b	6.4bc	6.4ab	6.5b	6.1b	6.3b	6.3b
6.0	7.4b	6.8ab	6.0b	6.6b	6.4b	6.6b	6.8ab
12.0	8.3a	7.3a	7.1a	8.1a	7.5a	7.6a	7.4a
Signif.	***	***	*	***	***	***	**

***, *, and ** = P<0.001, P<0.05, and P<0.01 respectively.

Means with the same letter within a column are not significantly different according to Duncan's Multiple Range Test.

Turfgrass visual quality ratings based on a 1-10 scale with 10=dark green turf, 1=dead/brown turf, and 6=minimally acceptable turf.

Table 61. Effect of irrigation on St. Augustinegrass visual quality for Established Turf N Rate Study at Site 2.

Irrigation	10/19	11/20	12/24	1/18	2/19	3/18	4/8
0.5" 3X/wk	7.4	6.5	6.3	6.9	6.0	6.3	6.7
0.1" Daily	7.4	6.7	6.3	6.9	6.4	6.5	6.5
Significance	ns	ns	ns	ns	ns	ns	ns

ns = $P > 0.05$

Turfgrass visual quality ratings based on a 1-10 scale with 10=dark green turf, 1=dead/brown turf, and 6=minimally acceptable turf.

Table 62. Effects of Irrigation regime and Nitrogen fertilization on quality of St. Augustinegrass.

Factor	04/18	05/05	05/28	06/20	07/02
Irrigation Regime	-----Quality (1-10)-----				
0.1" Daily	6.4	6.9	6.5	6.7	6.9
0.5" 3X/wk	6.3	6.6	6.3	6.7	6.8
Sig.	ns	ns	ns	ns	ns
N Rate (lb 1000 ⁻¹ yr ⁻¹).					
2	5.4c	6.0c	5.6c	6.0c	6.4c
4	6.3b	6.4c	6.0bc	6.6b	6.6bc
6	6.4b	6.9b	6.4b	7.0ab	7.0ab
12	7.1a	7.7a	7.6a	7.3a	7.4a
Sig.	**	**	**	**	**
Irr. X N Interaction					
Sig.	ns	ns	ns	ns	ns

ns and ** = $P > 0.05$ and $P < 0.01$

Table 63. Effects of Irrigation regime and Nitrogen fertilization on color of St. Augustinegrass

Factor	04/18	05/05	05/28	06/20	07/02
Irrigation Regime	-----Color (1-10)-----				
0.1" Daily	6.4	7.3a	6.1	6.9	7.1
0.5" 3X/wk	6.5	6.9b	5.9	6.8	7.0
Sig.	ns	*	ns	ns	ns
N Rate (lb 1000 ⁻¹ yr ⁻¹).					
2	5.9c	6.4c	5.2b	6.4b	6.4c
4	6.4b	6.8c	5.6b	6.7b	6.9b
6	6.5b	7.3b	6.0b	6.9ab	7.2b
12	7.2a	8.0a	7.3a	7.4a	7.9a
Sig.	**	**	**	**	**
Irr. X N Interaction					
Sig.	ns	ns	ns	ns	ns

*, **, and ns refer to $P < 0.05$, $P < 0.01$, and $P > 0.05$, respectively

Table 64. Effects of Irrigation regime and Nitrogen fertilization on clipping yield of St. Augustinegrass

Factor	04/15	05/05	05/29	06/09	07/03
Irrigation	-----g/m ² -----				
Regime					
0.1" Daily	11.1	21.2	18.0	23.0	38.5
0.5" 3X/wk	10.1	19.8	22.0	18.7	36.1
Sig.	ns	ns	ns	ns	ns
N Rate					
(lb 1000 ⁻¹ yr ⁻¹).					
2	21.2b	6.41b	4.7b	7.5b	14.1b
4	9.0b	17.7b	15.2b	16.0b	27.1b
6	9.0b	14.6b	15.0b	16.7b	33.8b
12	3.0a	43.3a	43.9a	43.8a	74.1a
Sig.	**	**	**	**	**
Irr. X N Interaction					
Sig.	ns	ns	ns	ns	ns

**, and ns refer to $P < 0.01$, and $P > 0.05$, respectively

Table 65. Effect of N fertilization on bahiagrass visual quality for Established Turf N Rate Study at Site 2.

lbs N/M	10/19	11/20	12/24	1/18	2/19	3/18	4/8
1.0	6.8b	6.6	6.7	6.6	6.0c	6.3b	6.3b
2.0	7.0b	6.8	7.1	7.0	6.5bc	6.6b	6.6b
4.0	7.6a	7.1	7.3	7.3	6.8ab	6.8a	6.8b
6.0	7.1b	7.2	6.9	7.6	7.1a	7.0a	7.4a
Signif.	*	ns	ns	ns	**	*	*

*, ns, and ** = $P < 0.05$, $P > 0.05$, and $P < 0.01$ respectively.

Means with the same letter within a column are not significantly different according to Duncan's Multiple Range Test.

Turfgrass visual quality ratings based on a 1-10 scale with 10=dark green turf, 1=dead/brown turf, and 6=minimally acceptable turf.

Table 66. Effect of irrigation on bahiagrass visual quality for Established Turf N Rate Study at Site 2.

Irrigation	10/19	11/20	12/24	1/18	2/19	3/18	4/8
0.5" 3X/wk	7.0	6.9	7.0	7.2	6.5	6.6	6.7
0.1" Daily	7.1	6.9	7.0	7.1	6.6	6.8	6.8
Significance	ns	ns	ns	ns	ns	ns	ns

ns = $P > 0.05$

Turfgrass visual quality ratings based on a 1-10 scale with 10=dark green turf, 1=dead/brown turf, and 6=minimally acceptable turf.

Table 67. Effects of Irrigation regime and Nitrogen fertilization on quality of Bahiagrass

Factor	04/18	05/05	05/28	06/20	07/02
Irrigation Regime	-----Quality (1-10)-----				
0.1" Daily	6.7	7.3a	7.2	6.9	7.1
0.5" 3X/wk	6.9	6.8b	7.2	6.6	6.8
Sig.	ns	*	ns	ns	ns
N Rate (lb 1000 ⁻¹ yr ⁻¹).					
1	6.6	6.6a	6.3c	6.8	6.9
2	6.7	7.0ab	7.3b	6.6	6.9
4	6.8	7.3a	7.3b	6.9	6.9
6	7.1	7.4a	7.9a	6.8	7.3
Sig.	ns	*	**	ns	ns
Irr. X N Interaction					
Sig.	ns	ns	ns	ns	ns

*, **, and ns refer to $P < 0.05$, $P < 0.01$, and $P > 0.05$, respectively.

Table 68. Effects of Irrigation regime and Nitrogen fertilization on color of Bahiagrass

Factor	04/18	05/05	05/28	06/20	07/02
Irrigation Regime	-----Color (1-10)-----				
0.1" Daily	6.9	7.7a	6.9	7.0a	7.3
0.5" 3X/wk	6.8	7.0b	8.8	6.6b	7.1
Sig.	ns	**	ns	*	ns
N Rate (lb 1000 ⁻¹ yr ⁻¹).					
1	6.6b	6.8c	6.0b	6.8	6.7b
2	6.9ab	7.1bc	6.9a	6.7	7.2a
4	6.9ab	7.6ab	7.0a	6.9	7.5a
6	7.3a	7.9a	7.6a	6.8	7.4a
Sig.	*	**	**	ns	**
Irr. X N Interaction					
Sig.	ns	ns	ns	ns	ns

*, **, and ns refer to $P < 0.05$, $P < 0.01$, and $P > 0.05$, respectively.

Table 69. Effects of Irrigation regime and Nitrogen fertilization on clipping yield of Bahiagrass

Factor	04/15	05/05	05/29	06/09	07/03
Irrigation Regime	-----g/m ² -----				
0.1" Daily	9.2	24.8	27.1b	55.5	120.5
0.5" 3X/wk	9.0	28.9	55.3a	60.1	133.8
Sig.	ns	ns	**	ns	ns
N Rate (lb 1000 ⁻¹ yr ⁻¹).					
1	4.6c	14.6b	25.6	36.5b	95.7c
2	6.0bc	22.0a	31.6	45.5b	109.1bc
4	14.6a	34.6a	56.8	74.1b	137.9ab
6	11.1ab	37.3a	50.9	75.4a	165.8a
Sig.	**	**	ns	**	**
Irr. X N Interaction					
Sig.	ns	ns	ns	ns	ns

**, and ns refer to $P < 0.01$, and $P > 0.05$, respectively

N SOURCE AND TIMING -FERTILIZER BLACKOUT STUDY

MATERIALS AND METHODS

The experiment was initiated June 3, 2009 at the University of Florida Fort Lauderdale Research and Education Center. Granular N sources (Table 70) were applied once to 6 replications of mature St. Augustinegrass at 2.0lbs.N 1000 ft.⁻² and watered in with 0.12 inch irrigation immediately following application. The experimental area had not received any fertilization for a period of 4 months and plots were randomized based on turfgrass quality, color and density. A single lysimeter was installed into each 2m x 4m plot. Lysimeters were constructed of heavy grade plastic with a leachate outflow pipe located on the bottom. PVC pipes attached to each lysimeter were connected to gravity flow collection points adjacent to the plots.

Turfgrass quality, color and density visual ratings (scale of 1-9 with 9=dark green, dense turf, 1=dead/brown turf, and 6=minimally acceptable turf) were taken throughout the experimental period. Turfgrass clipping samples were taken at a 3.0 inch height of cut approximately every 2 weeks or more when necessary. Tissue was oven dried at 60°C for a minimum of 48 hours before weighing.

Percolate water samples were collected weekly or more frequently following a rain event exceeding 0.25 inch. Samples were acid preserved and shipped to the UF Analytical Research Lab in Gainesville for NO₃-N analysis.

All data were subjected to statistical analysis and significant means were identified.

Table 70. N sources and manufacturers.

Code	Description	%N	Manufacturer
URE	granular urea	46	PCS Sales, Inc. Northbrook, IL
UXCU	70:30 urea:xcu	45	
BS	sewage sludge bio-solid	5	Milorganite, Milwaukee, WI
PCU	polymer coated urea	41	Pursell Inc., Sylacauga, AL
XCU	polymer coated urea	43	Agrium Advanced Technologies, AL

RESULTS

Turfgrass Quality, Color and Clipping Growth

Turfgrass quality was significantly affected by fertilizer treatment on most observation dates and the readily soluble N treatments generally had the quickest response with some slow and controlled release N forms providing better turfgrass quality over timeframe within the blackout period and then after that period (Tables 2a-2b). In the no-N check, turfgrass quality dipped below the 6.0 minimally acceptable rating on 6/25 and was consistently the lowest rated treatment (Tables 2a-2b). Turfgrass color ratings had similar treatment responses (Tables 3a-3b). Turfgrass clipping growth responded to the application of the various forms of N as anticipated by the availability of N from the N sources (Tables 4a-4b). The controlled release source PCU had the most clippings at the end of the reporting period while having the least early on (Tables 4a-4b).

N Leaching and Climatological Data

The trial was conducted during the rainy season months encompassing blackout period months. Thus, nearly 100 cm of rain and irrigation impacted the site during the trial months and June and July each had approximately 25 cm of rain (Figure 18).

Nitrate-N leaching was significantly-affected by N treatment with the urea treatment having the most cumulative leaching followed by the 70:30 soluble/slow combination treatment and other treatments (Table 74a-e, Figure 19). The 3 slow or controlled release N products had Nitrate-N leaching totals that were statistically—equal to the no-N check, were lower than the urea treatment, and statistically-equal to the 70:30 combination treatment (Tables 74a-e). Most of the leaching occurred during the first month after application (Table 74a). Thereafter, there were no significant differences in leaching.

In conclusion, while the application of N at a high rate to compensate for black out restrictions improved visual ratings and growth, there was increased N leaching from turf receiving readily-available N. Using complete slow or controlled-release N reduced N leaching to statistically-equal amounts achieved the no-N check and improved turfgrass visual ratings and growth at the end of the study.

Table 71a. N Timing: Turfgrass quality ratings.

TRT	5/18/09	6/15	6/22	6/25	7/2	7/10	7/20	8/6
URE	6.8	7.8a	7.9a	8.2bc	7.3b	7.0	7.2a	6.6b
UXCU	6.8	7.8a	7.9a	8.6ab	8.1a	6.7	7.0a	6.8ab
BS	6.7	6.9bc	7.2b	7.8c	7.2b	7.3	7.3a	6.7b
PCU	6.7	6.5c	5.8c	5.7d	6.1c	6.8	7.3a	7.2a
XCU	6.5	7.2b	8.1a	9.0a	8.4a	6.9	7.4a	6.8ab
CHK	6.7	6.5c	6.0c	5.8d	5.7c	6.3	5.8b	5.4c
Signif.	ns	**	**	**	**	ns	**	**

ns and ** = $P > 0.05$ and $P < 0.01$

Means with the same letter within a column are not significantly different according to Duncan's Multiple Range Test.

Turfgrass quality ratings based on a 1-9 scale with 9=dark green turf, 1=dead/brown turf, and 6=minimally acceptable turf.

Table 71b. N Timing: Turfgrass quality ratings.

TRT	8/21/09	9/3	9/18	10/2
URE	6.4b	6.5ab	6.8b	6.7b
UXCU	6.5b	6.2b	6.4b	6.4b
BS	6.8b	6.7ab	7.2ab	6.8ab
PCU	7.4a	7.0a	7.7a	7.5a
XCU	6.8b	6.6ab	6.7b	6.5b
CHK	5.6c	5.4c	5.5c	5.3c
Signif.	**	**	**	**

** = $P < 0.01$

Means with the same letter within a column are not significantly different according to Duncan's Multiple Range Test.

Turfgrass quality ratings based on a 1-9 scale with 9=dark green turf, 1=dead/brown turf, and 6=minimally acceptable turf.

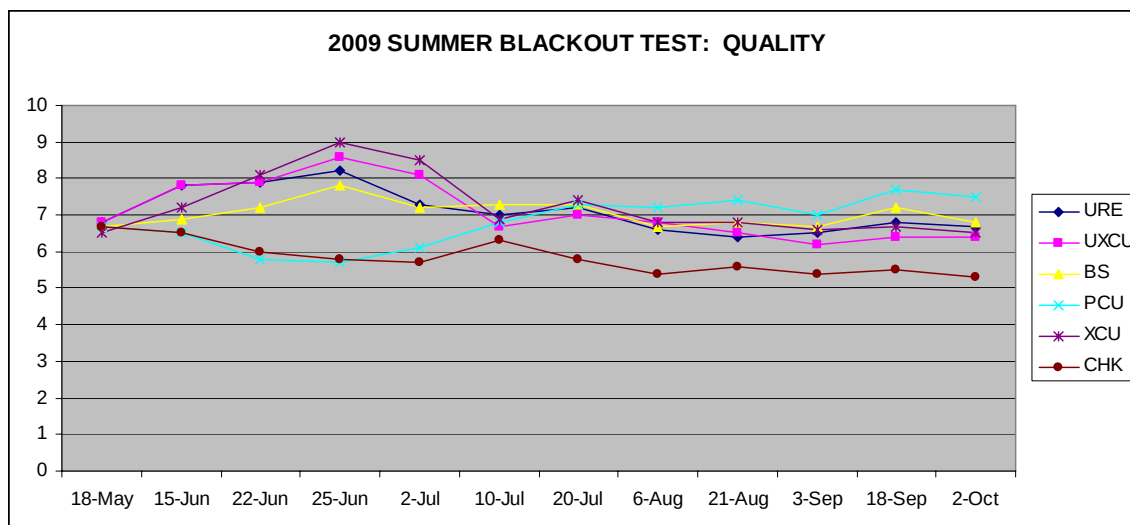


Figure 15. N Timing Blackout Test: Overall visual quality from 18 May—2 Oct. 2009.

Table 72a. N Timing: Turfgrass color ratings.

TRT	5/18/09	6/15	6/22	6/25	7/2	7/10	7/20	8/6
URE	6.4	8.1a	8.3a	8.2b	7.7b	7.2	7.3a	6.7b
UXCU	6.6	8.0a	8.3a	8.4ab	8.5a	6.8	7.2a	7.1ab
BS	6.3	7.3b	7.4b	7.4c	7.4b	7.7	7.4a	7.0ab
PCU	6.3	6.8bc	6.3c	5.6d	6.3c	7.1	7.5a	7.4a
XCU	6.3	7.2b	8.6a	9.0a	8.6a	7.3	7.7a	7.3a
CHK	6.5	6.5c	6.1c	5.5d	5.8c	6.3	6.0b	5.6c
Signif.	ns	**	**	**	**	ns	**	**

ns and ** = $P > 0.05$ and $P < 0.01$

Means with the same letter within a column are not significantly different according to Duncan's Multiple Range Test.

Turfgrass color ratings based on a 1-9 scale with 9=dark green turf, 1=dead/brown turf, and 6=minimally acceptable turf.

Table 72b. N Timing: Turfgrass color ratings.

TRT	8/21/09	9/3	9/18	10/2
URE	6.7b	6.8b	6.8b	6.2b
UXCU	6.9b	6.6b	6.6b	5.9b
BS	6.9b	6.8b	7.1ab	6.3b
PCU	7.4a	7.5a	7.5a	7.2a
XCU	7.0b	6.8b	6.9ab	6.2b
CHK	6.1c	5.8c	5.8c	5.3c
Signif.	**	**	**	**

** and * = $P < 0.01$ and $P < 0.05$

Means with the same letter within a column are not significantly different according to Duncan's Multiple Range Test.

Turfgrass color ratings based on a 1-9 scale with 9=dark green turf, 1=dead/brown turf, and 6=minimally acceptable turf.

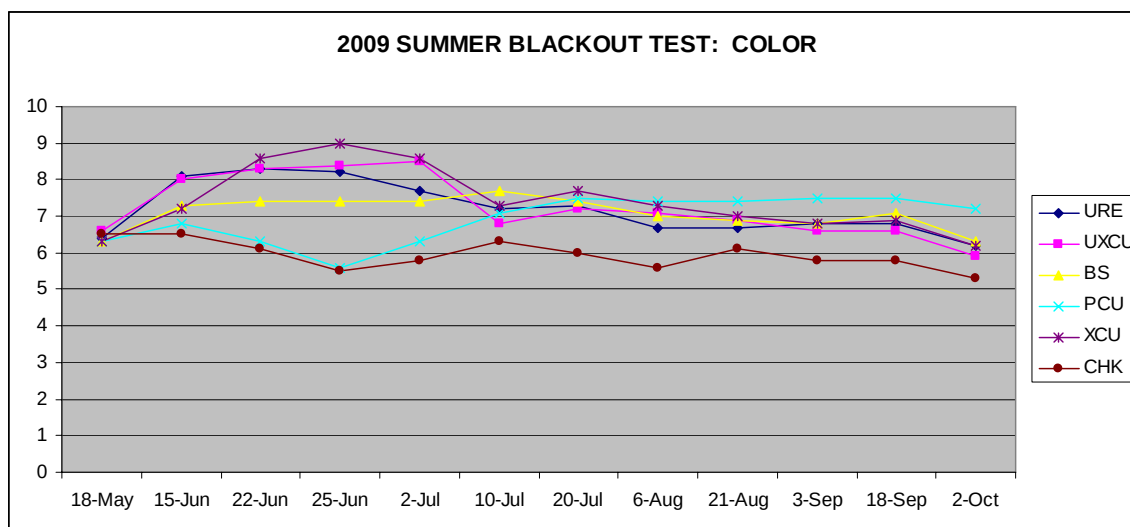


Figure 16. N Timing Blackout Test: Overall visual color from 18 May—2 Oct. 2009.

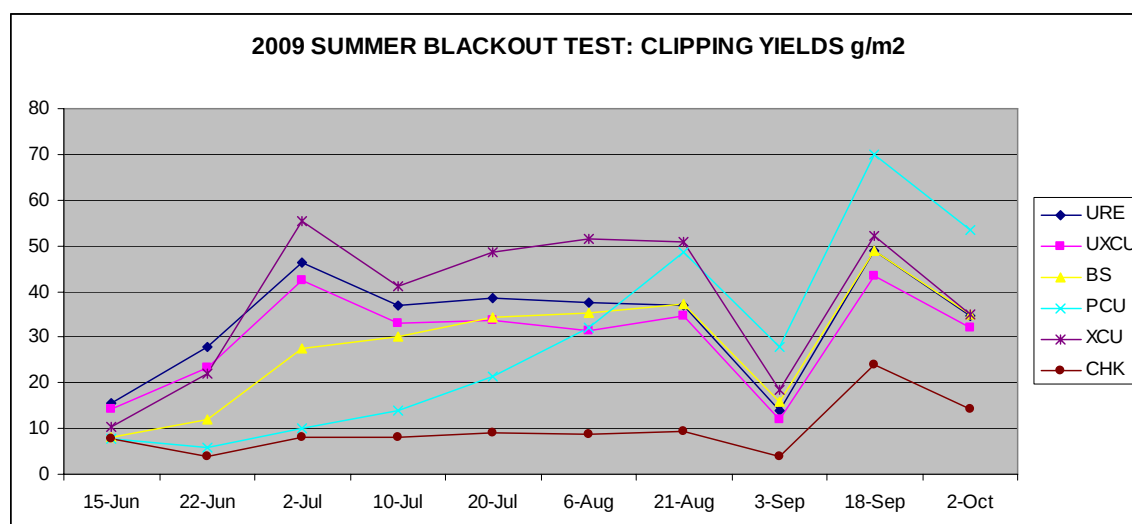


Figure 17. N Timing Blackout Test: Clipping tissue growth from 15 June—Oct. 2, 2009.

Table 73a. N Timing: Turfgrass clipping yields.

TRT	6/15/09	6/22	7/2	7/10	7/20
URE	15.6a	27.8a	46.2ab	36.8a	38.5b
UXCU	14.1a	23.2a	42.4b	33.1a	33.7b
BS	8.0b	11.9b	27.6c	30.0a	34.2b
PCU	7.8b	5.8b	10.1d	13.9b	21.4c
XCU	10.5ab	21.9a	55.3a	41.1a	48.7a
CHK	7.8b	3.9b	8.1d	8.2b	9.1d
Signif.	*	**	**	**	**

* and ** = $P < 0.05$ and $P < 0.01$

Means with the same letter within a column are not significantly different according to Duncan's Multiple Range Test.

Table 73b. N Timing: Turfgrass clipping yields.

TRT	8/6/09	8/21	9/3	9/18	10/2
URE	37.5b	36.8ab	13.8b	48.8b	34.6b
UXCU	31.5b	34.8b	12.1b	43.5b	32.2b
BS	35.2b	37.3ab	15.8b	48.8b	35.1b
PCU	32.1b	48.5ab	27.9a	70.1a	53.6a
XCU	51.4a	50.7a	18.5b	52.1b	35.1b
CHK	8.8c	9.4c	3.9c	24.1c	14.2c
Signif.	**	**	**	**	**

** and ns = $P < 0.01$ and $P > 0.05$

Means with the same letter within a column are not significantly different according to Duncan's Multiple Range Test.

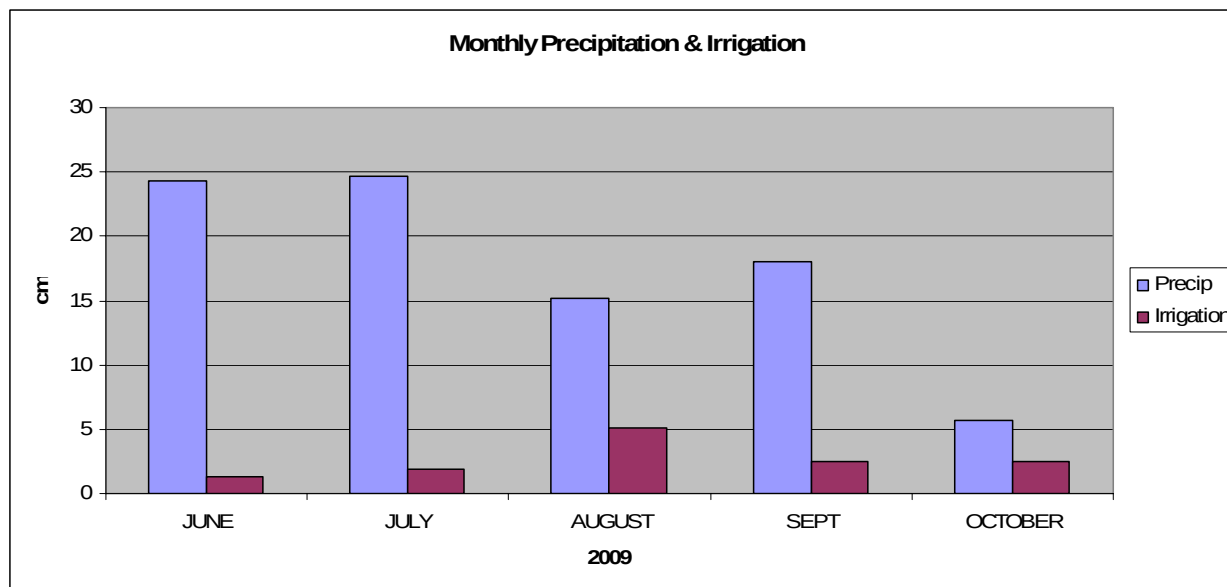


Figure 18. N Timing Blackout Test: Rainfall and irrigation June—October 2009.

Table 74a. N Timing: $\text{NO}_3\text{-N}$ leached (mg m^{-2})

TRT	6/3/09	6/8	6/10	6/15	6/17	6/24	6/29
URE	0	9.3	6.5	1107.3a	799.5a	985.6a	24.7
UXCU	0	3.1	2.8	565.1ab	127.0b	522.4ab	38.7
BS	0	13.2	8.2	55.6b	28.4b	50.9b	24.5
PCU	0	5.1	5.3	22.7b	3.8b	34.4b	7.1
XCU	0	4.4	1.5	34.4b	18.6b	189.7b	32.9
CHK	0	0.8	0.3	4.5b	0.0b	9.1b	0.8
Signif.	ns	ns	ns	**	**	**	ns

ns and ** = $P > 0.05$ and $P < 0.01$

Means with the same letter within a column are not significantly different according to Duncan's Multiple Range Test.

Table 74b. N Timing: $\text{NO}_3\text{-N}$ leached (mg m^{-2})

TRT	7/1/09	7/3	7/6	7/15	7/20	7/27
URE	14.5	2.3	0.10	9.8	9.6	6.7
UXCU	15.0	6.2	1.2	16.8	17.5	13.7
BS	20.6	9.4	1.5	28.3	23.0	19.9
PCU	16.3	9.3	0.05	12.5	27.1	20.8
XCU	25.4	10.5	0.4	9.2	42.4	19.0
CHK	0.4	0.0	0.04	0.0	0.7	3.3
Signif.	ns	ns	ns	ns	ns	ns

ns = $P > 0.05$

Table 74c. N Timing: NO₃-N leached (mg m⁻²)

TRT	8/6/09	8/12	8/17	8/24	8/31
URE	1.5	0.0	0.0	0.0	0.0
UXCU	9.5	2.5	41.1	13.4	38.8
BS	16.0	10.8	33.2	10.4	12.9
PCU	24.3	3.6	38.0	7.6	17.5
XCU	19.1	0.0	30.3	2.2	18.1
CHK	0.0	0.0	0.0	0.3	0.0
Signif.	ns	ns	ns	ns	ns

ns = P>0.05

Table 74d. N Timing: NO₃-N leached (mg m⁻²)

TRT	9/4/09	9/7	9/11	9/14	9/21
URE	0.0	0.3	0.1	0.0	0.0
UXCU	1.64	2.0	31.2	31.5	14.3
BS	0.0	2.0	12.7	10.3	7.1
PCU	0.7	0.6	13.8	18.2	7.4
XCU	0.6	2.2	23.3	28.1	7.2
CHK	0.0	0.2	0.0	0.0	0.0
Signif.	ns	ns	ns	ns	ns

ns = P>0.05

Table 74e. N Timing: NO₃-N leached (mg m⁻²)

TRT	9/28/09	10/6/09	TOTAL (6/8/09-10/6/09)
URE	0.0	0.0	3111.2a
UXCU	25.0	39.6	1596.4b
BS	9.9	9.5	408.7bc
PCU	8.0	10.7	307.4bc
XCU	15.1	24.1	541.4bc
CHK	0.0	0.0	20.5c
Signif.	ns	ns	**

ns and ** = P>0.05 and P<0.01

Means with the same letter within a column are not significantly different according to Duncan's Multiple Range Test.

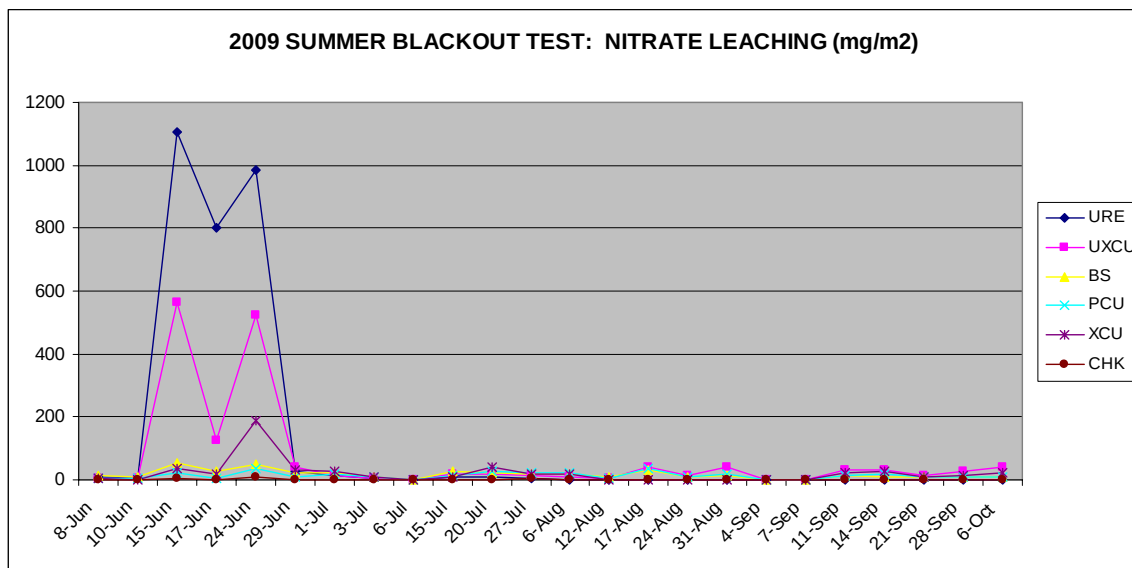


Figure 19. N Timing Blackout Test: Nitrate Leaching from 8 June – October 6, 2009.

GAINESVILLE PROJECTS – DR. JERRY SARTAIN

PHOSPHORUS RESPONSE AND ORTHOPHOSPHATE LEACHING IN FLORATAM ST. AUGUSTINEGRASS AND EMPIRE ZOYSIAGRASS

Hypotheses and Research Objectives

The following hypotheses were formulated:

- (I) Leaf growth rate, turf visual quality and percent green turf cover will increase to a maximum with increasing leaf tissue P concentration beyond which no additional response to P supply and increasing leaf tissue P will be observed.
- (II) Rate of P depletion from solution by ‘Empire’ Zoysiagrass and ‘Floratam’ St. Augustinegrass grown in hydroponic culture will be inversely related to P leaf tissue P concentration.
- (III) Greater P supply and leaf tissue P concentration will result in greater dry matter and P partitioning to leaf tissue.
- (IV) Phosphorus use efficiency will be inversely related to P supply and leaf tissue P concentration.
- (V) There is a maximum phosphorus application rate to ‘Floratam’ St. Augustinegrass and ‘Empire’ Zoysiagrass below which P leaching is minimized.
- (VI) Rate of P leaching will be inversely related to plant growth and uptake rate and will increase with increasing rainfall and soil PSR.
- (VII) Growth rate and turf visual quality will increase in response to increasing P application rate, Mehlich 1 extractable soil P and leaf tissue P.

The overall objective of this research was to determine the critical leaf tissue P concentration for maximum sustainable levels of growth and quality in ‘Floratam’ St. Augustinegrass and ‘Empire’ Zoysiagrass and to identify the threshold P application rate that minimizes P leaching from these turfgrass species grown under field conditions. Specific objectives addressed in this dissertation are the following:

- (i) To determine critical P concentrations in leaf tissue of ‘Floratam’ St. Augustinegrass and ‘Empire’ Zoysiagrass based on leaf growth rate, visual quality and percent green turf cover.
- (ii) To evaluate the influence of leaf tissue P concentration on the rate of P depletion from solution (P influx) by these turfgrass species grown in hydroponic culture.
- (iii) To study the effect of P supply and leaf tissue P concentration on dry matter and P partitioning as well as P-use efficiency in these turfgrass species under glasshouse and field conditions.
- (iv) To assess the relationship between P supply and P leaching rate in ‘Empire’ Zoysiagrass and ‘Floratam’ St. Augustinegrass grown under field conditions.
- (v) To investigate the interaction between plant uptake, rainfall, irrigation, M1-P and PSR ratio with P leaching rate in these turfgrass systems.

- (vi) To study the effect P supply rate, M1-P and leaf tissue P concentration on growth rate and visual quality in 'Empire' Zoysiagrass and 'Floratam' St. Augustinegrass grown under field conditions.

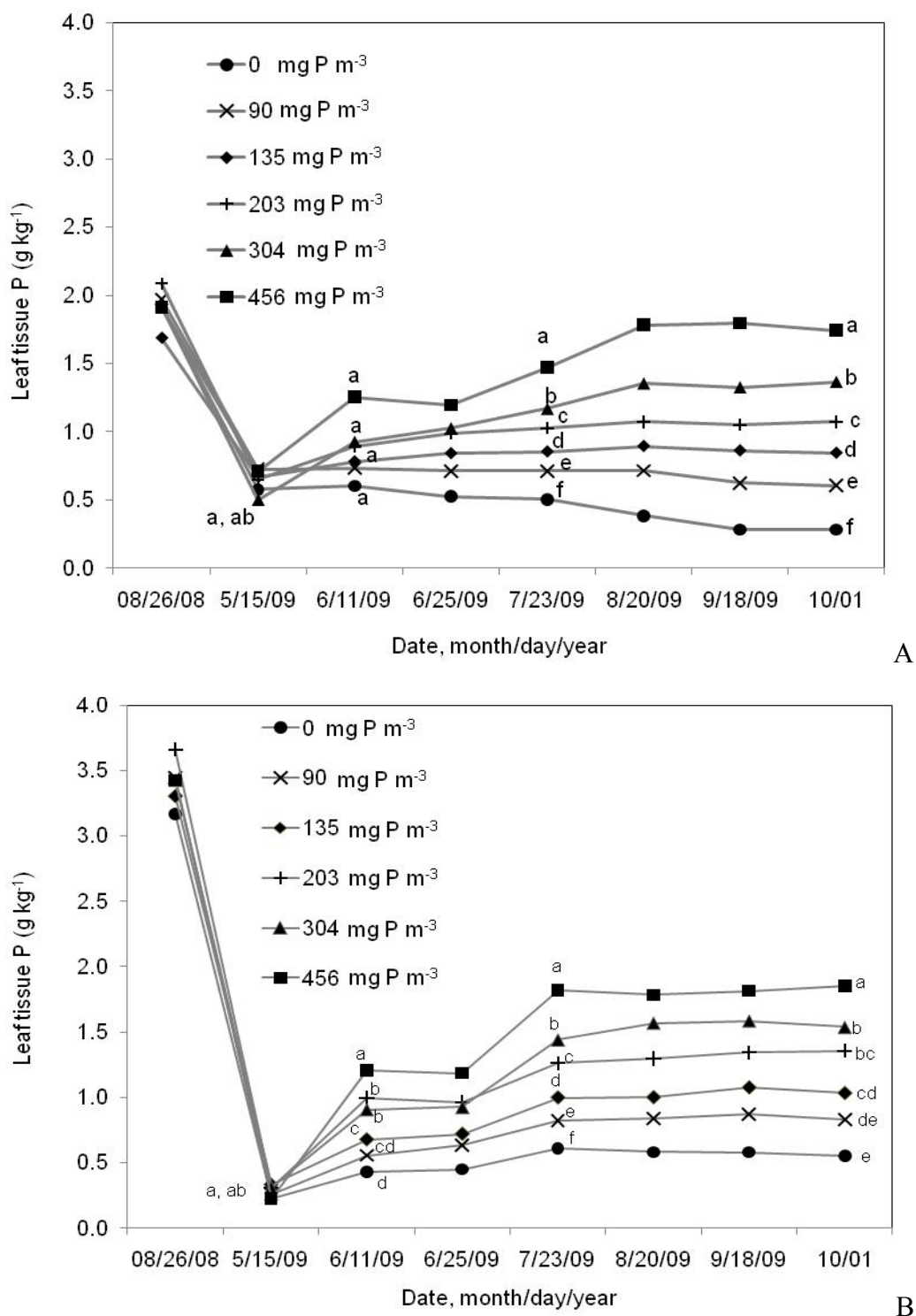
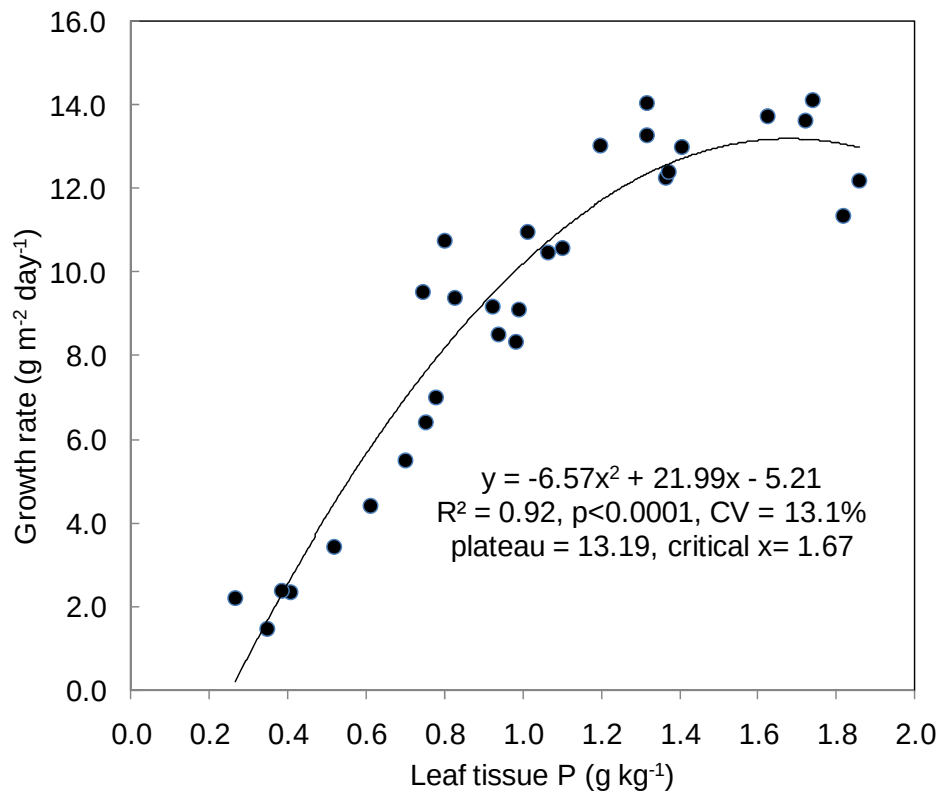
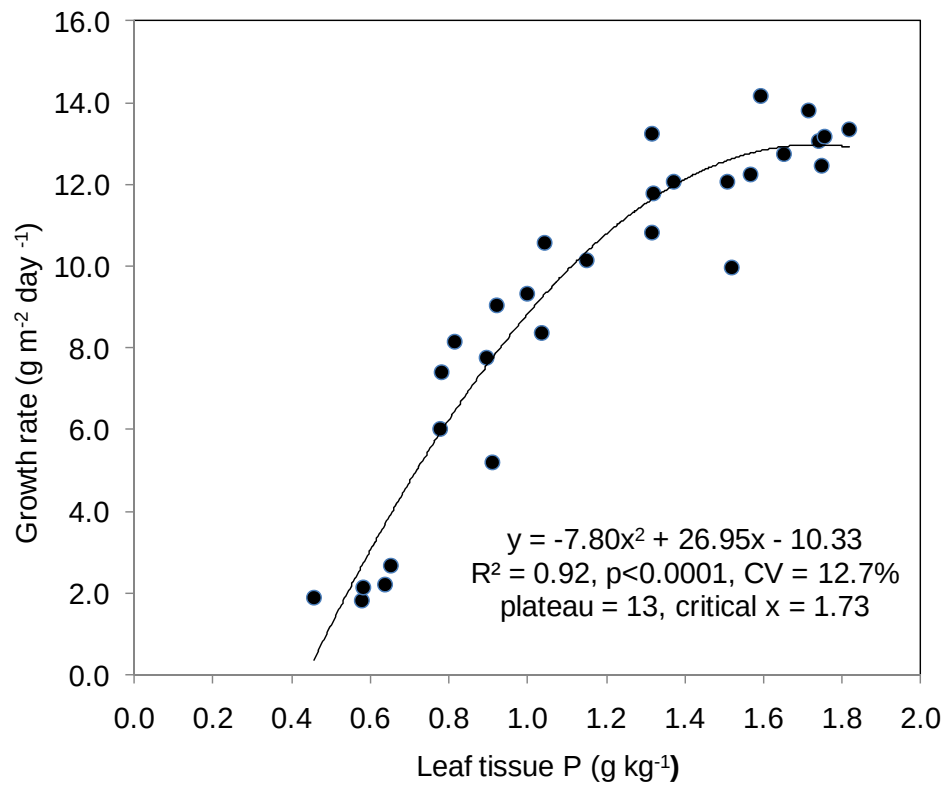


Figure 20. Phosphorus concentration in leaf tissue over time as influenced by phosphorus supply rate. A) Empire zoysiagrass and B) Floratam St. Augustinegrass. Symbols labeled with the same letter within a sampling date are not significantly different at $p = 0.05$ by single degree of freedom contrast analysis.



A



B

Figure 21. Aboveground tissue growth rate relative to leaf tissue P concentration. A) Empire zoysiagrass and B) Floratam St. Augustinegrass.

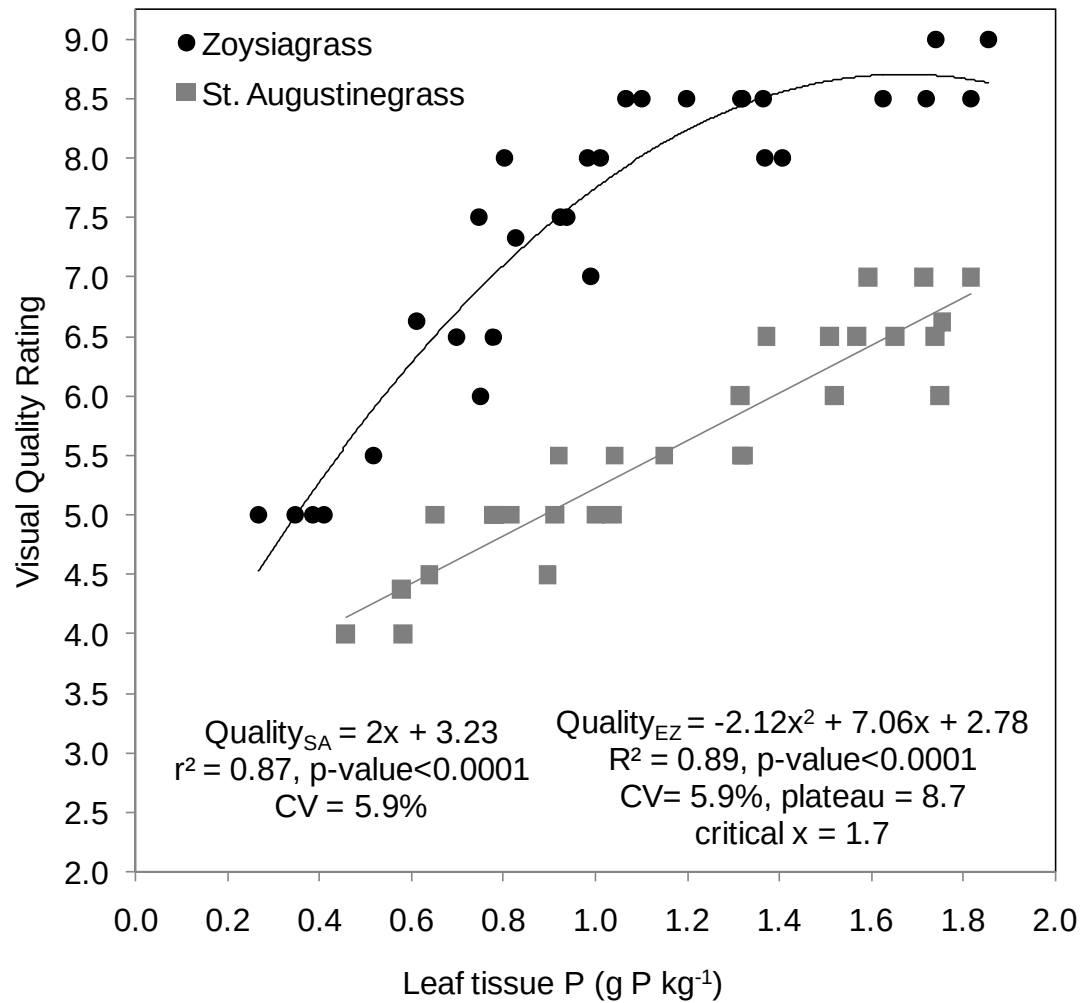


Figure 22. Empire zoysiagrass (EZ) and Floratam St. Augustinegrass (SA) visual quality rating relative to leaf tissue P concentration.

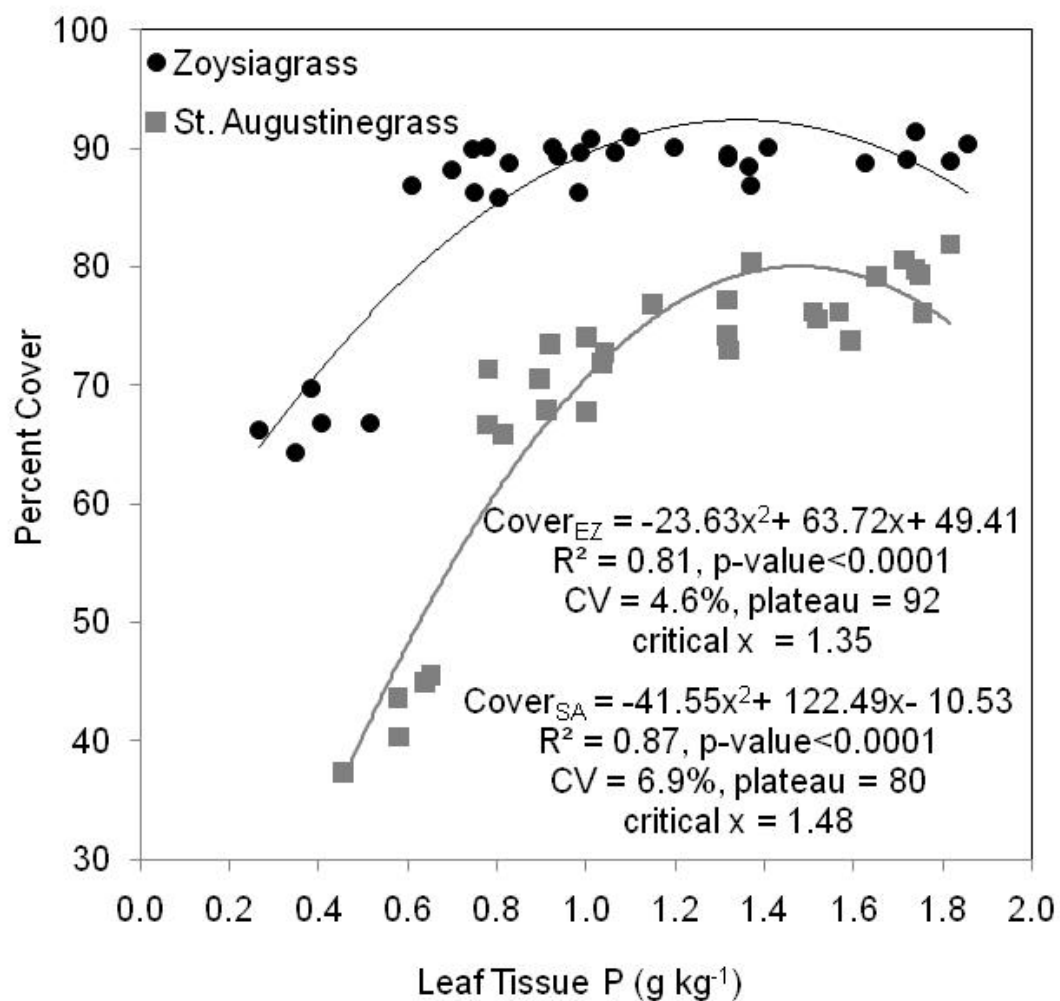


Figure 23. Empire zoysiagrass (EZ) and Floratam St. Augustinegrass (SA) percent cover relative to leaf tissue P concentration.

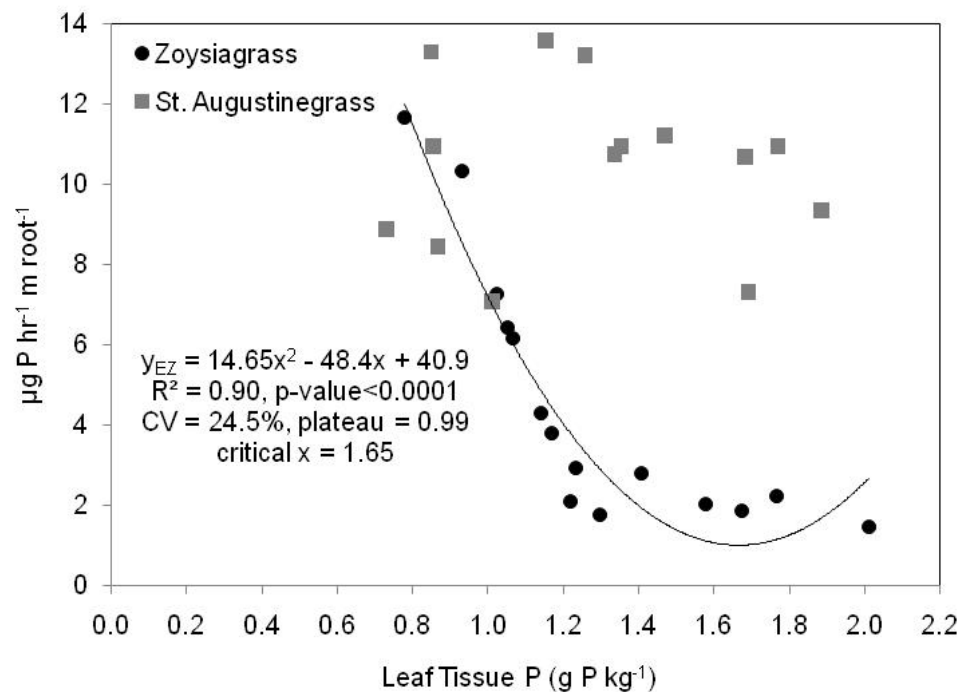


Figure 24. Phosphorus depletion rate from the nutrient solution by Empire zoysiagrass (EZ) and Floratam St. Augustinegrass (SA) as related to phosphorus concentration in leaf tissue.

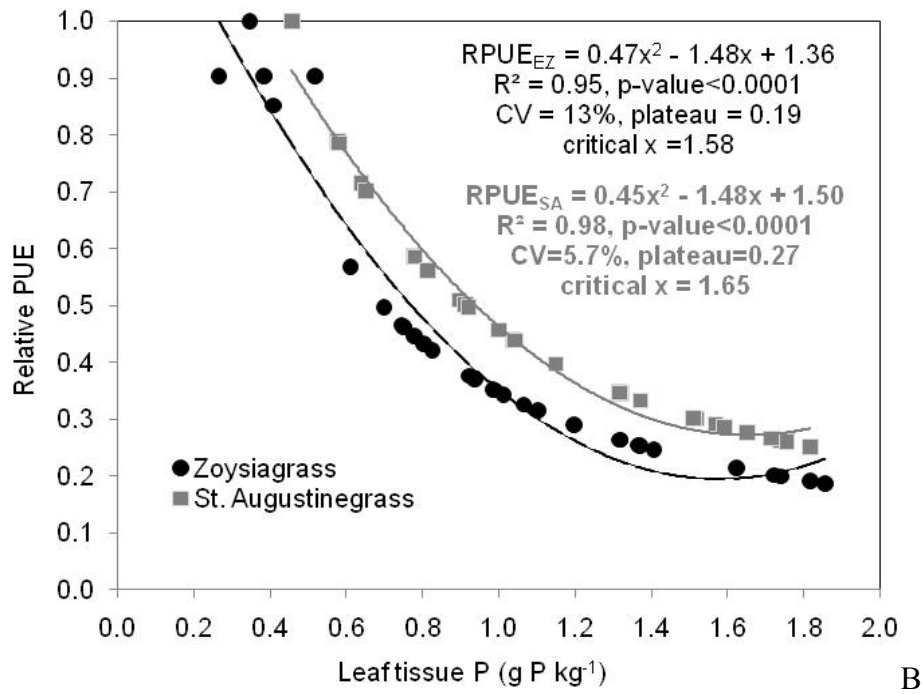
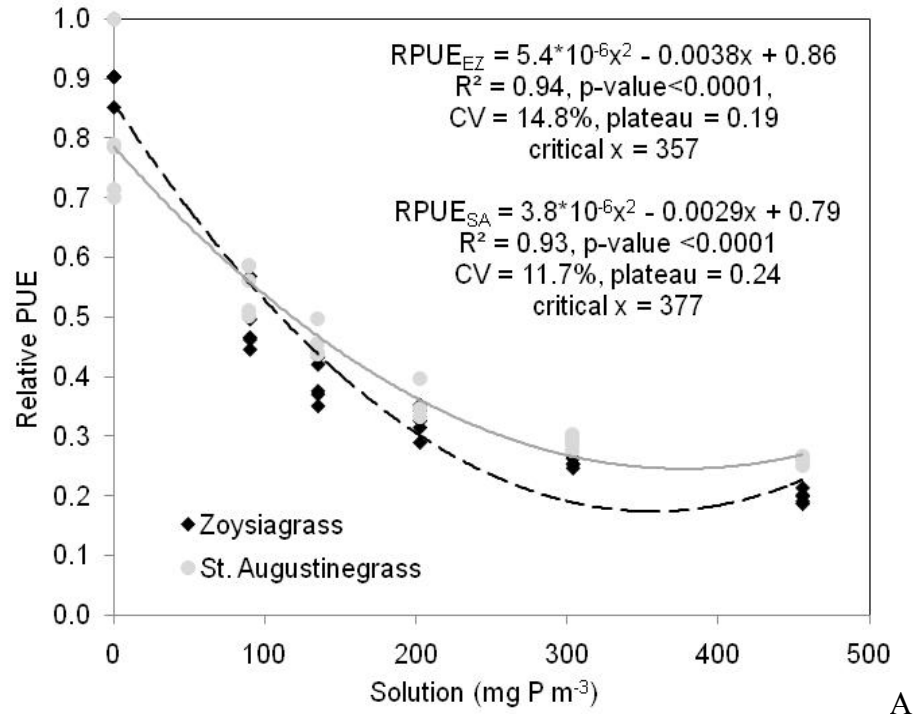


Figure 25. Relative P use efficiency (RPUE) of Empire zoysiagrass (EZ) and Floratam St. Augustinegrass (SA). A) RPUE in relation phosphorus concentration in solution and B) RPUE as influenced by leaf tissue P concentration.

Table 75. Baseline soil chemical characterization (n=20).

Variable	Units	Value
Mehlich 1 extractable P	mg kg ⁻¹	3.47
Mehlich 1 extractable Al	mg kg ⁻¹	11.0
Mehlich 1 extractable Fe	mg kg ⁻¹	1.46
Soil P storage capacity	mg kg ⁻¹	-1.65
Total carbon	g kg ⁻¹	0.40
Total nitrogen	g kg ⁻¹	0.10
pH		6.0
Soil electrical conductivity	μS cm ⁻¹	28.3
Relative P adsorption capacity		0.01
Phosphorus saturation ratio		0.33
Silt+Clay	%	<2

Table 76. Effect of phosphorus application rate on Mehlich 1 extractable soil phosphorus (M1-P), soil phosphorus storage capacity (SPSC) and phosphorus saturation ratio (PSR) in the top 15 cm of the soil profile during the first growth season (2008).

Fertilizer Application Rate	Floritam St. Augustinegrass			Empire zoysiagrass		
	M1-P	SPSC	PSR	M1-P	SPSC	PSR
	mg P kg ⁻¹			mg P kg ⁻¹		
0 g P m ⁻²	2.27	-0.88	0.38	2.52	-1.29	0.38
0.08 g P m ⁻²	1.61	-0.20	0.27	2.92	-1.70	0.46
0.2 g P m ⁻²	1.90	-0.51	0.28	3.15	-1.93	0.51
0.5 g P m ⁻²	2.70	-1.32	0.44	3.55	-2.34	0.57
1.25 g P m ⁻²	2.91	-1.53	0.42	3.40	-2.18	0.56
p-value	0.1784	0.1789	0.0526	0.4037	0.4050	0.2393

Table 77. Effect of phosphorus application rate on Mehlich 1 extractable soil phosphorus (M1-P), soil phosphorus storage capacity (SPSC) and phosphorus saturation ratio (PSR) in the top 15 cm of the soil profile during the second growth season (2009).

Fertilizer Application Rate	Floritam St. Augustinegrass			Empire zoysiagrass		
	M1-P	SPSC	PSR	M1-P	SPSC	PSR
	mg P kg ⁻¹			mg P kg ⁻¹		
0 g P m ⁻²	4.56 ^b	-3.23 ^a	0.75 ^b	3.79 ^c	-2.58 ^a	0.62 ^c
0.04 g P m ⁻²	5.00 ^b	-3.67 ^b	0.76 ^b	5.76 ^b	-4.56 ^{ab}	0.92 ^b
0.1 g P m ⁻²	5.48 ^b	-4.17 ^b	0.76 ^b	6.54 ^b	-5.35 ^b	1.05 ^b
0.25 g P m ⁻²	5.84 ^b	-4.54 ^b	0.92 ^b	9.66 ^a	-8.50 ^c	1.31 ^a
0.625 g P m ⁻²	9.75 ^a	-8.54 ^b	1.07 ^a	9.53 ^a	-8.37 ^c	1.50 ^a
p-value	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

Values within a given column with the same letter are not statistically different at p=0.05 according to single degree of freedom contrast analysis.

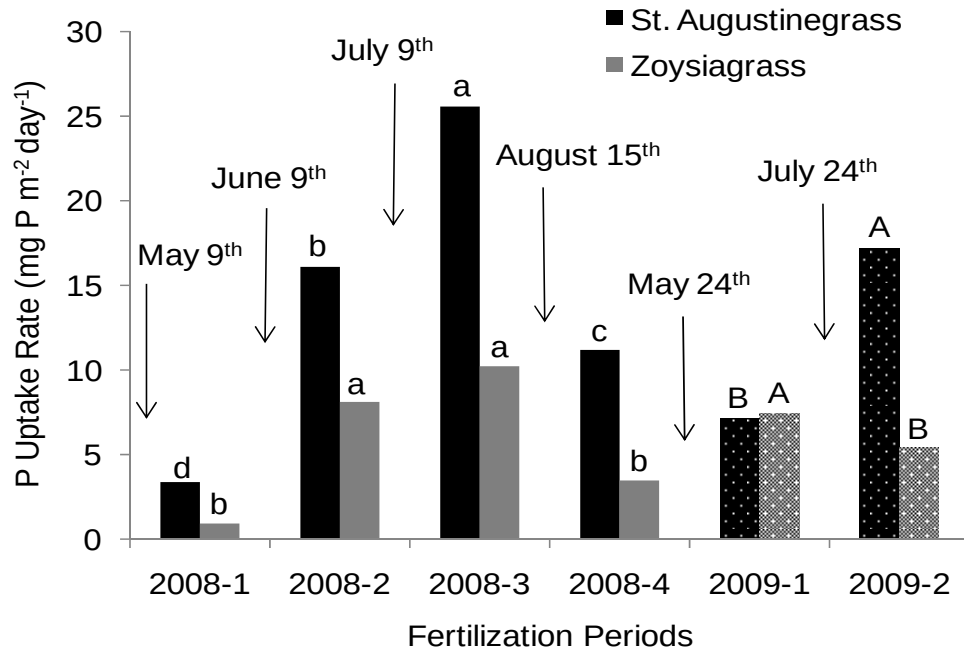


Figure 26. Phosphorus uptake rate in Empire zoysiagrass and Floratam St. Augustinegrass during each fertilization period. A fertilization period starts when a fertilizer application is conducted and ends when the following fertilization takes place. The date when each fertilizer application was carried out is indicated next to an arrow. Columns labeled with the same letter within a turfgrass species and year are not significantly different at $p = 0.05$ by single degree of freedom contrast analysis. Lower case letters indicate differences among fertilization periods during 2008 and upper case letters indicate differences among fertilizing periods during 2009.

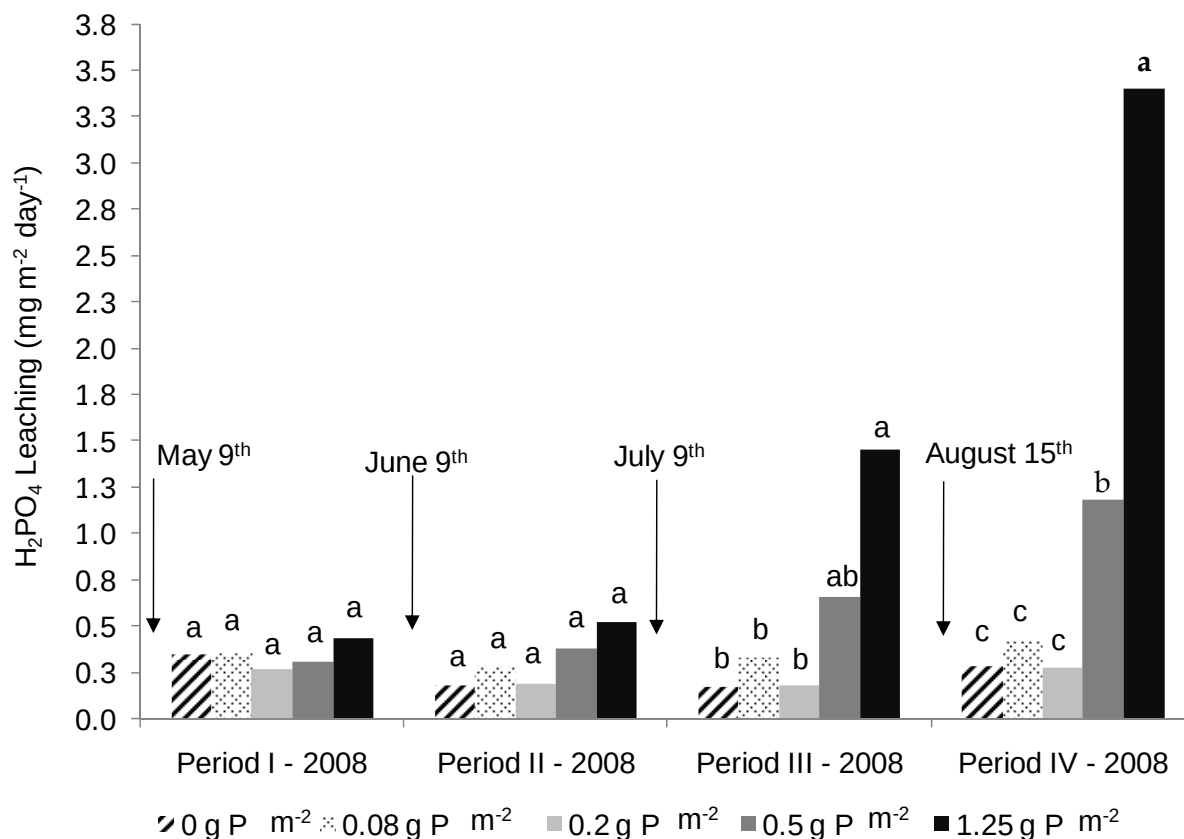


Figure 27. Orthophosphate leaching rate in Empire zoysiagrass as influenced by phosphorus application rate within each fertilizer application period during the first growing season (2008). The date when each fertilizer application was carried out is indicated next to an arrow. Columns with the same letter within an application period are not significantly different at $p=0.05$ according to single degree of freedom contrast analysis.

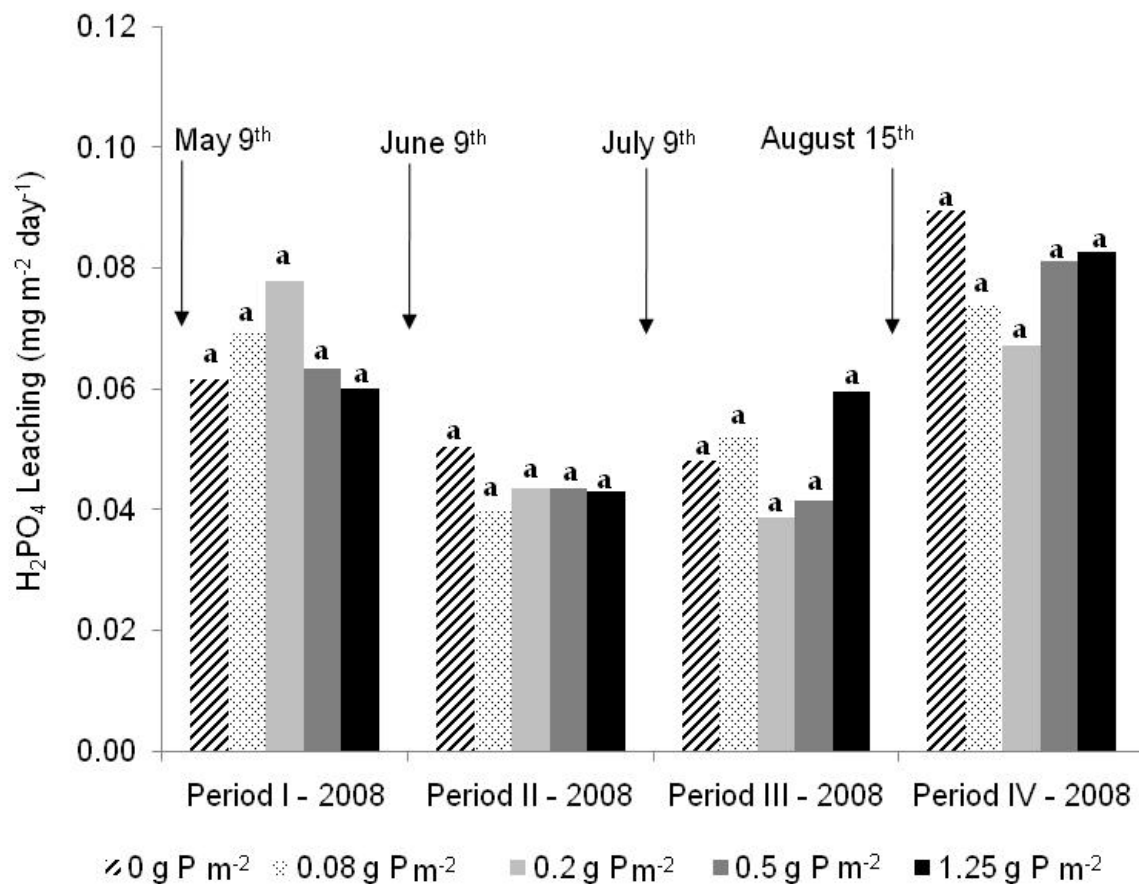


Figure 28. Orthophosphate leaching rate in Floratam St. Augustinegrass as influenced by phosphorus application rate within each fertilizer application period during the first growing season (2008). The date when each fertilizer application was carried out is indicated next to an arrow. Columns with the same letter within an application period are not significantly different at $p=0.05$ according to single degree of freedom contrast analysis.

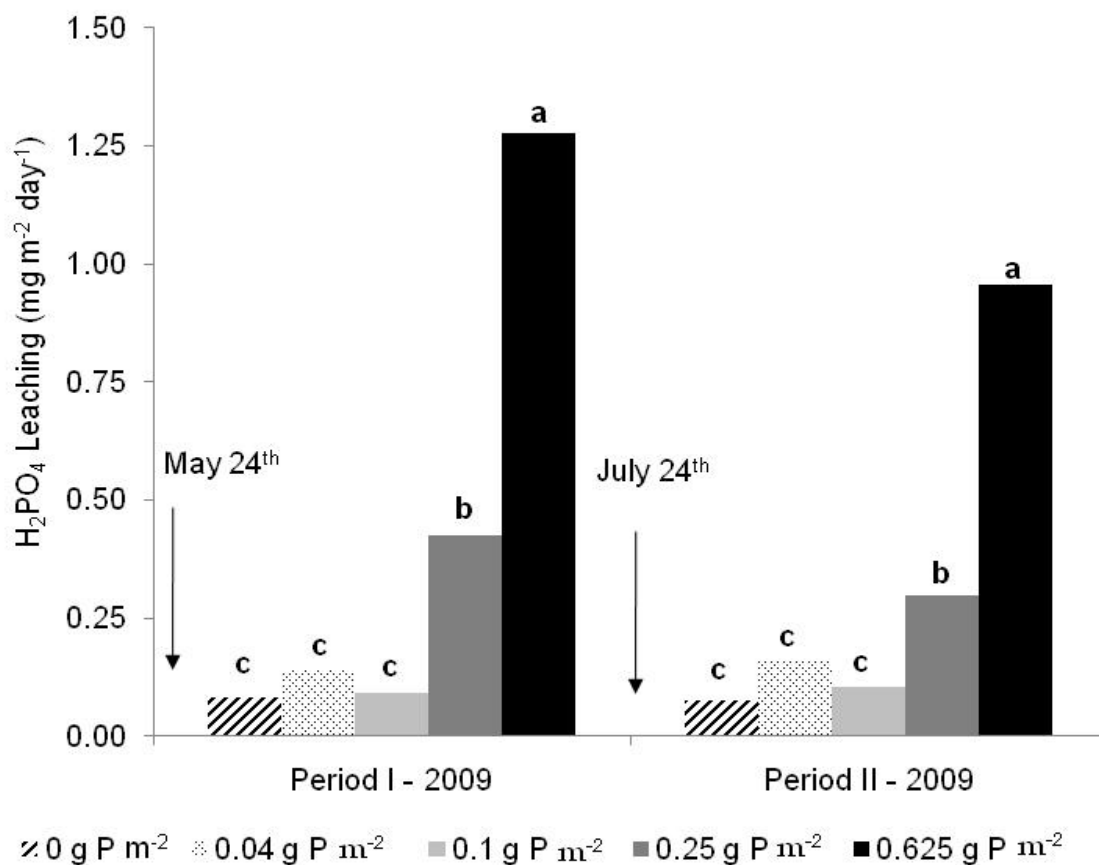


Figure 29. Orthophosphate leaching rate in Empire zoysiagrass as influenced by phosphorus application rate within each fertilizer application period during the second growing season (2009). The date when each fertilizer application was carried out is indicated next to an arrow. Columns with the same letter within an application period are not significantly different at $p=0.05$ according to single degree of freedom contrast analysis.

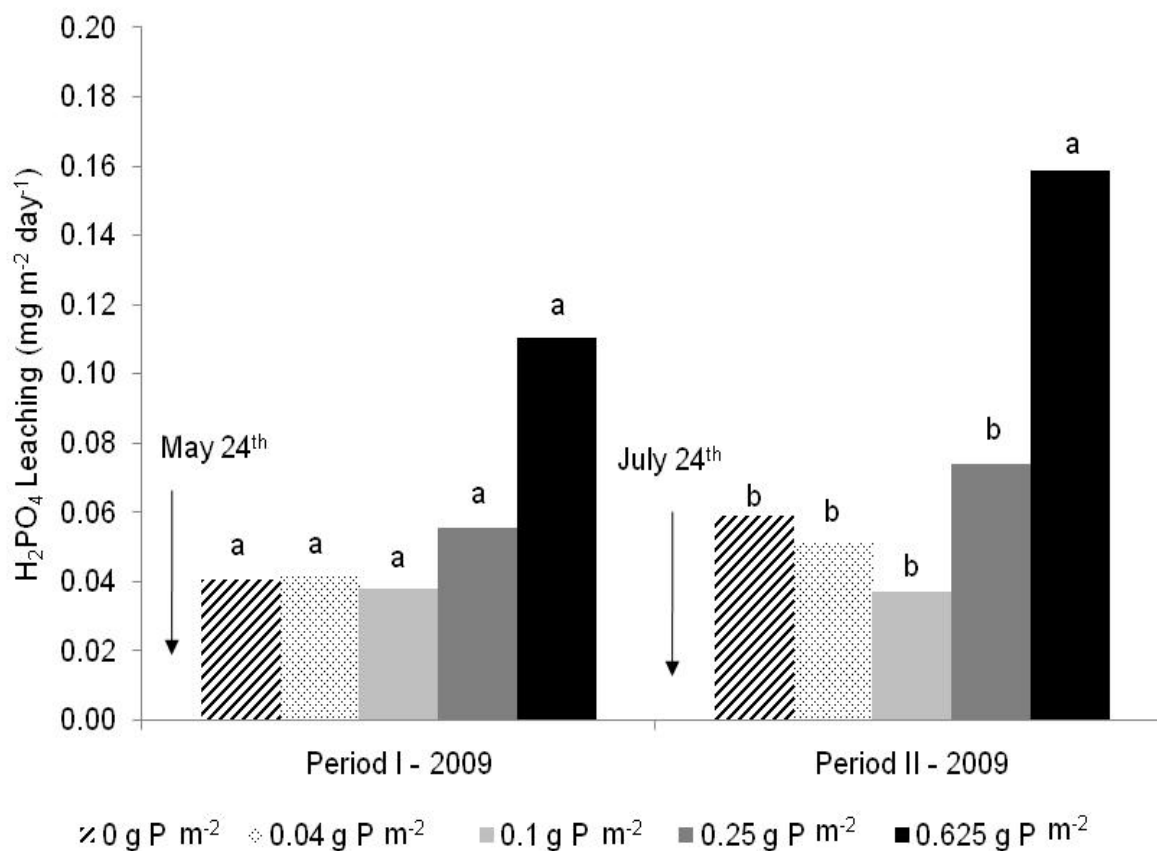


Figure 30. Orthophosphate leaching rate in Floratam St. Augustinegrass as influenced by phosphorus application rate within each fertilizer application period during the second growing season (2009). The date when each fertilizer application was carried out is indicated next to an arrow. Columns with the same letter within an application period are not significantly different at $p=0.05$ according to single degree of freedom contrast analysis.

Table 78. Percent cumulative phosphorus leached from fertilizer application between May 2008 and June 2010 in Floratam St. Augustinegrass.

Fertilizer Application Period	Phosphorus Application Rate (g m ⁻²)				
	0(0)	0.08(0.04)	0.2(0.1)	0.5(0.25)	1.25(0.625)*
2008-1	0.00	0.48	0.22	0.03	-0.01
2008-2	0.00	0.05	0.06	0.00	-0.01
2008-3	0.00	0.09	-0.02	-0.02	0.00
2008-4	0.00	-0.02	-0.06	-0.02	0.00
2009-1	0.00	0.04	-0.04	0.02	0.08
2009-2	0.00	-0.11	-0.14	0.06	0.19
2010	0.00	-0.17	-0.04	0.11	0.22
** kg P ha ⁻¹	0.00	-0.01	0.00	0.03	0.14

*Values outside parentheses correspond to P application rates during 2008 (g P m⁻² every 4 weeks). Values within parenthesis correspond to the P application rates during 2009 (g P m⁻² every 8 weeks).

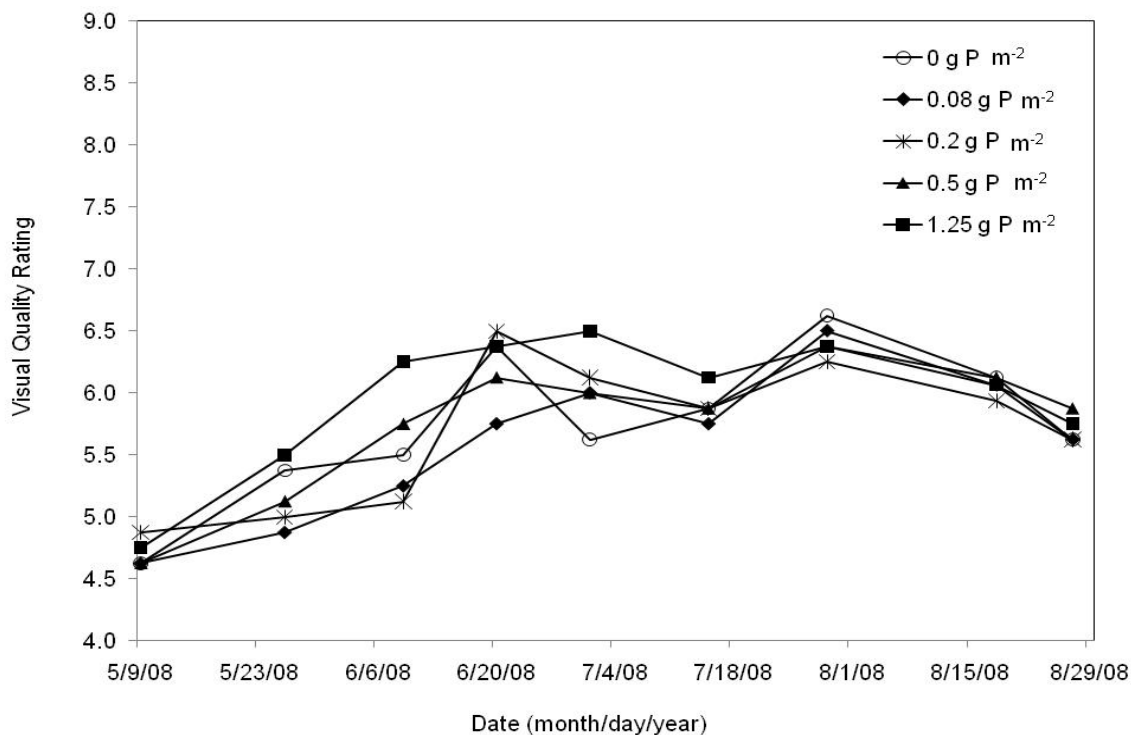
** kilograms of P leached over the control treatment per hectare between May 2008 and June 2010.

Table 79. Percent cumulative phosphorus leached from fertilizer application between May 2008 and June 2010 in Empire Zoysiagrass.

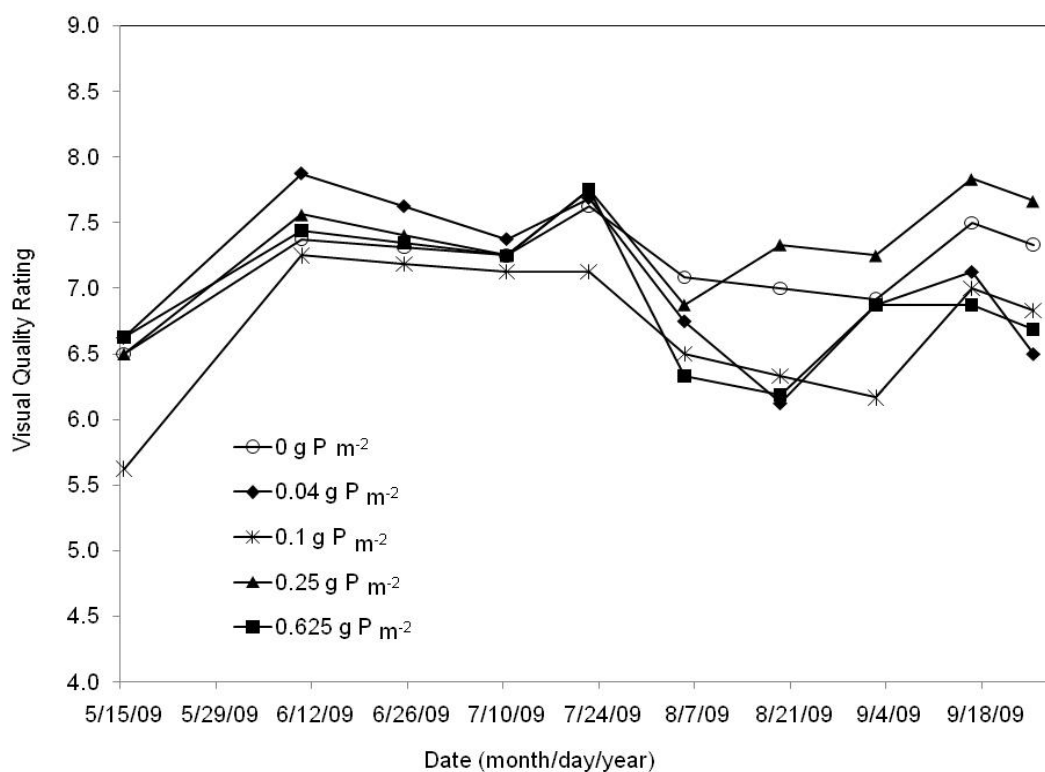
Fertilizer Application Period	Phosphorus Application Rate (g m ⁻²)				
	0(0)	0.08(0.04)	0.2(0.1)	0.5(0.25)	1.25(0.625)*
2008-1	0.00	0.56	-1.48	-0.24	0.41
2008-2	0.00	2.31	-0.72	0.58	0.70
2003-1	0.00	4.19	-0.38	1.88	2.11
2008-4	0.00	3.84	-0.27	2.21	2.56
2009-1	0.00	3.59	-0.61	2.86	3.81
2009-2	0.00	4.46	-0.43	3.18	4.37
2010	0.00	5.88	-0.29	3.39	4.71
** kg P ha ⁻¹	0.00	0.24	-0.03	0.85	2.95

*Values outside parentheses correspond to P application rates during 2008 (g P m⁻² every 4 weeks). Values within parenthesis correspond to the P application rates during 2009 (g P m⁻² every 8 weeks).

** kilograms of P leached over the control treatment per hectare between May 2008 and June 2010.

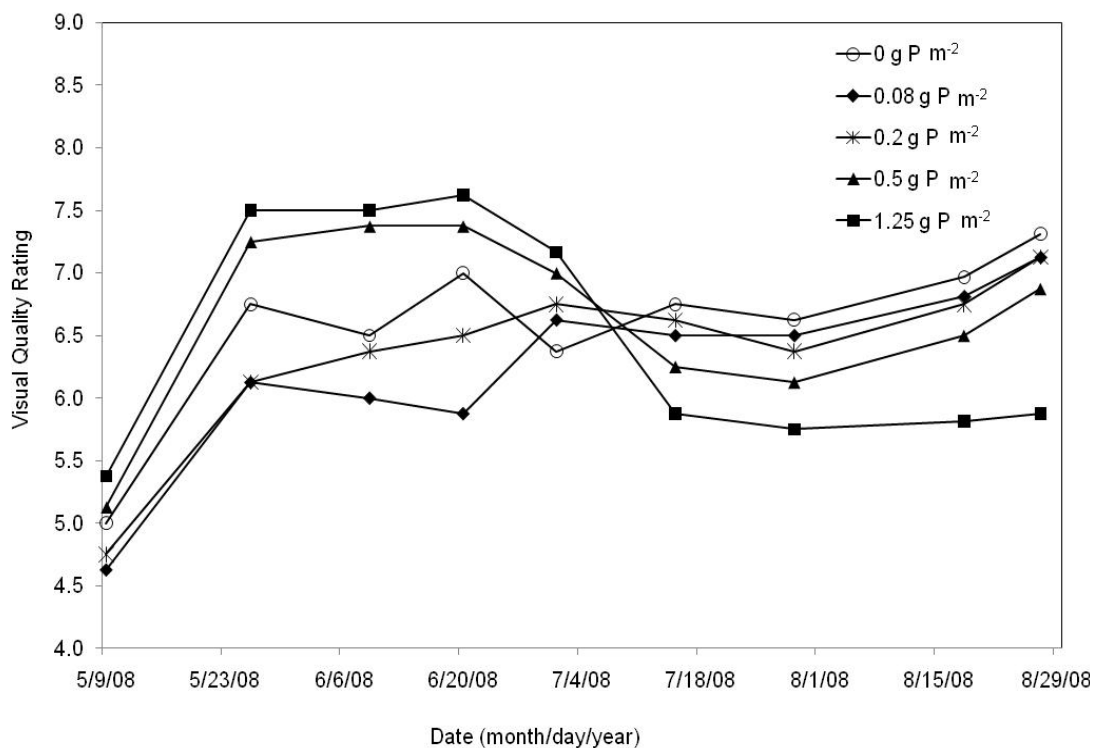


A

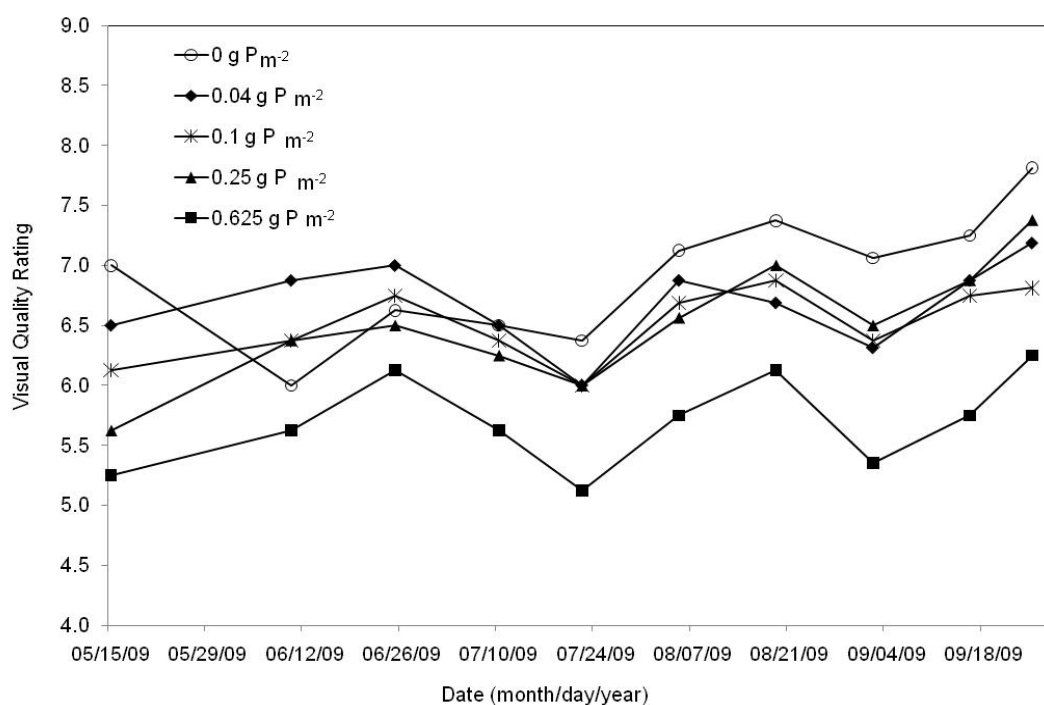


B

Figure 31. Empire zoysiagrass visual quality over time in response to phosphorus application rate. A) first growing season (2008) and B) second growing season (2009).



A



B

Figure 32. Floratam St. Augustinegrass visual quality over time in response to phosphorus application rate. A) first growing season (2008) and B) second growing season (2009).

Table 80. Mehlich 1 extractable soil phosphorus, leaf growth rate, phosphorus concentration in leaf tissue and visual quality of Empire zoysiagrass and Floratam St. Augustinegrass as influenced by phosphorus application rate during the first growth season (2008).

Application Rate	Floratam St. Augustinegrass				Empire Zoysiagrass			
	Mehlich 1 extractable mg P kg ⁻¹	Leaf P concentration g P kg ⁻¹	Leaf growth rate g m ⁻² day ⁻¹	Visual quality rating	Mehlich 1 extractable mg P kg ⁻¹	Leaf P concentration g P kg ⁻¹	Leaf growth rate g m ⁻² day ⁻¹	Visual quality rating
0 g P m ⁻²	2.27	4.21 ^c	3.32 ^b	6.7	2.52	2.50 ^{cd}	2.49	5.8
0.08 g P m ⁻²	1.61	3.81 ^d	2.38 ^d	6.3	2.92	2.38 ^d	2.14	5.6
0.02 g P m ⁻²	1.90	4.31 ^c	2.79 ^{cd}	6.4	3.15	2.67 ^{bc}	2.35	5.7
0.5 g P m ⁻²	2.70	4.83 ^b	3.17 ^{bc}	6.7	3.55	2.86 ^{ab}	1.96	5.8
1.25 g P m ⁻²	2.91	5.35 ^a	3.90 ^a	6.5	3.40	3.08 ^a	2.02	6.0
p-value	0.1966	<0.0001	<0.0001	0.1469	0.3968	<0.0001	0.6207	0.5448

Data points labeled with the same letter within a given column are not significantly different at $p = 0.05$ by single degree of freedom contrasts analysis.

Table 81. Mehlich 1 extractable soil phosphorus, leaf growth rate, phosphorus concentration in leaf tissue and visual quality of Empire zoysiagrass and Floratam St. Augustinegrass as influenced by phosphorus application rate during the second growth season (2009).

Application Rate	Floratam St. Augustinegrass				Empire Zoysiagrass			
	Mehlich 1 extractable mg P kg ⁻¹	Leaf P concentration g P kg ⁻¹	Leaf growth rate g m ⁻² day ⁻¹	Visual quality rating	Mehlich 1 extractable mg P kg ⁻¹	Leaf P concentration g P kg ⁻¹	Leaf growth rate g m ⁻² day ⁻¹	Visual quality rating
0 g P m ⁻²	4.56 ^b	3.97 ^d	3.14 ^a	6.8 ^a	3.79 ^c	2.90 ^{cd}	1.83	7.1 ^{ab}
0.04 g P m ⁻²	5.00 ^b	4.28 ^c	2.84 ^b	6.5 ^a	5.76 ^{bc}	2.83 ^d	1.81	6.9 ^b
0.01 g P m ⁻²	5.48 ^b	4.32 ^{bc}	2.70 ^b	6.4 ^a	6.54 ^b	3.11 ^c	1.89	6.7 ^c
0.25 g P m ⁻²	5.84 ^b	4.58 ^{ab}	2.64 ^b	6.5 ^a	9.66 ^a	3.38 ^b	2.05	7.3 ^a
0.625 g P m ⁻²	9.75 ^a	4.65 ^a	2.45 ^b	5.6 ^b	9.53 ^a	3.76 ^a	1.61	6.8 ^b
p-value	<0.0001	<0.0001	0.0258	<0.0001	<0.0001	<0.0001	0.4755	0.0069

Data points labeled with the same letter within a given column are not significantly different at $p = 0.05$ by single degree of freedom contrasts analysis.

Table 82. Floratam St. Augustinegrass leaf growth rate ($\text{g DM m}^{-2} \text{ day}^{-1}$) per fertilizer application period during each evaluation year as influenced by phosphorus application rate.

Application Period	g P m^{-2}					p-value **
	0(0)	0.08(0.04)	0.2(0.1)	0.5(0.25)	1.25(0.625)*	
2008-1	1.10c	0.44c	0.68c	0.91c	0.88c	0.0961
2008-2	3.71ab (a)	2.25b (b)	2.77b (ab)	3.65ab (a)	4.44ab (a)	0.0023
2008-3	4.77a (b)	3.80a (b)	4.32a (b)	4.49a (b)	5.70a (a)	0.0175
2008-4	2.60c	2.24b	2.45b	2.77b	3.45b	0.2281
Overall-2008	3.32	2.38	2.79	3.17	3.90	
2009-1	2.73b (a)	2.08b (b)	2.01b (b)	2.22b (ab)	1.60b (b)	0.0126
2009-2	3.55a	3.59a	3.39a	3.06a	3.30a	0.7279
Overall-2009	3.14	2.84	2.70	2.64	2.45	

* P application rates placed outside parentheses correspond to P application rates during 2008 (g P m^{-2} every 4 weeks). Values within parenthesis correspond to the P application rates during 2009 (g P m^{-2} every 8 weeks).

Data points labeled with the same letter within a given column and year are not significantly different at $p = 0.05$ by single degree of freedom contrasts analysis.

Data points labeled with the same letter between parentheses within a given row (fertilizer application period) are not significantly different at $p = 0.05$ by contrasts analysis.

** p-value for phosphorus application rate effect comparisons within a given fertilizer application period.

Table 83. Empire Zoysiagrass leaf growth rate ($\text{g DM m}^{-2} \text{ day}^{-1}$) per fertilizer application period during each evaluation year as influenced by phosphorus application rate.

Application Period	g P m^{-2}					p-value **
	0(0)	0.08(0.04)	0.2(0.1)	0.5(0.25)	1.25(0.625)*	
2008-1	0.44b	0.41b	0.43c	0.33c	0.50b	0.8061
2008-2	3.49a	2.93a	3.23ab	2.22ab	2.92a	0.7397
2008-3	3.45a	2.93a	3.20a	3.04a	2.74a	0.8732
2008-4	1.71ab	1.65ab	1.84ab	1.43bc	1.11b	0.3303
Overall-2008	2.49	2.14	2.35	1.96	2.02	
2009-1	2.44a	2.38a	2.53a	2.47a	2.00a	0.8861
2009-2	1.22b	1.25b	1.25b	1.63b	1.23b	0.5612
Overall-2009	1.83	1.81	1.89	2.05	1.61	

* Values outside parentheses correspond to P application rates during 2008 (g P m^{-2} every 4 weeks). Values within parenthesis correspond to the P application rates during 2009 (g P m^{-2} every 8 weeks).

Data points labeled with the same letter within a given column and year are not significantly different at $p = 0.05$ by single degree of freedom contrasts analysis.

**p-value for phosphorus application rate effect comparisons within a given fertilizer application period.

Table 84. Empire zoysiagrass and Floratam St. Augustinegrass phosphorus uptake rate and use efficiency as influenced by phosphorus application rate during the first growth season (2008).

Application Rate	Floratam St. Augustinegrass			Empire Zoysiagrass		
	P Use Efficiency kg DM g ⁻¹ P	Relative P Use Efficiency	P Uptake Rate mg P m ⁻² day ⁻¹	P Use Efficiency kg DM g ⁻¹ P	Relative P Use Efficiency	P Uptake Rate mg P m ⁻² day ⁻¹
0 g P m ⁻²	0.26 ^b	0.79 ^b	15.0 ^{bc}	0.43 ^b	0.70 ^{ab}	6.60
0.08 g P m ⁻²	0.29 ^a	0.87 ^a	10.6 ^d	0.48 ^a	0.75 ^a	5.75
0.02 g P m ⁻²	0.25 ^b	0.77 ^b	13.5 ^{cd}	0.42 ^{bc}	0.67 ^{bc}	7.01
0.5 g P m ⁻²	0.22 ^c	0.68 ^c	16.5 ^b	0.38 ^{cd}	0.61 ^{bd}	6.27
1.25 g P m ⁻²	0.19 ^d	0.61 ^d	22.6 ^a	0.35 ^d	0.57 ^d	6.88
p-value	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.7951

Data points labeled with the same letter within a given column are not significantly different at p = 0.05 by single degree of freedom contrasts analysis.

Table 85. Empire zoysiagrass and Floratam St. Augustinegrass phosphorus uptake rate and use efficiency as influenced by phosphorus application rate during the second growth season (2009).

Application Rate	Floratam St. Augustinegrass			Empire Zoysiagrass		
	P Use Efficiency kg DM g ⁻¹ P	Relative P Use Efficiency	P Uptake Rate mg P m ⁻² day ⁻¹	P Use Efficiency kg DM g ⁻¹ P	Relative P Use Efficiency	P Uptake Rate mg P m ⁻² day ⁻¹
0 g P m ⁻²	0.27 ^a	0.87 ^a	12.7	0.38 ^{ab}	0.81 ^a	5.46
0.08 g P m ⁻²	0.24 ^b	0.79 ^b	12.8	0.37 ^a	0.82 ^a	5.39
0.02 g P m ⁻²	0.24 ^b	0.78 ^b	12.2	0.34 ^{bc}	0.75 ^b	6.12
0.5 g P m ⁻²	0.23 ^b	0.75 ^b	12.5	0.32 ^c	0.79 ^b	7.10
1.25 g P m ⁻²	0.23 ^b	0.75 ^b	11.7	0.28 ^d	0.63 ^c	6.16
p-value	0.0005	0.0002	0.8378	<0.0001	<0.0001	0.3286

Data points labeled with the same letter within a given column are not significantly different at p = 0.05 by single degree of freedom contrasts analysis.

GAINESVILLE PROJECTS – DR. LAURIE TRENHOLM

PROJECT: NITRATE LEACHING AND TURF QUALITY IN NEWLY SODDED ST. AUGUSTINEGRASS AND ZOYSIAGRASS

Introduction

While there are numerous published reports on the fate of N applied to mature turfgrass, limited research exists on the fate of N applied to newly planted turf areas. Shaddox and Sartain (2001) noted that 0.03% of applied N was collected as runoff during establishment of sprigged bermudagrass on a 10% slope. Nitrate leaching from this sloped site ranged from 8% to 12% of applied N. The plots received irrigation at a rate twice that of the water lost to evapotranspiration (ET), likely contributing to these leaching levels. Geron et al. (1993) concluded that N source had little contribution to $\text{NO}_3\text{-N}$ leaching from newly established (year 1) and established (year 2) turf that was either seeded or sodded to 'Baron' Kentucky bluegrass. Highest annual flow weighted $\text{NO}_3\text{-N}$ leaching occurred in year 1 compared to yr 2 (average 14.6 and $2.3 \text{ mg}\cdot\text{L}^{-1}$, respectively), regardless of establishment method.

Easton and Petrovic (2004) reported greater $\text{NO}_3\text{-N}$ leaching losses from a mixture of Kentucky bluegrass and perennial ryegrass (*Lolium perenne* L.) treated with soluble urea than from an untreated control. Leaching losses were greatest in the first year following turf establishment. The authors concluded that the potential for increased $\text{NO}_3\text{-N}$ leaching was greatest during establishment, but that the faster establishment time in grasses that receive fertilization during the first year reduced subsequent losses of N and P compared to an unfertilized control.

Erickson et al. (2001) observed less $\text{NO}_3\text{-N}$ leaching ($4.1 \text{ kg}\cdot\text{ha}^{-1}$ annually) from sodded 'Floritam' St. Augustinegrass than from a mixed-species landscape ($48.3 \text{ kg}\cdot\text{ha}^{-1}$ annually) during the first year following establishment. In a subsequent paper, Erickson et al. (2008) reported that both turf and mixed species landscape types leached less than 2% of the applied N as inorganic-N over time, as both landscape types matured and the root mass expanded on the mixed-species landscape plants.

Bowman et al. (2002) observed a 92% reduction in $\text{NO}_3\text{-N}$ leaching from St. Augustinegrass grown in lysimeters from a second treatment application as compared to the first treatment. Nitrogen was applied as ammonium nitrate at a rate of $5.0 \text{ g}\cdot\text{m}^{-2}$ on both treatment dates. The authors attributed the sharp reduction in $\text{NO}_3\text{-N}$ leaching following the second treatment application to development of a more extensive root system, a larger microbial population to increase N immobilization, and less water percolation in the columns. Over the course of the study, lower cumulative levels of $\text{NO}_3\text{-N}$ and a lower percentage of applied N leached from 'Raleigh' St. Augustinegrass than from five other warm-season grass species. Similarly, Bowman et al. (1998) attributed lower $\text{NO}_3\text{-N}$ leaching from two creeping bentgrass (*Agrostis palustris* Huds.) genotypes to production of a deeper root system and concluded that management strategies to enhance rooting may reduce $\text{NO}_3\text{-N}$ leaching.

This research was undertaken to determine the extent of $\text{NO}_3\text{-N}$ leaching losses from newly sodded turf due to N rate and irrigation regime.

Materials and Methods

Lysimeters were installed in 2004 and 2005. Plots measured $4.0\text{m} \times 4.0\text{m}$. High-density polyethylene (HDPE) drainage lysimeters were installed in the center of each plot, with the top approximately 10 cm below the soil surface. Lysimeters measured 57 cm diam. and 88 cm in height with a volume of 168 L. Lysimeters were

assembled by placing HDPE cylinders into a single piece galvanized steel base unit measuring 25.4 cm in height. A bulkhead fitting was inserted into the base of each unit, to which collection tubing (0.95 cm low density polyethylene) was attached. The tubing was run underground to central aboveground collection portals. Lysimeters were installed by boring and removing soil in 15.2 cm sections to a depth of 107 cm. Lysimeters were placed in holes and 38 L of washed egg rock (1.9 – 6.4 cm) were placed in the bottom of each lysimeter. The gravel was covered with fitted non-woven polyolefin cloth that was secured with a hoop of 1.3 cm HDPE tubing to reduce soil intrusion into the reservoir. Soil was replaced into the lysimeters as it had been removed from the soil profile. Soil was gently tamped with a tamping tool (17 kg and 858 cm²) to approximate original soil bulk density.

Grasses were established as sod in the spring of each year from 2005-2008. Zoysiagrass trials were conducted in 2005 and 2008, St. Augustinegrass in 2006 and 2007. Nitrogen treatments were applied the same day as planting and again at 30 days after planting on half of the plots. Treatment rates and applications are listed in Table 86. Irrigation treatments are described in Table 87.

Table 86. N treatments applied over a 4-yr period to Empire zoysiagrass and Floratam St. Augustinegrass in Citra, FL.

Chau, F.E.				
Nitrogen Treatment	Number of Fertilizations †		Nitrogen Rate	Total N Applied
			-----kg·ha ⁻¹ -----	
1	1		24.5	2.5
2	1		49.0	5.0
3	1		98.0	10.0
4	2		24.5	40.0
5	2		49.0	98.0
6	2		98.0	196.0

Table 87. Irrigation treatments applied over a 4-yr period to Empire zoysiagrass and Floratam St. Augustinegrass in Citra, FL.

	Irrigation regime 1		Irrigation regime 2	
	Frequency	Weekly amount	Frequency	Weekly amount
		cm		cm
Days 1-7	3 per day	6.3	1 per day	9.1
Days 8-14	1 per day	4.2	1 per day	9.1
Days 15-21	3 per week	3.9	1 per day	9.1
Day 22 - termination	2 per week	2.6	2 per week	2.6
Total irrigation applied		27.4		40.3

Leachate samples were collected twice weekly in 2005 and 2006 and weekly in 2007 and 2008 as previously described. Turf was mowed as needed throughout the study period, typically an average of twice monthly. Mowing heights were 8.8 and 5 cm, respectively, for St. Augustinegrass and zoysiagrass. Clippings were returned to the ground.

Turf quality was assessed biweekly for visual quality and color over the growing season on a scale of 1 to 9, where 1 = dead or dormant brown turf and 9 = optimal healthy, green turf. Weather data were collected from an onsite weather network system (<http://fawn.ifas.ufl.edu>), which provides meteorological information in 15-min intervals.

Shoot harvests were collected twice throughout the trial periods with a walk-behind mower. Shoot tissue was dried and weighed. No shoot data are available for zoysiagrass in 2008.

Results - Zoysiagrass

Total NO₃-N leached

There were no differences in NO₃-N leaching losses in 2005 due to any treatment effect (Table). In 2008, there were differences in mass loading due to nitrogen treatment. Plots that received N at 98 kg ha⁻¹ either once or twice and those that received 49 kg N ha⁻¹ one time were in the highest statistical ranking for leaching losses (Table). Single degree of freedom contrast analysis indicated a difference between treatment 1 (24.5 kg N ha⁻¹ applied once) and treatment 3 (98 kg N ha⁻¹ applied once). In 2008, total amount of N applied appeared to be more of a factor in NO₃-N leaching losses than timing of application, although higher amounts applied at 30 days after planting also had considerable losses. Analysis of variance indicated that there were no differences in percent of applied N leached in either year due to any treatment, although single degree of freedom contrast analysis showed a difference in percent of applied N leached between treatments 1 and 3 in 2005.

Turf quality differed in 2005 due to irrigation regime (Table), with better quality from irrigation regime 2 (6.2 vs 5.9, data not shown). This regime applied more water through the establishment period, resulting in reduced water stress during establishment, but is not the recommended irrigation schedule for newly planted sod. Turf color in 2005 differed due to nitrogen treatment, with higher scores from higher N application rates. All color scores were above the minimally acceptable score of 6.0.

In 2008, turf quality differed due to main effects of both nitrogen treatment and irrigation, with higher quality scores from the highest N application rate (Table). Higher quality scores (6.7 vs. 6.4, data not shown) were seen in plots that received irrigation regime 1. Turf color differed due to nitrogen treatment in 2008, with highest scores resulting from highest N application rates (Table). Again, all scores were well above acceptable.

Table 88. Analysis of variance (ANOVA) for NO₃-N leaching, percent of applied N leached, turf quality and turf color in response to nitrogen treatment (NT) and irrigation regime (IR) of newly sodded Empire zoysiagrass in 2005 and 2008 in Citra, FL.

Source of variation	Total nitrate leached	Percent applied nitrate leached	Average turf quality	Average turf color	Shoot Growth
	kg N ha ⁻¹	%			
2005					
N treatment (NT)	NS	NS	NS	***	*
Irrigation regime (IR)	NS	NS	*	NS	NS
NT x IR	NS	NS	NS	NS	NS
2008					
NT	**	NS	***	***	NA
IR	NS	NS	**	NS	NA
NT x IR	NS	NS	NS	NS	NA

*, **, *** Significant at the 0.05, 0.01, and 0.001 probability levels, respectively.

NS Not significant at the 0.05 probability level.

Table 89. Nitrate-N leaching (total mass and percent of applied N) and single degree of freedom contrast analysis in response to nitrogen treatment (NT) in newly sodded Empire zoysiagrass in 2005 and 2008 in Citra, FL.

Nitrogen Treatment (NT)	2005		2008	
	Total Nitrate Leached	Nitrate Leached	Total Nitrate Leached	Nitrate Leached
	(kg ha ⁻¹)	(% applied N)	(kg ha ⁻¹)	(% applied N)
6	57.0	29.1	41.8 a†	21.3
5	35.9	36.7	27.6 ab	28.2
4	28.3	56.6	15.8 bc	31.6
3	32.0	32.7	40.4 a	41.3
2	30.1	61.4	21.2 bc	43.2
1	18.7	74.9	8.3 c	33.0
<u>Contrasts</u>				
NT1 vs. NT2	NS	NS	NS	NS
NT1 vs. NT3	NS	*	**	NS
NT1 vs. NT4	NS	NS	NS	NS
NT2 vs. NT4	NS	NS	NS	NS
NT3 vs. NT6	NS	NS	NS	NS

*, ** Significant at the 0.05 and 0.01 probability levels, respectively

NS Not significant at the 0.05 probability level.

† Within columns, means followed by different letters differ significantly at $P = 0.05$.

Table 90. Turf quality and color ratings in response to nitrogen treatment (NT) in newly sodded Empire zoysiagrass in 2005 and 2008 in Citra, FL. Scores were based on a scale of 1 to 9, where 1 = dead, brown turf and 9 = optimal healthy, green turf. A score of 6 was considered minimally acceptable for a home lawn.

Nitrogen Treatment	2005		Shoot Growth‡	2008	
	Average turf quality	Average turf color		Average turf quality	Average turf color
6	6.5 a †	8.6 a	0.69 a	7.2 a	7.6 a
5	6.2 ab	8.3 b	0.51 b	6.7 b	7.2 b
4	6.0 bc	7.9 c	0.27 c	6.4 b	6.8 c
3	5.9 bc	7.9 c	0.25 c	6.5 b	6.9 c
2	5.8 c	7.8 c	0.21 c	6.3 b	6.7 cd
1	5.9 bc	7.8 c	0.15 c	6.4 b	6.6 d

† Within columns, means followed by different letters differ significantly at $P = 0.05$.

‡ units in g m^{-2} .

Results- St. Augustinegrass

Total NO₃-N Leached

Analysis of variance indicated that there were no differences in cumulative NO₃⁻N leached in either year due to N treatment or IR or their interaction (Table 3). However, single degree of freedom contrasts in 2006 indicated that nitrogen rate affected cumulative NO₃-N leaching (Table 4). Contrasts differed significantly between treatments 1 and treatments 2 and 3, with higher leaching occurring at the higher N application rates. There was no difference between treatment 1 and 4 and between treatment 2 and 5, indicating no differences in leaching due to one application at day of planting or applications at both day of planting and 30 DAP at these rates. At the highest N rate, significantly more NO₃-N leached from plots that received two treatment applications than from those that received one application. In 2007, contrasts showed no differences in NO₃-N leaching between treatments.

The percent of applied N leached did not differ due to treatment effects in either year (Table 3). Single degree of freedom contrasts in 2006 showed differences between treatments 1 and 2 and treatment 2 vs. 5 (Table 4). In 2007, percentage leached varied between the lowest and highest rates of applied N when applied at time of planting. Highest percentages were lost from lowest rates of applied N. It is not unusual that percentages of N lost increase at lower N rates, as even low levels of NO₃-N leaching can result in high percentages given small amounts of N applied.

It is notable that the percentage of NO₃-N leached (averaged over all other treatments) was 73.4 and 56.4% for application 1 and 2, respectively, in 2006 (data not shown). This represents a 23% reduction in percentage leached from day of sodding to 30 days after sodding. In 2007, NO₃-N leached from application 1 vs. application 2 was 51.0 and 33.9%, respectively, a 33.5% reduction in leaching between the two application dates.

Table 91. Analysis of variance (ANOVA) for NO₃-N leaching, percent of applied N leached, turf quality, turf color, and shoot growth in response to nitrogen treatment (NT) and irrigation regime (IR) of newly sodded Floratam St. Augustinegrass in 2006 and 2007 in Citra, FL.

Source of variation	Total nitrate leached	Percent applied N leached	Average turf quality	Average turf color	Daily Shoot Growth
	kg N ha ⁻¹	%			g m ⁻²
	2006				
N treatment (NT)	NS	NS	**	**	NS
Irrigation regime (IR)	NS	NS	NS	NS	NS
NT x IR	NS	NS	NS	NS	NS
	2007				
NT	NS	NS	***	***	***
IR	NS	NS	NS	NS	NS
NT x IR	NS	NS	*	NS	NS

*, **, *** Significant at the 0.05, 0.01, and 0.001 probability levels, respectively.

NS Not significant at the 0.05 probability level.

Table 92. Nitrate-N leaching (total mass and percent of applied N) and single degree of freedom contrast analysis in response to nitrogen treatment (NT) in newly sodded Floratam St. Augustinegrass in 2006 and 2007 in Citra, FL.

Nitrogen Treatment (NT)	2006		2007	
	Total Nitrate Leached	Nitrate Leached	Total Nitrate Leached	Nitrate Leached
	(g·m ⁻²)	(% applied N)	(g·m ⁻²)	(% applied N)
1	0.7	26.7	1.6	62.7
2	3.2	64.8	2.9	59.0
3	3.7	37.8	3.1	31.2
4	1.5	29.8	2.3	45.5
5	3.7	37.7	3.5	36.0
6	5.7	29.2	4.0	20.3
<u>Contrasts</u>				
NT1 vs. NT2	**	**	NS	NS
NT1 vs. NT3	**	NS	NS	*
NT1 vs. NT4	NS	NS	NS	NS
NT1 vs. NT5	**	NS	NS	NS
NT1 vs. NT6	***	NS	*	**
NT2 vs. NT4	NS	**	NS	NS
NT2 vs. NT5	NS	*	NS	NS
NT3 vs. NT5	NS	NS	NS	NS
NT3 vs. NT6	*	NS	NS	NS

*, **, *** Significant at the 0.05, 0.01, and 0.001 probability levels, respectively
 NS not significant at the 0.05 probability level.

Turf Visual Ratings

Turf visual quality and color ratings differed in 2006 only in response to N treatment (Table 3). Both TQ and TC were highest with treatment 6 and lowest with treatment 2 (Table 5). Color scores were always above a minimally acceptable score and TQ was above acceptable from N treatment 1, 4, 5, and 6. In 2007, all scores were above acceptable, with highest scores from treatment 6 and lowest from treatment 1. Turf visual responses to nitrogen are often reported in established turf, so it is probable that the slight, although significant, responses reported here are most likely due to residual pre-harvest fertilization, which may imply that nitrogen fertilization was not needed during the establishment period.

Table 93. Turf quality and color ratings in response to nitrogen treatment (NT) in newly sodded Floratam St. Augustinegrass in 2006 and 2007 in Citra, FL. Scores were based on a scale of 1 to 9, where 1 = dead, brown turf and 9 = optimal healthy, green turf. A score of 6 was considered minimally acceptable for a home lawn.

Nitrogen Treatment	2006		2007	
	Average turf quality	Average turf color	Average turf quality	Average turf color
6	6.6 a †	7.2 a	7.5 a	7.6 a
5	6.5 b	7.1 b	7.2 b	7.4 b
4	6.3 c	6.8 c	7.0 c	7.1 c
3	5.9 e	6.4 e	6.9 d	6.9 d
2	5.6 f	6.1 f	6.8 e	6.9 d
1	6.1 d	6.6 d	6.6 f	6.7 e

† Within columns, means followed by different letters differ significantly at $P = 0.05$.

Shoot Growth

There were no differences in shoot growth, calculated as daily growth throughout the trial period in 2006, due to any treatment (Table). In 2007, highest shoot growth resulted from treatment 6 (Table). Treatment 5 had significantly greater growth than treatments 1 and 2.

Table 94. Daily shoot growth of newly sodded Floratam St. Augustinegrass in 2006 and 2007 in Citra, FL.

Daily Shoot Growth	2006	2007
	g m ⁻²	
Nitrogen Treatment		
6	0.57	0.61 a †
5	1.18	0.35 b
4	0.22	0.27 bc
3	0.11	0.32 bc
2	0.07	0.22 c
1	0.12	0.23 c

† Within columns, means followed by different letters differ significantly at $P = 0.05$.

Conclusions for Both Species

Although analysis of variance did not indicate statistical differences in NO₃-N leached at $P = 0.05$ due to N or IR in either year in St. Augustinegrass, contrast analysis indicated differences between some individual treatments. When these differences existed, the highest rate of applied N differed from the lower rates. There were more differences in leaching losses from zoysiagrass due to both N treatment and irrigation. It is also important to note that the levels of NO₃-N leaching reported from this research on newly sodded grass are considerably higher than what has been reported to leach from established grasses. Although fertilizer timing did not appear to influence leaching as much as rate, the reductions reported in NO₃-N leached between the first and second N applications should be considered in a nutrient management plan to reduce nutrient leaching. While there were some minimal differences in turf quality and color due to treatments, all treatments produced acceptable quality and color in 3 of 4 years. There is no advantage to applying higher N rates after sodding to achieve acceptable turf quality or color.

Although no effect on $\text{NO}_3\text{-N}$ leaching was observed due to irrigation regime, IR 1 used 43% less water than IR 2 and therefore should be considered for water conservation during the first 3 weeks of turf establishment. Turf quality in zoysiagrass differed due to IR in both years, but the findings were not conclusive for one regime over the other. In contrast to findings reported here on irrigation, Morton et al. (1988) reported higher $\text{NO}_3\text{-N}$ concentrations leached from Kentucky bluegrass that received higher amounts of irrigation. Perhaps if a wider range of irrigation regimes were compared in the current study, differences would have been more readily apparent.

Results of this research indicate that N fertilization should be withheld for a minimum of 30 to until 60 days after sodding St. Augustinegrass or zoysiagrass to reduce potential $\text{NO}_3\text{-N}$ leaching.

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NITRATE LEACHING AND TURF QUALITY IN ESTABLISHED 'FLORATAM' ST. AUGUSTINEGRASS AND 'EMPIRE' ZOYSIAGRASS

Introduction

With increasing urbanization, there are concerns that urban turf fertilization may contribute to nonpoint source pollution of ground and surface waters. To this end, there are some who support a cessation of or placement of severe restrictions on turf fertilization, although numerous research reports have clearly documented that many factors can influence N leaching from turf areas. These factors include N application rate (Brown et al., 1977; Shuman, 2001; Easton and Petrovic, 2004; Frank et al., 2006), N source (Geron et al., 1993; Easton and Petrovic, 2004), irrigation management (Starrett et al., 1995; Morton et al., 1998) maturity of the grass (Frank et al., 2006), and root architecture (Bowman et al., 1998; Bowman et al., 2002).

Frank et al. (2006) observed a range of 0 to 0.08 kg ha⁻¹ labeled fertilizer N in leachate from established Kentucky bluegrass (*Poa pratensis* L.) that received urea N at 98 kg ha⁻¹ annually compared to 0.01 to 0.73 kg N ha⁻¹ leached from turf fertilized with 245 kg urea N ha⁻¹ annually. The authors concluded that the two years of research indicated that application of the low NR provided minimal potential for groundwater pollution, but that the high rate, particularly when applied as a single application, water soluble N source, may result in nitrate N (NO₃-N) levels in excess of the USEPA safe levels of 10 mg NO₃-N L⁻¹. The authors cited a need for subsequent years of research to verify these findings.

Morton et al. (1988) reported greatest annual flow-weighted NO₃-N concentration (4.02 mg L⁻¹) in a mixture of Kentucky bluegrass and red fescue (*Festuca rubra* L.) that received high N (244 kg ha⁻¹ yr⁻¹) and excessive irrigation (3.75 cm wk⁻¹ regardless of rainfall). Annual N losses for this treatment totaled 32 kg inorganic-N ha⁻¹. The authors concluded that inorganic N leaching losses from appropriate home lawn care practices would not contribute to ground water contamination, but that care should be used when fertilizing lawns in coastal watersheds.

Easton and Petrovic (2004) reported greater NO₃-N leaching losses from a mixture of Kentucky bluegrass and perennial ryegrass (*Lolium perenne* L.) treated with soluble urea than from an untreated control. Leaching losses were highest in the first year following turf establishment. The authors concluded that the potential for increased NO₃-N leaching is greatest during establishment, but that the faster establishment time in turf that received fertilization during the first year reduced subsequent losses of N and phosphorus compared to unfertilized control plots.

Erickson et al. (2001) observed less NO₃-N leaching (4.1 kg N ha⁻¹ annually) in the first year following establishment from sodded Floratam St. Augustinegrass than from a mixed-species landscape planting (48.3 kg N ha⁻¹ annually). Reporting on the long-term N leaching on this project (Erickson et al., 2008), the authors observed that both turf and mixed-species landscape plantings leached less than 2% of the applied N as inorganic-N over time. The decrease in leaching from the mixed-species landscape plantings was attributed to increased root mass over time and the cessation of fertilizer treatments applied to the mature mixed-species landscape plantings.

Bowman et al. (2002) observed a 92% reduction in NO₃-N leaching from St. Augustinegrass from a second treatment application as compared to the first treatment in a greenhouse study. Nitrogen was applied as ammonium nitrate at a rate of 50 kg N ha⁻¹ on both treatment dates. The authors attributed the reduction in NO₃-N leaching following the second treatment application to development of a more extensive root system as the grasses matured, a larger microbial population to increase N immobilization, and less water percolation through the columns. Over the course of the study, lower cumulative levels of NO₃-N and a lower percentage of applied

N leached from 'Raleigh' St. Augustinegrass than from five other species of warm-season grasses. Similarly, Bowman et al. (1998) attributed lower $\text{NO}_3\text{-N}$ leaching from two creeping bentgrass (*Agrostis palustris* Huds.) genotypes to production of a deeper root system and they concluded that management strategies to enhance rooting may reduce $\text{NO}_3\text{-N}$ leaching.

Current N fertilization recommendations for maintenance of St. Augustinegrass (Trenholm et al., 2011) and zoysiagrass (Unruh et al., 2011) in Florida include a range of rates from 98 to 294 kg N ha⁻¹ annually, depending upon geographical region of the state and aesthetic preference. Trenholm and Unruh (2007) observed best turf quality and color from application of 200 or 350 kg N ha⁻¹ to St. Augustinegrass. The authors noted that zoysiagrass could be maintained with 147 kg N ha⁻¹ in central Florida (Trenholm and Unruh, 2009). Dunn et al. (1995) reported that a maximum rate of 98 kg N ha⁻¹ annually was sufficient for 'Meyer' zoysiagrass maintenance, but noted that more N may be necessary where sandy soils predominated.

Given that Florida currently has regulations at both state and local levels regarding fertilization of lawngrasses and due to a lack of $\text{NO}_3\text{-N}$ leaching data on St. Augustinegrass and zoysiagrass, this research was undertaken as part of a larger project to obtain specific information for Best Management Practices (BMP) verification on $\text{NO}_3\text{-N}$ leaching as a result of lawngrass fertilization. The objectives of this research were to evaluate total $\text{NO}_3\text{-N}$ leaching and turf response from a wide range of NRs and from two different irrigation regimes in established Floratam St. Augustinegrass and 'Empire' zoysiagrass.

Materials and Methods

This research was conducted at the G.C. Horn Turfgrass Field Laboratory at the University of Florida Plant Science Research and Education Unit in Citra, FL. Soil type was a Tavares sand (Hyperthermic Uncoated Typic Quartzipsamments), with a pH of 6.8 and an organic matter content of less than 4%.

Plots measured 4.0m x 4.0m. High-density polyethylene (HDPE) drainage lysimeters were installed in the center of each plot, with the top approximately 10 cm below the soil surface. Lysimeters measured 57 cm diam. and 88 cm in height with a volume of 168 L. Lysimeters were assembled by placing HDPE cylinders into a single piece galvanized steel base unit measuring 25.4 cm in height. A bulkhead fitting was inserted into the base of each unit, to which collection tubing (0.95 cm low density polyethylene) was attached. The tubing was run underground to central aboveground collection portals. Lysimeters were installed by boring and removing soil in 15.2 cm sections to a depth of 107 cm. Lysimeters were placed in holes and 38 L of washed egg rock (1.9 – 6.4 cm) were placed in the bottom of each lysimeter. The gravel was covered with fitted non-woven polyolefin cloth that was secured with a hoop of 1.3 cm HDPE tubing to reduce soil intrusion into the reservoir. Soil was replaced into the lysimeters as it had been removed from the soil profile. Soil was gently tamped with a tamping tool (17 kg and 858 cm²) to approximate original soil bulk density. Empire zoysiagrass and Floratam St. Augustinegrass were sodded in late June 2005. Grasses received an initial fertilization with 24.5 kg N ha⁻¹ on 24 June 2005. Irrigation was provided as needed to prevent wilt during establishment.

Nitrogen rate treatments were applied on 22 July and 20 Sept. 2005, 3 Apr., 6 June, 1 Aug., and 30 Sept. 2006, 2 Apr., 31 May, 8 Aug., and 3 Oct. 2007 as 46-0-0 urea. The urea was dissolved in water and applied through a backpack sprayer to uniformly cover each plot with a rate of 0.12 L m⁻². Treatments were irrigated in with 0.6 cm of water after application. In 2005, research was conducted over an approximately 4-mo growing period with annual application rates of 32, 64, 128, and 196 kg N ha⁻¹. In the subsequent 2 yrs, the research timing was representative of a typical north central FL growing season of approximately 7-mo. The rates for 2006 and 2007 were modified to reflect the longer growing season and to obtain information on a higher range of N application, resulting in annual application rates of 49, 196, 343, or 490 kg N ha⁻¹ applied in approximately 60-d intervals. These rates were applied at the request of the funding agency to provide information on $\text{NO}_3\text{-N}$ fate if a homeowner were to greatly exceed recommended NRs. Results are reported as annual $\text{NO}_3\text{-N}$ mass flux and

for each 60-day fertilizer cycle between treatment applications. The fertilizer cycles are defined as Spring Fertilizer Cycle (SFC), Early Summer Fertilizer Cycle (ESFC), Late Summer Fertilizer Cycle (LSFC), and Fall Fertilizer Cycle (FFC). Irrigation treatments consisted of 1.3 cm applied twice weekly (IR1) or 2.6 cm applied once weekly (IR2). These rates were chosen to simulate typical watering restrictions enacted in parts of Florida. When rainfall met or exceeded these amounts, irrigation was suspended.

Turf was mowed weekly at a height of 8.9 cm with clippings returned. Pesticides were applied as needed based on visual identification of a pest. Chlorothalonil (2,4,5,6-tetrachloroisophthalonitrile) fungicide was applied to zoysiagrass plots on 15 May 2007 for control of Zoysia patch disease (*Rhizoctonia* spp.). Potassium (K) was applied three times annually throughout the growing season at 49 kg K ha⁻¹ each application.

Leachate samples were collected twice weekly throughout the growing season, beginning the day after first treatment application. Samples were collected by applying a vacuum to the collection tubing and withdrawing percolate from the reservoir of the lysimeter until dry. To prevent a perched water table from forming, lysimeters were evacuated more than twice weekly if heavy rain events (> 2.5 cm) occurred. The large surface area of the lysimeters minimized preferential flow within lysimeters. Volume was measured by collecting leachate into a graduated cylinder as lysimeters were emptied. Twenty-ml aliquots of the leachate were transferred to collection vials and placed on ice in the field and then frozen at 0° C until NO₃-N analysis was done. Nitrate concentration was measured using a continuous segmented flow analyzer (AutoAnalyzer 3, Seal Analytical, Mequon, WI) at the University of Florida Analytical Research Laboratory in Gainesville. Leachate volumes were also measured for each plot. Concentrations that were lower than the minimum detection limit (MDL) of 0.05 mg L⁻¹ were corrected to the MDL value.

Turf quality (TQ) was assessed biweekly over the growing season on a scale of 1 to 9, where 1 = dead, brown turf and 9 = optimal healthy, green turf. A score of 6 was considered a minimally acceptable score for a home lawn. When disease damage occurred, TQ was assessed from the non-diseased portion of the plot. Spring green-up was assessed in 2006 and 2007 as a measurement of the percentage of the plot that had live green grass following winter dormancy.

Weather data were collected for the months in which research was conducted from an onsite weather network system (<http://fawn.ifas.ufl.edu>), which provides meteorological information in 15-min intervals.

Experimental design was a split-split plot design, where irrigation treatments were main plots and grasses were sub plots. Nitrogen rates were randomized within grasses as sub-sub plots. There were 4 replications. Proc ANOVA (SAS Institute, 2003) was used to analyze data and means were separated with the Waller Duncan *k*-ratio *t*-test. Differences were determined at the 0.05 significance level. Due to differences in data between years, results are presented by year. Leachate data were found to be normally distributed and were adjusted for outliers that exceeded plus or minus two standard deviations.

Results

Precipitation

Actual monthly rainfall and historical averages for the growing seasons during the study period are shown in Fig. 1. Monthly rainfall for all years of the study was generally below historical averages; rainfall on an annual basis over the months comprising the study period was 19 and 17% below average for 2006 and 2007, respectively. However, there were months (Aug and Oct 2005, July 2006, and Oct 2007) when rainfall exceeded historical averages and some dates where daily rainfall events exceeded 25 mm. For example, in 2006, there were 5 daily rainfall events during LSFC that exceeded 25 mm.

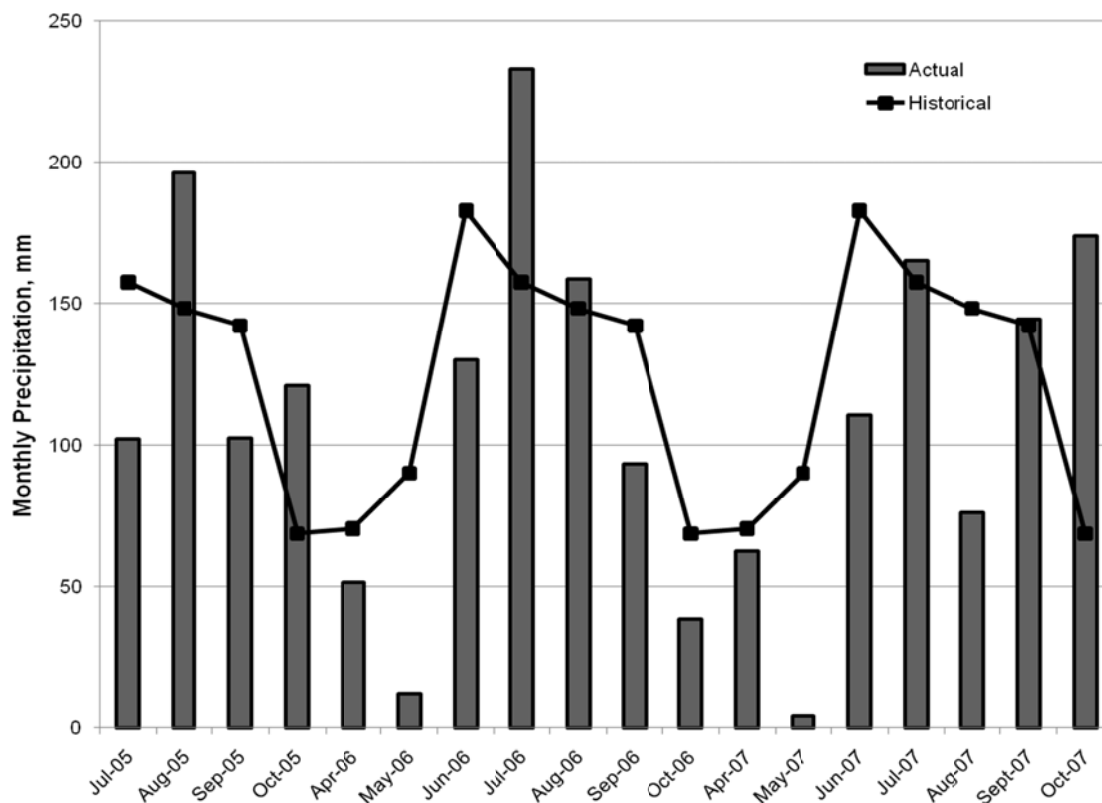


Fig. 33. Monthly precipitation for the months in which research was conducted over the 3-yr study period in Citra, FL.

NO₃-N Leaching

In 2005, NO₃-N mass flux did not differ in response to main effects or interactions (Table 1). In 2006, there were differences from the interaction of NR × grass in the ESFC and the FFC and the interaction of NR × IR in the FFC and for total annual flux (Table 1). In 2006, each fertilizer cycle and annual flux had differences in response to the main effect of grass, regardless of interactions (Table 2). In St. Augustinegrass, only the LSFC had differences from NR, while in zoysiagrass, there was a trend towards higher NO₃-N leaching at the highest NR, particularly in the FFC and for annual leaching. In the FFC of 2006, NO₃-N mass flux increased under both IRs as NR increased; however, there were no differences in leaching within NR in response to IR (Table 3). Annual NO₃-N loading was not affected by NR under IR1, while NO₃-N loading increased with NR under IR2. As with the FFC, IR did not affect NO₃-N within NR. Averaged over all other treatments, annual NO₃-N

flux from St. Augustinegrass in 2006 was 1.4 kg N ha⁻¹, compared to 10.1 kg N ha⁻¹ from zoysiagrass (data not shown).

Table 94. Analysis of variance (ANOVA) for NO₃-N leached and turf quality in response to nitrogen rate (NR) and irrigation regime (IR) of established Floratam St. Augustinegrass and Empire zoysiagrass from 2005 to 2007 in Citra, FL.

Source of variation	Nitrate-N leached					Turf quality†				
	SFC ‡	ESF C	LSF C	FF C	Annua l	SFC C	ESF C	LSF C	FFC	Average
<u>2005</u>										
Nitrogen rate (NR)	NA§	NA	NS¶	NS	NS	NA	NA	***	NS	**
Grass (G)	NA	NA	NS	NS	NS	NA	NA	***	NS	***
Irrigation (IR)	NA	NA	NS	NS	NS	NA	NA	NS	NS	NS
NR×G	NA	NA	NS	NS	NS	NA	NA	**	***	***
NR×IR	NA	NA	NS	NS	NS	NA	NA	NS	NS	NS
G×IR	NA	NA	NS	NS	NS	NA	NA	NS	NS	NS
NR×G×IR	NA	NA	NS	NS	NS	NA	NA	NS	NS	NS
<u>2006</u>										
NR	NS	**	NS	*	**	***	***	***	***	***
G	**	***	***	*	***	NS	*	NS	NS	NS
IR	**	NS	NS	NS	NS	*	NS	NS	NS	*
NR×G	NS	*	NS	***	NS	***	***	***	***	***
NR×IR	NS	NS	NS	***	*	***	***	***	NS	***
G×IR	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
NR×G×IR	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
<u>2007</u>										
NR	*	***	**	**	***	**	***	**	**	**
G	**	***	***	**	***	*	NS	NS	NS	NS
IR	NS	*	**	NS	*	NS	NS	NS	NS	NS
NR×G	***	***	*	*	***	***	***	***	***	***
NR×IR	***	NS	NS	NS	***	***	***	***	***	***
G×IR	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
NR×G×IR	NS	NS	*	NS	*	NS	NS	NS	NS	NS

†Turf quality based on a scale from 1-9, where 1 = dead, brown turf and 9 = optimal healthy, green turf. A score of 6 was considered a minimally acceptable score for a home lawn.

‡ SFC = Spring Fertilizer Cycle, ESFC = Early Summer Fertilizer Cycle, LSFC = Late Summer Fertilizer Cycle, FFC= Fall Fertilizer Cycle

§ NA = Not applicable. Research began with LSFC in 2005.

¶ NS = Not significant at the 0.05 probability level.

*, **, *** Significant at the 0.05, 0.01, and 0.001 probability levels, respectively.

There was an interaction of NR × grass × IR in the LSFC and for annual NO₃-N mass flux in 2007 (Table 1). There were no differences in St. Augustinegrass in annual NO₃-N load in response to NR under IR1, while loading was greatest at the highest NR under IR2 (Table 4). There were no differences in NO₃-N loading within NR as influenced by IR. Zoysiagrass had greater annual NO₃-N mass flux under IR1 as NR increased and from the two highest NRs under IR2. Analyzed within NRs, greatest loading occurred from zoysiagrass under

IR1 at both 196 and 490 kg N ha⁻¹, with no differences at 49 and 343 kg N ha⁻¹ from IR. In 2007, zoysiagrass was more sensitive to NO₃-N loading under the less frequent but higher volume IR2 for annual leaching. Nitrate N losses from zoysiagrass decreased from 157.9 to 7.1 kg ha⁻¹ NO₃-N under IR1, a decrease of 96% as NR decreased from 490 to 49 kg N ha⁻¹. The percentage decrease under IR2 was 95%, with means of 90.1 to 4.4 kg N ha⁻¹ as NR decreased.

Irrigation at the rates and timings tested had limited effect on NO₃-N loading results, particularly in St. Augustinegrass, with some tendency for greater NO₃-N loss from zoysiagrass at the more frequent IR1 in 2007. The irrigation rates employed in this study (2.54 cm wk⁻¹) were generally equivalent to or slightly less than the ET₀. Consequently, percolate was not excessive and the percent of applied N leached was generally ≤ 1% of the applied amount to St. Augustinegrass. It is likely that greater response to irrigation might be seen in both species if a wider range of scheduling and rates were tested; especially if irrigation rates significant exceeded ET, thereby resulting in greater percolate volume.

Table 95. Nitrate-N leached from established Floratam St. Augustinegrass and Empire zoysiagrass in response to nitrogen rate (NR) in 2006 and 2007 in Citra, FL.

Annual nitrogen rate ---kg ha ⁻¹ ---	Nitrate-N leached									
	St. Augustinegrass					Zoysiagrass				
	SFC †	ESFC	LSFC	FFC	Annual	SFC	ESFC	LSFC	FFC	Annual
-----kg ha ⁻¹ -----										
2006										
490	2.3 a‡	1.6 a	0.3 a	1.1 a	5.3 a	7.3 a	6.0 a	10.1	5.7 a	29.1 a
343	1.9 a	0.3 a	0.1 c	0.6 a	2.9 a	2.9 a	1.4 b	5.7	3.6 b	13.7 b
196	0.3 a	0.3 a	0.2 b	0.2 a	0.9 a	6.7 a	1.4 b	7.6	1.0 c	16.7 b
49	0.3 a	0.2 a	0.2 b	0.1a	0.9 a	6.5 a	2.2 ab	3.7	0.3 d	12.7 b
2007										
490	0.2 a	0.6 c	0.3 a	8.0 a	9.1 a	29.1 a	75.8 a	7.0 a	12.5 b	124.3 a
343	0.3 a	1.0 a	0.2 b	0.6 b	2.1 b	22.3 b	40.3 b	4.0 ab	17.9 a	84.5 b
196	0.2 a	0.8 b	0.3 b	1.6 b	2.9 b	6.4 c	17.2 c	0.6 b	6.2 bc	30.5 c
49	0.1 a	0.3 d	0.2 b	0.4 b	1.1 b	1.9 d	2.4 d	0.4 b	1.0 c	5.7 d

† SFC = Spring Fertilizer Cycle, ESFC = Early Summer Fertilizer Cycle, LSFC = Late Summer Fertilizer Cycle, FFC= Fall Fertilizer Cycle

‡ Values within a column by year followed by the same letter do not differ at $P = 0.05$

Table 96. Nitrate–N leached in response to the interaction of nitrogen rate (NR) and irrigation regime (IR) in established Floratam St. Augustinegrass and Empire zoysiagrass in Fertilizer Cycle 4 and for the growing season in 2006 in Citra, FL.

Annual nitrogen rate -----kg N ha ⁻¹ -----	Nitrate-N leached		
	Fall Fertilizer Cycle		
	-----kg N ha ⁻¹ -----		
	IR1†	IR2	P Value
490	1.4 a ‡	5.4 a	NS §
343	1.0 b	3.1 b	NS
196	0.7 c	0.5 c	NS
49	0.2 d	0.3 d	NS
	Annual Load		
490	19.3 a	15.2 a	NS
343	7.4 b	9.2 b	NS
196	14.0 ab	3.6 c	NS
49	11.8 ab	1.8 d	NS

† IR1 = Irrigation regime 1, twice weekly at 1.3 cm. IR2 = Irrigation regime 2, weekly at 2.6 cm.

‡ Values within a column for a cycle followed by the same letter do not differ at $P = 0.05$

§ NS = Not significant within a row at $P = 0.05$.

Table 97. Annual nitrate–N leached in response to the interaction of grass, nitrogen rate (NR) and irrigation regime (IR) in established Floratam St. Augustinegrass and Empire zoysiagrass in 2007 in Citra, FL.

Annual nitrogen rate ----- kg N ha ⁻¹ -----	Nitrate-N leached		
	IR1†	IR2	P Value
	----- kg N ha ⁻¹ -----		
	St. Augustinegrass		
490	7.2 a	6.4 a ‡	NS §
343	1.4 a	0.5 b	NS
196	1.1 a	4.1 b	NS
49	1.1 a	1.6 b	NS
	Zoysiagrass		
490	157.9 a	90.1 a	*
343	99.8 b	69.1 a	NS
196	50.3 c	10.7 b	*
49	7.1 d	4.4 b	NS

† IR1 = Irrigation twice weekly at 1.3 cm. IR2 = Irrigation weekly at 2.6 cm.

‡ Values within a column for a grass followed by the same letter do not differ at $P = 0.05$

§ NS, = Not significant

* Significant at the 0.05 probability level within a row

Concentration of NO₃–N in percolate ranged from 0.05 to 0.86 mg L⁻¹ from St. Augustinegrass for 2006 and 2007 (Table 5), well below the EPA drinking water standards of 10 mg L⁻¹ regardless of N rate. Zoysiagrass concentrations were below EPA standards in 2006, ranging from 1.11 to 8.72 and from 0.45 to 23.57 mg L⁻¹ in 2007.

Table 98. Means of NO₃-N concentration in percolate for 2006 and 2007 from established Floratam St. Augustinegrass and Empire Zoysiagrass in Citra, FL.

Annual nitrogen rate ----kg ha ⁻¹ ----	Nitrate-N leached			
	<u>2006</u>		<u>2007</u>	
	St. Augustinegrass	Zoysiagrass	St. Augustinegrass	Zoysiagrass
	-----mg L ⁻¹ -----			
490	0.86 a†	0.80 a	8.72 a	23.57 a
343	0.21 a	0.17 b	2.25 b	10.83 b
196	0.07 a	0.21 b	1.79 b	3.55 c
49	0.05 a	0.08 b	1.11 b	0.45 d
<u>ANOVA</u>	<u>2006</u>		<u>2007</u>	
Nitrogen rate	***		***	
(NR)				
Grass (G)	***		***	
Irrigation (IR)	NS ‡		**	
NR×G	**		***	
NR×IR	NS		***	
G×IR	NS		**	
NR×G×IR	NS		**	

† Values within a column followed by the same letter do not differ at $P = 0.05$

‡ NS = Not significant within a row at $P = 0.05$.

, * Significant at the 0.01, and 0.001 probability levels, respectively.

Correlation analysis of spring green-up with NO₃-N leached during the SFC and the ESFC for 2007 indicated that there were no significant associations in St. Augustinegrass between spring green-up and NO₃-N leached (Table 6). This was logical, since green up occurred rapidly in this species. Zoysiagrass had significant correlations with NO₃-N leached in both the SFC and the ESFC for each of the green-up rating dates in 2007. Zoysiagrass treated with the higher NRs had less live green tissue during the early growing season in 2007 due to increased presence of Large Patch (*Rhizoctonia solani* J.G. Kuhn), resulting in greater NO₃-N leached. Turf recovery began following fungicide treatment in mid-May and, by the LSFC, grass growth had resumed with improved cover of plots and NO₃-N leaching levels were reduced. This illustrates the importance of a healthy turfgrass cover and the cultural practices that sustain cover in reducing potential nutrient leaching.

Table 99. Correlation coefficients (r) and probability values (P) for NO₃-N leached vs. spring green up in spring and early summer fertilizer cycles in 2007 for Floratam St. Augustinegrass and Empire Zoysiagrass in Citra, FL.

Nitrate-N leached	Percent spring green up rating date				
	22 Mar	12 Apr	26 Apr	17 May	31 May
<u>St. Augustinegrass</u>					
Spring Fertilizer Cycle†	0.01	-0.02	-0.04	-0.04	-0.02
	P =	P =	P =	P =	P =
	0.9735	0.9060	0.8224	0.8251	0.9273
Early Summer Fertilizer Cycle	0.01	0.02	0.00	-0.02	-0.03
	P =	P =	P =	P =	P =
	0.9471	0.9131	0.9798	0.9197	0.8746
<u>Zoysiagrass</u>					
Spring Fertilizer Cycle	-0.33	-0.65	-0.65	-0.78	-0.76
	P =	P =	P =	P =	P =
	0.0653	0.0001	0.0001	0.0001	0.0001
Early Summer Fertilizer Cycle	-0.35	-0.58	-0.61	-0.72	-0.69
	P =	P =	P =	P =	P =
	0.0494	0.0004	0.0002	0.0001	0.0001

† SFC = Spring Fertilizer Cycle, ESFC = Early Summer Fertilizer Cycle.

There are varying reports of NO₃-N leaching from various turf species in response to increasing NR in the literature. For example, similar to results of St. Augustinegrass reported here, Easton and Petrovic (2004) found no differences in NO₃-N leaching due to NR in cool season grasses in the second yr of a 2-yr study when N was applied from numerous sources at either 50 or 100 kg N ha⁻¹. In contrast, ‘Tifdwarf’ bermudagrass (*Cynodon dactylon* L. Pers x *C. transvaalensis* Burt-Davy) putting greens lost 9.1 to 15.2 kg NO₃-N ha⁻¹ as NRs increased from 24 to 98 kg applied N ha⁻¹, respectively, when N was applied as ammonium sulfate (Brown et al., 1977). Frank et al. (2006) reported higher total NO₃-N losses when N was applied at annual rates of 245 compared to 98 kg N ha⁻¹ in Kentucky bluegrass.

Other reports have contrasted NO₃-N leaching between turf species and with other plant species used in the landscape. Erickson et al. (2001) reported annual inorganic-N loss of 4.1 kg ha⁻¹ from St. Augustinegrass as compared to 48.3 kg ha⁻¹ from a mixed species landscape in the first year of the study. The authors concluded that St. Augustinegrass was a more effective filter for leachate reduction than a mixed landscape planting. Lowest NO₃-N leaching was reported from St. Augustinegrass when compared to other warm-season turfgrass species (Bowman et al. 2002). The authors attributed the reduced loading in St. Augustinegrass to the significantly greater root length density (RLD) in this species at soil depths > 30 cm.

Increased NO₃-N leaching from zoysiagrass in response to NR and irrigation is consistent with numerous reports of NO₃-N leaching in many turf species. Bowman et al. (2002) reported that ‘Meyer’ zoysiagrass was the least efficient of six warm-season turfgrasses at reducing N leaching and that St. Augustinegrass was the most efficient. In a mixed stand of Kentucky bluegrass and red fescue, Morton et al. (1988) reported higher inorganic N concentrations in percolate when irrigation was applied at a rate of 3.75 cm wk⁻¹ (excessive irrigation) than when applied on a tensiometer based irrigation schedule. Similarly, Snyder et al. (1984) reported less NO₃-N leached from bermudagrass that received sensor-based irrigation treatments than from plots receiving a daily irrigation regime. Brown et al. (1977) reported that NO₃-N losses were minimized when irrigation was matched with evapotranspiration (ET). Starrett et al. (1995) reported 30 times greater N in leachate from the columns that received heavy irrigation following fertilization treatment compared to a lighter more frequent irrigation following fertilizer treatment.

Turf Quality

Turf quality scores varied in all years from the interaction of NR $\times$ grass and NR $\times$ IR in 2006 and 2007 (Table 2). In St. Augustinegrass, the 3 highest NRs provided acceptable TQ in all fertilizer cycles, with the exception of turf that received ≤ 196 kg N ha⁻¹ in SFC of 2006 (Table 7). The lowest NR provided adequate TQ only in ESFC of 2007.

Zoysiagrass quality followed a different trend, with acceptable TQ at all NRs in 2006 except for the lowest and highest rates in FFC of 2006 and at the two highest rates in SFC of 2007 (Table 7). In SFC of 2007, the plots receiving the highest NRs had greater incidence of large patch disease as previously discussed. Plots at the lower NRs were not as severely affected. All of the plots maintained good TQ following fungicide application for the remainder of the year. Zoysiagrass had few differences in TQ in response to NR in 2007, other than in LSFC, when highest quality was reported from application of N at 196 kg ha⁻¹, with lower TQ in plots receiving higher NRs. Previous research (Trenholm and Unruh 2009), also indicates that zoysiagrass can maintain sufficient TO at lower NRs.

Table 100. Average turf quality of established Floratam St. Augustinegrass and Empire Zoysiagrass in response to nitrogen rate by fertilizer cycle n 2006, and 2007 in Citra, FL.

Annual Nitrogen Rate ----kg ha ⁻¹ - ---	Turf quality†									
	St. Augustinegrass					Zoysiagrass				
	SFC ‡	ESF C	LSF C	FFC	Average	SFC ‡	ESFC	LSFC	FFC	Average
	<u>2006</u>									
490	6.7 a §	9.0 a	7.8 a	7.3 a	7.2 a	6.5 a	8.7 a	7.2 a	5.8 d	6.7 b
343	6.5 b	8.5 b	7.4 b	6.9 b	6.9 b	6.4 b	8.6 b	7.1 b	6.3 b	6.8 a
196	5.8 c	7.4 c	6.6 c	6.2 c	6.1 c	6.4 c	8.5 c	7.0 c	6.4 a	6.6 c
49	4.6 d	5.4 d	5.0 d	4.1 d	4.5 d	6.2 d	8.0 d	6.8 d	5.9 c	6.3 d
	<u>2007</u>									
490	7.4 a	9.8 a	7.7 a	7.3 a	7.5 a	4.9 b	8.0 a	7.0 b	6.7 a	6.2 a
343	7.0 b	9.5 b	7.6 b	7.1 b	7.3 b	5.5 ab	8.4 a	6.9 c	6.4 a	6.4 a
196	6.2 c	8.5 c	6.8 c	6.5 c	6.6 c	6.0 a	8.6 a	7.1 a	6.5 a	6.6 a
49	4.2 d	6.6 d	5.4 d	4.8 d	4.9 d	6.4 a	8.6 a	6.8 d	6.4 a	6.6 a

† Turf quality was based on a scale of 1 to 9, where 1 = dead, brown turf and 9 = optimal healthy, green turf. A score of 6 was considered minimally acceptable for a home lawn.

‡ SFC = Spring Fertilizer Cycle, ESFC = Early Summer Fertilizer Cycle, LSFC = Late Summer Fertilizer Cycle, FFC= Fall Fertilizer Cycle

§ Values within a column followed by the same letter do not differ at $P = 0.05$

Conclusions

These results suggest that actively growing, healthy turfgrass mitigates NO₃-N leaching from fertilization events. Maintenance of a healthy turfgrass cover is critical to reducing NO₃-N leaching, and therefore all turf management practices can be important best management strategies for reducing NO₃-N leaching. St.

Augustinegrass leaching had little association with NR, even when N was applied at the very high rates imposed here. Over the duration of the study, St. Augustinegrass quality was above acceptable at N rates of $\geq 196 \text{ kg ha}^{-1} \text{ yr}^{-1}$. Zoysiagrass showed greater potential for increased $\text{NO}_3\text{-N}$ leaching when turfgrass was damaged from disease and cover was lacking. However, as demonstrated in previous research (Dunn et al., 1995; Trenholm and Unruh, 2009) as well as the current research, zoysiagrass requirements for N are less than those of St. Augustinegrass. Acceptable TQ scores were maintained at $\leq 196 \text{ kg N ha}^{-1}$ annually, at which rates potential $\text{NO}_3\text{-N}$ losses were reduced. These results suggest that N recommendations for maintenance of Empire zoysiagrass in central and north Florida may need to be revised downward, since quality can be maintained at lower N levels, disease incidence is reduced, and potential leaching could be minimized. While it is outside of the scope of this research to determine if impairment of ground or surface waters will result from application of the currently recommended N rates, this research indicates that these rates will produce minimal $\text{NO}_3\text{-N}$ leaching, particularly from St. Augustinegrass. Further research is needed to determine the impacts of runoff from lawn fertilizers.

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PROJECT: NITRATE LEACHING AND TURF QUALITY IN ESTABLISHED ST. AUGUSTINEGRASS AND ZOYSIAGRASS DUE TO N SOURCE

Introduction

Current university recommendations, state regulations and numerous local ordinances pertaining to turfgrass fertilization favor use of slow-release N sources or mandate use of lower rates of water soluble N sources. There are varying results of actual NO₃-N loading due to N source in the scientific literature, with the majority of the research having been done on cool-season grasses.

Easton and Petrovic (2004) reported greater NO₃-N leaching losses from a mixture of Kentucky bluegrass (*Poa pratensis* L.) and perennial ryegrass (*Lolium perenne* L.) treated with soluble urea than from an untreated control. The authors concluded that greater uptake from soluble vs. natural organic N sources may mitigate the greater potential for increased NO₃-N loading from soluble sources. Wu et al. (2010) reported greater NO₃-N loading from tall fescue [*Schedonorus phoenix* (Scop.) Holub] when soluble N sources were applied at high rates, with minimal differences between sources when applied at lower rates. The authors concluded that a good quality lawn could be maintained at the lower application rate of 195 kg N ha⁻¹ with minimal threat to groundwater quality from N loading. Guillard and Kopp (2004), working in a cool-season mixture of grasses typically used for home lawns in the NE, concluded that slow-release formulations could potentially reduce NO₃-N leaching losses, but that results were also influenced by season, with greater loading occurring from late fall through early spring.

In a greenhouse study, creeping bentgrass (*Agrostis palustris* L.) grown in an 80% sand mixture had higher NO₃-N percolate concentration from soluble sources (Mancino and Troll, 1990). The authors noted, however, that all NO₃-N levels were low, regardless of N source. Petrovic (2004) noted higher NO₃-N loading in Kentucky bluegrass from water soluble N sources. The author also noted the influence of rainfall on the results.

In bermudagrass, Snyder et al. (1984) observed greater NO₃-N loading from plots that received a soluble N source compared to those that received a sulfur coated urea. Brown et al. (1982) observed greater leaching losses from overseeded bermudagrass on a sand green from soluble N sources and concluded that use of organic sources could be a strategy to minimize N loss on a sand-based green.

This research was undertaken to determine the effects of N source on NO₃-N loading and turf quality of Floratam St. Augustinegrass and Empire zoysiagrass.

Materials and Methods

Lysimeters were installed in 2004 as previously described and grasses were established as sod in the spring of 2005. Nitrogen source treatments began in July 2008 as granular applications. Treatments began mid-summer in 2008 to give the turf time to reach a uniform quality and color from a previous experiment on N rates; therefore only 2 treatment applications were applied in 2008. From 2009-2011, treatments were applied in 4 equal applications every 60 days throughout the growing season. Treatments were as follows:

1. Control
2. Ammonium nitrate @ 1 lb N 1,000 ft⁻²
3. Urea @ 1 lb N 1,000 ft⁻²
4. 30% sulfur coated urea @ 1 lb N 1,000 ft⁻²
5. 50% sulfur coated urea @ 1 lb N 1,000 ft⁻²
6. 32.8% polymer coated urea @ 1 lb N 1,000 ft⁻²

7. 32.8 polymer coated urea @ 2 lb N 1,000 ft⁻² every 120 days
8. Milorganite @ 1 lb N 1,000 ft⁻²

Leachate samples were collected weekly as previously described. Beginning in year 2, samples were collected year round, rather than just during the active study time. Turf was mowed as needed throughout the study period, typically an average of twice monthly. Mowing heights were 8.8 and 5 cm, respectively, for St. Augustinegrass and zoysiagrass. Clippings were returned to the ground.

Turf quality was assessed biweekly for visual quality and color over the growing season on a scale of 1 to 9, where 1 = dead or dormant brown turf and 9 = optimal healthy, green turf. In years where disease was prominent on zoysiagrass plots, color scores were assessed from the green portion of the plot only. A score of 6 was considered a minimally acceptable score for a home lawn. Weather data were collected from an onsite weather network system (<http://fawn.ifas.ufl.edu>), which provides meteorological information in 15-min intervals.

Shoot harvests were collected throughout the growing season in each year with a walk-behind mower. Shoot tissue was dried and weighed. Data are presented as g of shoot tissue m⁻².

Results

Nitrate-N Loading

Two fertilizer cycles were run in 2008, from July-Oct. For the July-Aug cycle and for the cumulative total, there was a significant interaction of grass and N source. Where these differences occurred, St. Augustinegrass had no differences due to N source, while zoysiagrass loading was greatest from ammonium nitrate. For July and August only, loading was greater from zoysiagrass than from St. Augustinegrass. Mass flux was less than 1% of the applied N in year 1.

Table 101. Analysis of variance (ANOVA) and means for NO₃-N leaching in response to N source in established Floratam St. Augustinegrass and Empire zoysiagrass in 2008 in Citra, FL.

		FC3	FC4	Annual Total	Percent of Applied N
Grass	Treatment	NO ₃ -N leached (kg ha ⁻¹)			
	Ammonium Nitrate	0.7 a†	0.1	0.8 a	0.8 a
	Urea	0.3 b	0.1	0.4 b	0.4 b
	30% SRN	0.3 b	0.1	0.4 b	0.4 b
	50% SRN	0.2 b	0.1	0.3 b	0.3 b
	PCU @ 49 kg ha ⁻¹ every 60 days	0.2 b	0.1	0.3 b	0.3 b
	PCU @ 98 kg ha ⁻¹ every 120 days	0.2 b	0.1	0.3 b	0.3 b
	Milorganite	0.3 b	0.1	0.3 b	0.3 b
	Control	0.2 b	0.1	0.3 b	NA
St. Augustinegrass	Ammonium Nitrate	0.3	0.1	0.4	0.4
	Urea	0.2	0.1	0.3	0.3
	30% SRN	0.2	0.1	0.3	0.3
	50% SRN	0.2	0.1	0.3	0.3
	PCU @ 49 kg ha ⁻¹ every 60 days	0.3	0.1	0.4	0.4
	PCU @ 98 kg ha ⁻¹ every 120 days	0.2	0.1	0.3	0.3
	Milorganite	0.2	0.1	0.3	0.3
	Control	0.2	0.1	0.3	NA
Zoysiagrass	Ammonium Nitrate	1.2 a	0.1	1.3 a	1.3 a
	Urea	0.3 b	0.1	0.4 b	0.4 b
	30% SRN	0.3 b	0.1	0.4 b	0.5 b
	50% SRN	0.3 b	0.1	0.4 b	0.4 b
	PCU @ 49 kg ha ⁻¹ every 60 days	0.2 b	0.1	0.3 b	0.3 b
	PCU @ 98 kg ha ⁻¹ every 120 days	0.2 b	0.1	0.3 b	0.3 b
	Milorganite	0.2 b	0.1	0.3 b	0.3 b
	Control	0.3 b	0.1	0.4 b	NA
ANOVA					
	Grass	*	NS	NS	NS
	N	***	NS	***	***
	Grass*N	***	NS	***	***

*, *** Significant at the 0.05 and 0.001 probability levels, respectively.

NS Not significant at the 0.05 probability level.

† Within columns, means followed by different letters differ significantly at $P = 0.05$.

In 2009, there were no differences in NO₃-N loading for any cycle or cumulative total, except for during the winter cycle, where there was a grass and N source interaction. For this period, loading from ammonium nitrate in zoysiagrass was greater than from other N sources, with no differences due to N source in St. Augustinegrass. Mass flux again was 1% or less of the applied N.

Table 102. Analysis of variance (ANOVA) and means for NO₃-N leaching in response to N source in established Floratam St. Augustinegrass and Empire zoysiagrass in 2009 in Citra, FL.

Treatment	Winter †	FC1	FC2	FC3	FC4	Annual Total	Percent of Applied N
	NO ₃ -N leached (kg ha ⁻¹)						
Ammonium Nitrate	0.8 a†	0.2	0.3	0.2	0.4	1.9	1.0
Urea	0.3 b	0.2	0.2	0.2	0.3	1.3	0.7
30% SRN	0.4 b	0.2	0.2	0.3	0.4	1.5	0.8
50% SRN	0.3 b	0.2	0.2	0.3	0.4	1.3	0.7
PCU @ 49 kg ha ⁻¹ every 60 days	0.3 b	0.2	0.2	0.2	0.4	1.2	0.6
PCU @ 98 kg ha ⁻¹ every 120 days	0.3 b	0.2	0.3	0.3	0.7	1.8	0.9
Milorganite	0.3 b	0.3	0.3	0.2	0.3	1.3	0.7
Control	0.3 b	0.1	0.2	0.2	0.3	1.2	NA
ANOVA							
Grass	NS	NS	NS	NS	NS	NS	NS
N	***	NS	NS	NS	NS	NS	NS
Grass*N	***	NS	NS	NS	NS	NS	NS

*** Significant at the 0.001 probability level

NS Not significant at the 0.05 probability level.

† Within columns, means followed by different letters differ significantly at $P = 0.05$.

2010 had no differences due to treatment or grass for any period. Mass flux ranged from 1.3 (PCU treatments) to 1.9% (urea) of the applied N.

Table 103. Analysis of variance (ANOVA) and means for NO₃-N leaching in response to N source in established Floratam St. Augustinegrass and Empire zoysiagrass in 2010 in Citra, FL.

Treatment	Winter †	FC1	FC2	FC3	FC4	Annual Total	Percent of Applied N
	NO ₃ -N leached (kg ha ⁻¹)						
Ammonium Nitrate	0.8	0.7	0.5	0.5	0.3	2.8	1.4
Urea	0.5	0.7	0.6	0.5	0.4	2.7	1.9
30% SRN	0.5	0.8	0.3	0.5	0.3	2.4	1.4
50% SRN	0.6	0.7	0.5	0.4	0.3	2.6	1.8
PCU @ 49 kg ha ⁻¹ every 60 days	0.7	0.5	0.7	0.5	0.4	2.9	1.3
PCU @ 98 kg ha ⁻¹ every 120 days	0.8	1.1	0.5	0.8	0.8	3.9	1.3
Milorganite	0.5	0.8	0.4	0.7	0.7	3.2	1.7
Control	0.5	0.5	0.3	0.5	0.3	2.2	NA
ANOVA							
Grass	NS	NS	NS	NS	NS	NS	NS
N	NS	NS	NS	NS	NS	NS	NS
Grass*N	NS	NS	NS	NS	NS	NS	NS

NS Not significant at the 0.05 probability level.

In 2011, there was an interaction of grass and N for FC2 (mid-June – mid-August). There were no differences in loading in St. Augustinegrass for that FC, while zoysiagrass had greater leaching from the polymer coated product applied at 2 lbs N per 1,000 ft⁻² every 120 days. There were also differences due to N source for FC1 and the annual total. In FC1, greater loading occurred from the application of the polymer coated product applied at 2 lbs N per 1,000 ft⁻² every 120 days. For the cumulative total, ammonium nitrate, milorganite and the polymer coated product applied at 2 lbs N per 1,000 ft⁻² ranked in the highest statistical category for nitrate-N loading. Application of the 2 lb rate of the polymer coated product resulted in greater annual loading than from urea, the sulfur coated sources and the same product applied at 1 lb N per 1,000 ft⁻². Ammonium nitrate, milorganite and the polymer coated product applied at 2 lbs N per 1,000 ft⁻² had significantly greater loading than the control plots.

There were no differences in percent of applied N leached due to treatment in 2011. Percent of applied N lost due to loading in St. Augustinegrass ranged from 0.7 (urea) to 6.0 (polymer sulfur coated at 2 lbs N 1,000 ft⁻² every 60 days) (data not shown). In zoysiagrass, percentages ranged from 6.8 (polymer sulfur coated at 1 lb N 1,000 ft⁻² every 30 days) to 18.9 (polymer sulfur coated at 2 lbs N 1,000 ft⁻² every 60 days). The higher percentages are attributable to increased zoysia patch in zoysiagrass, resulting in delayed spring green up, loss of stand and poor plot coverage.

Table 104. Analysis of variance (ANOVA) and means for NO₃-N leaching in response to N source in established Floratam St. Augustinegrass and Empire zoysiagrass in 2011 in Citra, FL.

Treatment	Winter †	FC1	FC2	FC3	FC4	Annual Total	Percent of Applied N
	NO ₃ -N leached (kg ha ⁻¹)						
Ammonium Nitrate	5.8 ab†	2.2 bc	0.4 b	1.2	4.8	14.4 ab	7.4 ab
Urea	3.6 bc	1.7 bc	1.4 b	2.1	1.8	10.6 bc	5.4 b
30% SRN	4.3 a-c	1.5 bc	1.3 b	0.8	1.1	8.9 bc	4.6 b
50% SRN	1.1 bc	1.3 bc	1.3 b	1.2	2.6	7.5 bc	3.8 b
PCU @ 49 kg ha ⁻¹ every 60 days	2.6 bc	1.4 bc	1.0 b	1.9	1.5	8.4 bc	4.3 b
PCU @ 98 kg ha ⁻¹ every 120 days	9.2 a	7.1 a	4.1 a	1.9	2.1	24.4 a	12.5 a
Milorganite	5.9 ab	3.2 b	1.6 b	3.8	2.8	17.2 ab	8.8 ab
Control	0.4 c	0.1 c	0.1 b	0.3	0.4	1.2 c	NA
ANOVA							
Grass	NS	NS	NS	NS	NS	NS	NS
N	NS	**	**	NS	NS	*	NS
Grass*N	NS	NS	*	NS	NS	NS	NS

*, ** Significant at the 0.05 and 0.01 probability levels, respectively

NS not significant at the 0.05 probability level.

† Within columns, means followed by different letters differ significantly at $P = 0.05$.

Some differences due to treatment rate occurred in zoysiagrass in 2011, with greater loading from the 2 lb N per 1,000 ft⁻² application of the polymer sulfur coated product. It should be noted that the zoysiagrass was not in a healthy condition on many of the plots in 2011 due to presence of zoysia patch, which resulted in reduced live turf in the spring and early summer and contributed to greater annual nitrate-N loading. In all 4 years of this research, application of 2 lbs per 1,000 ft⁻² of a polymer-sulfur coated product to healthy St. Augustinegrass did not cause greater nitrate-N loading than application at the 1 lb N per 1,000 ft⁻² rate. The higher application rate may be considered for these products and may be beneficial for maintaining healthy turf in those municipalities where summer N and P fertilization is banned.

Quality and Color Scores

In 2008, there were differences due to main effects of grass and N for both cycles and for seasonal averages. All quality scores were above the acceptable score of 6.0, except for the 50% sulfur coated plots and control plots in FC4. There were no differences in quality in treated plots in either cycle; however, when averaged over the season, quality was higher in plots that received 30% sulfur coated compared to 50% sulfur coated urea. Scores were higher in zoysiagrass in both cycles and for the seasonal total.

Table 105. Analysis of variance (ANOVA) and means for turf quality in response to N source in established Floratam St. Augustinegrass and Empire zoysiagrass in 2008 in Citra, FL.

	FC3	FC4	Average Quality
Treatment			
Ammonium Nitrate	6.3 a†	6.3 a	6.3 a
Urea	6.2 ab	6.3 a	6.3 a
30% SRN	6.4 a	6.3 a	6.4 a
50% SRN	5.6 b	5.5 b	5.5 b
PCU @ 49 kg ha ⁻¹ every 60 days	5.8 ab	5.8 ab	5.8 ab
PCU @ 98 kg ha ⁻¹ every 120 days	6.2 ab	6.1 ab	6.2 ab
Milorganite	6.3 a	6.2 a	6.3 a
Control	6.1 ab	5.6 ab	5.9 ab
Grass			
St. Augustinegrass	6.1	6.0	6.1
Zoysiagrass	6.6	6.3	6.5
ANOVA			
Grass	***	**	**
N	*	*	*
Grass*N	NS	NS	NS

*, **, *** Significant at the 0.05, 0.01 and 0.001 probability levels, respectively

NS not significant at the 0.05 probability level.

† Within columns, means followed by different letters differ significantly at $P = 0.05$.

Color scores in 2008 differed due to the interaction of grass and N source for both cycles and the total. In St. Augustinegrass, ammonium nitrate, urea and 30% sulfur coated had the highest ratings for both cycles and the seasonal average. In FC 4, the 50% sulfur coated product also ranked in the highest category. Scores were above acceptable with the exception of milorganite and control plots (FC4) and control plots only (seasonal total). In zoysiagrass, scores were statistically equal in all treated plots, with the exception of the 1 lb application rate of the polymer sulfur coated product in FC4. All scores, including control plots were above acceptable.

Table 106. Analysis of variance (ANOVA) and means for turf color in response to N source in established Floratam St. Augustinegrass and Empire zoysiagrass in 2008 in Citra, FL

		FC1	FC2	Average Color
Grass	Treatment			
St. Augustinegrass	Ammonium Nitrate	6.7 a†	6.6 a	6.6 a
	Urea	6.7 a	6.5 ab	6.6 a
	30% SRN	6.7 a	6.5 ab	6.6 a
	50% SRN	6.4 b	6.2 a-c	6.3 bc
	PCU @ 49 kg ha ⁻¹ every 60 days	6.4 b	6.0 cd	6.2 cd
	PCU @ 98 kg ha ⁻¹ every 120 days	6.5 b	6.2 a-c	6.4 b
	Milorganite	6.4 b	5.7 d	6.1 d
	Control	6.1 c	5.3 e	5.8 e
Zoysiagrass	Ammonium Nitrate	6.6 ab	6.9 a	6.7 a
	Urea	6.7 a	6.8 ab	6.7 a
	30% SRN	6.7 a	6.8 ab	6.7 a
	50% SRN	6.7 a	6.7 ab	6.7 a
	PCU @ 49 kg ha ⁻¹ every 60 days	6.7 a	6.6 b	6.7 a
	PCU @ 98 kg ha ⁻¹ every 120 days	6.6 ab	6.8 ab	6.6 a
	Milorganite	6.7 a	6.7 ab	6.7 a
	Control	6.4 b	6.3 c	6.3 b
ANOVA				
	Grass	NS	**	**
	N	***	***	***
	Grass*N	**	**	***

, * Significant at the 0.01 and 0.001 probability levels, respectively

NS not significant at the 0.05 probability level.

† Within columns, means followed by different letters differ significantly at $P = 0.05$.

In 2009, both quality and color scores for each cycle and for the annual total differed due to N. Highest quality ratings were from the soluble products and the 30% sulfur coated product. Color rankings varied throughout the season, with initial highest scores from the soluble products and higher scores from controlled release products in FC3 and 4. Scores were generally above acceptable from the soluble sources after FC1, except for milorganite, which did not reach an acceptable color score throughout the season. 50% sulfur coated likewise was below acceptable in FC3 and 4 and the polymer sulfur coated product had average scores below acceptable in FC2 and 4, when no treatment had been applied for more than 60 days. Quality differed due to grass in FC 1 and 2, with higher scores in zoysiagrass. Color differed due grass in FC1 and the seasonal total, with higher scores again in zoysiagrass.

Table 107. Analysis of variance (ANOVA) and means for turf quality in response to N source in established Floratam St. Augustinegrass and Empire zoysiagrass in 2009 in Citra, FL.

Treatment	FC1	FC2	FC3	FC4	Average Quality
Ammonium Nitrate	5.2 a†	6.1 a	6.4 a	6.4 a	5.2 a
Urea	5.1 ab	6.1 a	6.2 a	6.1 ab	5.1 ab
30% SRN	4.9 bc	6.0 ab	6.3 a	6.1 ab	4.9 bc
50% SRN	4.9 bc	5.8 b	5.9 b	5.8 bc	4.9 bc
PCU @ 49 kg ha ⁻¹ every 60 days	4.8 cd	5.3 c	5.8 bc	5.6 bc	4.8 cd
PCU @ 98 kg ha ⁻¹ every 120 days	4.7 d	5.2 c	5.7 bc	5.4 c	4.7 d
Milorganite	4.7 d	5.3 c	5.6 c	5.4 c	4.7 d
Control	4.2 e	4.3 d	4.1 d	4.3 d	4.2 e
Grass					
St. Augustinegrass	4.6	5.3	5.7	5.5	5.2
Zoysiagrass	5.1	5.7	5.9	5.8	5.5
ANOVA					
Grass	**	*	NS	NS	NS
N	***	***	***	***	***
Grass*N	NS	NS	NS	NS	NS

*, **, *** Significant at the 0.05, 0.01 and 0.001 probability levels, respectively

NS not significant at the 0.05 probability level.

† Within columns, means followed by different letters differ significantly at $P = 0.05$.

Table 108. Analysis of variance (ANOVA) and means for turf color in response to N source in established Floratam St. Augustinegrass and Empire zoysiagrass in 2009 in Citra, FL

	FC1	FC2	FC3	FC4	Average Color
Treatment					
Ammonium Nitrate	5.2 ab†	6.3 a	6.0 ab	6.4 a	5.8 a
Urea	5.3 a	6.3 a	5.9 bc	6.1 ab	5.7 ab
30% SRN	5.0 bc	6.3 a	6.0 a-c	6.4 a	5.7 ab
50% SRN	5.3 a	6.1 a	5.8 cd	5.8 bc	5.6 b
PCU @ 49 kg ha ⁻¹ every 60 days	4.9 cd	5.4 b	6.1 a	6.2 ab	5.5 c
PCU @ 98 kg ha ⁻¹ every 120 days	4.8 d	5.5 b	6.1 a	5.8 bc	5.4 c
Milorganite	4.7 e	5.5 b	5.6 d	5.5 c	5.2 d
Control	3.9 f	4.4 c	4.0 e	4.0 d	4.0 e
Grass					
St. Augustinegrass	4.6	5.6	5.6	5.5	5.2
Zoysiagrass	5.1	5.8	5.8	6.0	5.6
ANOVA					
Grass	**	NS	NS	NS	*
N	***	***	***	***	***
Grass*N	NS	NS	NS	NS	NS

*, **, *** Significant at the 0.05, 0.01 and 0.001 probability levels, respectively

NS not significant at the 0.05 probability level.

† Within columns, means followed by different letters differ significantly at $P = 0.05$.

2010 quality scores had interactions of grass and N source for all evaluation periods (Table). Averaged over the season and for the FCs, St. Augustinegrass had highest scores from the soluble sources, while zoysiagrass had highest ranked scores from ammonium nitrate, sulfur coated products, polymer coated products and milorganite. Similar trends were observed for color scores. Both grasses reached acceptable quality levels by FC2, with the exception of urea on zoysiagrass, due to leaf burn and increased zoysia patch. Zoysiagrass had faster green-up in FC1, while St. Augustinegrass did not reach acceptable levels until FC2.

Table 109. Analysis of variance (ANOVA) and means for turf quality in response to N source in established Floratam St. Augustinegrass and Empire zoysiagrass in 2010 in Citra, FL.

		FC1	FC2	FC3	Average Quality
Grass	Treatment				
St. Augustinegrass	Ammonium Nitrate	5.4 a†	6.7 b	6.6 ab	6.2 ab
	Urea	5.4 a	7.1 a	6.8 a	6.4 a
	30% SRN	5.2 ab	6.4 bc	6.5 a-c	6.0 bc
	50% SRN	5.1 b	6.2 c	6.4 bc	5.8 c
	PCU @ 49 kg ha ⁻¹ every 60 days	5.3 ab	6.3 c	6.5 a-c	6.0 bc
	PCU @ 98 kg ha ⁻¹ every 120 days	5.4 a	6.2 c	6.2 c	5.9 c
	Milorganite	4.5 c	5.5 d	5.6 d	5.1 d
Zoysiagrass	Control	2.8 d	3.4 e	3.8 e	3.3 e
	Ammonium Nitrate	5.2 a	6.3 a	6.6 a	6.0 a
	Urea	4.9 ab	5.7 b	5.7 bc	5.4 bc
	30% SRN	5.1 ab	6.3 a	6.1 ab	5.8 a
	50% SRN	5.1 ab	6.0 ab	5.8 bc	5.6 ab
	PCU @ 49 kg ha ⁻¹ every 60 days	5.1 ab	6.0 ab	6.3 ab	5.7 ab
	PCU @ 98 kg ha ⁻¹ every 120 days	4.8 bc	5.6 b	5.9 bc	5.4 bc
	Milorganite	4.9 ab	6.0 ab	6.1 ab	5.6 ab
	Control	4.5 c	5.7 b	5.3 c	5.1 c
ANOVA					
	Grass	NS	NS	NS	NS
	N	***	***	***	***
	Grass*N	***	***	***	***

*** Significant at the 0.001 probability levels

NS not significant at the 0.05 probability level.

† Within columns, means followed by different letters differ significantly at $P = 0.05$.

Table 110. Analysis of variance (ANOVA) and means for turf color in response to N source in established Floratam St. Augustinegrass and Empire zoysiagrass in 2010 in Citra, FL

		FC1	FC2	FC3	Average Color
Grass	Treatment				
St. Augustinegrass	Ammonium Nitrate	5.5 b†	7.0 a	7.0 ab	6.4 a
	Urea	5.8 a	7.1 a	7.1 a	6.6 a
	30% SRN	5.4 b	6.5 b	6.8 bc	6.2 b
	50% SRN	5.4 b	6.5 b	6.6 cd	6.1 b
	PCU @ 49 kg ha ⁻¹ every 60 days	5.5 b	6.4 b	6.8 bc	6.2 b
	PCU @ 98 kg ha ⁻¹ every 120 days	5.5 b	6.4 b	6.4 d	6.1 b
	Milorganite	5.0 c	5.9 c	6.1 e	5.6 c
	Control	4.7 d	5.3 d	4.8 f	5.0 d
Zoysiagrass	Ammonium Nitrate	6.3 ab	7.3 a	7.0 a	6.8 a
	Urea	6.4 a	7.2 ab	6.8 b	6.8 a
	30% SRN	6.3 ab	7.2 ab	6.9 ab	6.8 a
	50% SRN	6.3 ab	7.2 ab	6.8 ab	6.7 a
	PCU @ 49 kg ha ⁻¹ every 60 days	6.1 b	7.1 ab	6.8 ab	6.6 ab
	PCU @ 98 kg ha ⁻¹ every 120 days	5.9 c	7.0 b	6.9 ab	6.5 b
	Milorganite	5.9 c	7.0 b	6.8 ab	6.5 b
	Control	4.8 d	5.4 c	5.3 c	5.2 c
ANOVA					
	Grass	**	**	NS	***
	N	***	***	***	***
	Grass*N	***	***	***	***

, * Significant at the 0.01 and 0.001 probability levels, respectively

NS not significant at the 0.05 probability level.

† Within columns, means followed by different letters differ significantly at $P = 0.05$.

2011 quality scores had interactions of grass and N source for all evaluation periods and the seasonal average (Table). In general, St. Augustinegrass quality was highest in the soluble, sulfur coated and the polymer coated source applied every 60 days. Scores in treated plots were above or close to acceptable levels throughout the season. Similar responses were seen in color scores. The zoysiagrass plots had no differences due to N source for any evaluation period and clearly showed effects of too much N over several years causing zoysia patch, resulting in plots with little live cover for much of the season. Scores for treated plots were never at an acceptable level and, although the scores did not differ significantly, only control plots reached acceptable quality in FC3. Color scores in zoysiagrass differed due to treated vs. control plots throughout most of the season. Color scores were rated on the color of the green living grass on the plots, so they scored at higher ranges than quality scores and therefore all treated plots were above acceptable from FC2 through FC4.

Table 111. Analysis of variance (ANOVA) and means for turf quality in response to N source in established Floratam St. Augustinegrass and Empire zoysiagrass in 2011 in Citra, FL.

		FC1	FC2	FC3	FC4	Average Quality
Grass	Treatment					
St. Augustinegrass	Ammonium Nitrate	5.9 a†	7.0 b	6.9 ab	6.4 a	6.4 ab
	Urea	6.0 a	7.2 a	7.0 a	6.6 a	6.5 a
	30% SRN	5.9 a	7.1 ab	7.0 a	6.5 a	6.5 a
	50% SRN	6.1 a	7.1 ab	7.0 a	6.5 a	6.6 a
	PCU @ 49 kg ha ⁻¹ every 60 days	6.0 a	7.0 b	7.0 a	6.5 a	6.5 a
	PCU @ 98 kg ha ⁻¹ every 120 days	5.9 a	6.7 c	6.8 b	6.5 a	6.3 bc
	Milorganite	6.0 a	6.4 c	6.3 c	6.1 b	6.2 c
	Control	4.0 b	4.8 d	5.0 d	5.0 c	4.5 d
Zoysiagrass	Ammonium Nitrate	5.2	5.0	5.0	4.8	5.0
	Urea	4.8	4.6	5.1	5.1	4.8
	30% SRN	4.9	5.4	5.5	5.3	5.2
	50% SRN	5.4	5.2	5.5	5.4	5.4
	PCU @ 49 kg ha ⁻¹ every 60 days	5.4	4.9	5.4	5.4	5.2
	PCU @ 98 kg ha ⁻¹ every 120 days	4.5	4.4	4.9	4.9	4.6
	Milorganite	4.9	4.9	5.1	5.0	4.9
	Control	5.4	5.6	6.1	5.8	5.6
	ANOVA					
	Grass	NS	**	*	*	*
	N	**	**	NS	NS	*
	Grass*N	***	***	***	**	***

*, **, *** Significant at the 0.05, 0.01 and 0.001 probability levels, respectively

NS not significant at the 0.05 probability level.

† Within columns, means followed by different letters differ significantly at $P = 0.05$.

Table 112. Analysis of variance (ANOVA) and means for turf color in response to N source in established Floratam St. Augustinegrass and Empire zoysiagrass in 2011 in Citra, FL

		FC1	FC2	FC3	FC4	Average Quality
Grass	Treatment					
St. Augustinegrass	Ammonium Nitrate	5.7 a†	7.1 a	7.0 a	6.6 b	6.4 a
	Urea	5.7 a	7.0 a	7.0 a	6.6 b	6.4 a
	30% SRN	5.6 b	6.9 b	7.0 a	6.6 b	6.3 b
	50% SRN	5.5 c	6.8 b	7.0 a	6.5 b	6.2 bc
	PCU @ 49 kg ha ⁻¹ every 60 days	5.4 d	6.5 c	7.0 a	6.6 b	6.1 d
	PCU @ 98 kg ha ⁻¹ every 120 days	5.4 d	6.5 c	7.0 a	7.0 a	6.1 d
	Milorganite	5.3 e	6.3 d	6.8 b	6.5 b	6.0 e
	Control	4.5 f	4.8 e	4.5 c	4.0 a	4.5 f
Zoysiagrass	Ammonium Nitrate	5.8 a	7.0 a	7.3 a	6.5 a	6.5 a
	Urea	5.8 a	7.0 a	7.3 a	6.5 a	6.5 a
	30% SRN	5.8 a	6.8 b	7.0 a	6.5 a	6.4 a
	50% SRN	5.8 a	6.8 b	7.0 a	6.5 a	6.4 a
	PCU @ 49 kg ha ⁻¹ every 60 days	5.8 a	6.8 b	7.0 a	6.5 a	6.4 a
	PCU @ 98 kg ha ⁻¹ every 120 days	5.8 a	6.8 b	7.0 a	6.5 a	6.4 a
	Milorganite	5.8 a	6.8 b	7.0 a	6.5 a	6.4 a
	Control	4.7 b	4.9 c	5.1 b	5.1 b	4.9 b
	ANOVA					
	Grass	***	*	*	NS	***
	N	***	***	***	***	***
	Grass*N	**	***	*	***	NS

*, **, *** Significant at the 0.05, 0.01 and 0.001 probability levels, respectively

NS not significant at the 0.05 probability level.

† Within columns, means followed by different letters differ significantly at $P = 0.05$.

Shoot Harvests

Shoot harvests are reported as the average of shoot tissue mass collected in multiple harvests throughout the growing seasons (Table). Mass differed due to N source in all years, with an interaction of N source and grass in 2010. Greatest shoot growth was seen in the plots receiving soluble or 30% sulfur coated N sources in the first 2 years of the study. In 2010, soluble and sulfur coated sources produced more shoot mass in St. Augustinegrass than in milorganite or untreated plots. Zoysiagrass shoot production ranked in the highest statistical category from all treatments except for milorganite and the polymer sulfur coated product applied every 120 days. In 2011, 50% sulfur coated and polymer coated N applied at 1 lb N per 1,000 ft² every 60 days were also in the highest rankings when averaged over both grasses. These results are consistent with other research evaluating growth responses to N source.

Table 113. Analysis of variance (ANOVA) and means for shoot tissue harvests averaged over the growing season in response to N source in established Floratam St. Augustinegrass and Empire zoysiagrass in 2008-2011 in Citra, FL.

Treatment	2008	2009	2010	2011
Ammonium Nitrate	6.5 a†	6.7 a	10.1 a	13.2 ab
Urea	6.1 ab	6.0 ab	10.4 a	13.4 ab
30% SRN	6.4 a	7.1 a	8.8 ab	14.8 a
50% SRN	4.2 c	4.8 bc	10.5 a	11.5 ab
PCU @ 49 kg ha ⁻¹ every 60 days	3.2 cd	3.9 c	9.9 a	13.0 ab
PCU @ 98 kg ha ⁻¹ every 120 days	3.2 cd	3.5 c	8.1 bc	10.0 bc
Milorganite	4.4 bc	2.9 cd	6.7 c	7.6 c
Control	2.1 d	1.0 d	1.1 d	2.1 d
ANOVA				
N Source	***	***	***	***
Grass	NS	NS	**	NS
N*Grass	NS	NS	***	NS

, * Significant at the 0.01 and 0.001 probability levels, respectively

NS not significant at the 0.05 probability level.

† Within columns, means followed by different letters differ significantly at $P = 0.05$.

Conclusions

Nitrate leaching from St. Augustinegrass was not influenced by N source at the rates applied in this study. After spring green up (FC1), all sources generally produced acceptable turf quality and color, with the exception of milorganite in 2009 and 2010. Better quality and color were often achieved with the soluble and 30% sulfur coated sources, although other sources provided acceptable ratings. If reduction of shoot growth were an important goal, use of the polymer sulfur coated sources or milorganite would be a good strategy. Although these data were not analyzed for differences between FC, nitrate-N loading in the winter may be a concern, particularly in an extremely cold winter such as that experienced in 2011. While it may seem logical to suggest that omitting or reducing the late season treatment application might reduce this tendency, it is worthwhile to note that the last application of the polymer-sulfur coated product was in Aug. in 2011.

Nitrate-N loading from zoysiagrass was more prone to variation due to N source when there were grass and N source interactions, such as in 2008. When these differences existed, nitrate-N loading was greatest from ammonium nitrate. It is important to note, however, that previous research has determined that zoysiagrass cultivars such as Empire are better maintained with reduced N rates than those applied in this study. The rates applied here increased zoysia patch, delayed spring green up and reduced the overall stress tolerance of the grass, all of which may lead to greater nutrient loading over the growing season.

When nitrogen was applied at the rates tested in this study, NO₃-N loading did not differ in any year due to N source in St. Augustinegrass. Greater loading occurred in zoysiagrass from ammonium nitrate in 2008 only. These data suggest that consideration could be given to allow application of up to 1 lb of water soluble N per 1,000 ft² on an established, healthy turf. Consideration could also be given to allow application of up to 2 lbs N

per 1,000 ft² of a polymer sulfur coated product similar to the one tested here. When fertilizer application BMPs are followed and products are applied to a healthy turf, particularly St. Augustinegrass, there is no reason to limit N sources to slow release choices only based on results of this research.

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NITRATE-N LEACHING FROM 'FLORATAM' ST. AUGUSTINEGRASS AND 'ULTIMATEFLORA'®, ZOYSIAGRASS DURING WINTER MONTHS

Introduction

Fertilizer recommendations for warm-season grasses are typically timed to coincide with active grass growth, particularly where grasses may experience significant winter dormancy. There are some reports in the literature on NO₃-N loading from cool-season grasses due to late-season N application. A stand of Kentucky bluegrass (*Poa pratensis* L.) and creeping red fescue (*Festuca rubra* L.), fertilized at a rate of 49 kg N ha⁻¹ from mid-Sept to mid-Dec had increased NO₃-N concentration and mass losses in percolate from the later application dates (Mangiafico and Guillard, 2006). The authors concluded that late fall N applications, in combination with increased chance of precipitation at this time, increased the likelihood of potential nutrient leaching or runoff and resulting water impairment. They suggested that cool-season grass fertilization recommendations for fall fertilization be revised due to potential water quality concerns. Similarly, Guillard and Kopp (2004) reported highest NO₃-N leaching losses in a mixed sward of cool-season grasses from fertilizer applied in late fall through early spring, particularly when N was applied as a water soluble source.

Kentucky bluegrass had rapid uptake and immobilization of ¹⁵N-labeled urea, regardless of whether the N was applied in a series of spring or fall applications (Miltner et al., 1996). The authors concluded that even late fall N fertilization did not pose a potential threat to groundwater when the turf had high density and organic matter buildup as thatch. Petrovic (2004) reported that late fall N application to Kentucky bluegrass resulted in NO₃-N leaching at rates of 29 to 47% of applied N from water soluble N sources, while only 0-12% of the applied N leached when N was applied in a slow release

There are few reports documenting NO₃-N loading from warm-season grasses during winter months. Brown et al. (1977) reported greatest NO₃-N losses in 'Tifdwarf' bermudagrass (*Cynodon dactylon* L. x *C. transvaalensis* Burtt-Davy) during winter months. Snyder et al. (1984) reported greater NO₃-N leaching losses from bermudagrass fertilized in winter months than in warmer months. Winter fertilization in FL is not uncommon for lawn care professionals, who sometimes fertilize outside of the actual growing season due to fertilizer ordinances banning application in the summer months or due to contractual obligations.

This research was undertaken to observe the effects of 1) N rate and species and 2) month of application on NO₃-N loading and turf quality due to winter N application to Floratam St. Augustinegrass and UltimateFlora® zoysiagrass.

Materials and Methods

Lysimeters were installed for this project throughout the summer of 2006 as previously described. Installation was completed on September 6, 2006. Floratam St. Augustinegrass sod was planted on October 2, 2006 and UltimateFlora zoysiagrass sod on October 3, 2006. Nitrogen treatments were applied as water soluble urea (46-0-0) dissolved in water and applied through a backpack sprayer to uniformly cover each plot at a rate of 0.12 L m⁻². Treatments were irrigated in with 1.3 cm of water after application. Treatment application began on November 14, 2006 and continued monthly through March 19, 2007. Nitrogen rates were as follows:

1. Control (no fertilizer)
2. 1/8 lb. N monthly
3. 1/4 lb. N monthly
4. 1/2 lb. N monthly
5. 1 lb. N monthly

6. 2 lb. N monthly

Leachate samples were collected twice weekly as previously described, beginning November 13, 2006 (baseline sample) and continuing through April 19, 2007. Turf was mowed as needed throughout the study period, typically an average of twice monthly. Mowing heights were 8.8 and 5 cm, respectively, for St. Augustinegrass and zoysiagrass. Clippings were returned to the ground.

Turf quality was assessed biweekly over the growing season on a scale of 1 to 9, where 1 = dead or dormant brown turf and 9 = optimal healthy, green turf. A score of 6 was considered a minimally acceptable score for a home lawn. Weather data were collected from an onsite weather network system (<http://fawn.ifas.ufl.edu>), which provides meteorological information in 15-min intervals.

Experimental design was a split plot design, where grasses were main plots and N rates were sub plots. Where data were analyzed to determine differences due to month of application and the interaction of month, grass and N rate, a split-split plot design was used. There were 4 replications. Proc ANOVA and GLM (SAS Institute, 2003) were used to analyze data and means were separated with the Waller Duncan *k*-ratio *t*-test. Differences were determined at the 0.05 significance level. Due to differences in data between years, results are presented by year. Leachate data were found to be normally distributed and were adjusted for outliers that exceeded plus or minus two standard deviations.

Results

Climate

Monthly rainfall totals and average monthly temperatures for the study period for each year are reported in Table 1. In year 1, total rainfall exceeded the historical average for Nov-Apr by approximately 9%, while the totals for years 2 and 3 were 20 and 57% below average, respectively. Average monthly temperatures did not vary excessively from the historical average for any year.

Table 114. Climatology and average historical data for the periods during which the research was conducted from 2006 to 2009 in Citra, FL.

<u>Rainfall</u>	2006-07	2007-08	2008-09	Average
	-----mm-----			
Nov	47.0	1.6	13.7	54.0
Dec	93.0	47.2	17.8	63.4
Jan	60.2	79.8	54.4	71.3
Feb	175.5	121.2	34.0	85.0
Mar	54.4	107.4	42.4	93.2
Apr	62.7	6.3	31.0	83.7
Total	492.8	363.5	193.3	450.6
<u>Temperature</u>	-----°C-----			
Nov	16.1	16.5	15.8	18.4
Dec	16.7	16.4	16.4	17.8
Jan	14.9	13.6	13.4	15.8
Feb	13.8	15.9	13.8	12.8
Mar	17.9	17.3	17.8	18.0
Apr	19.4	20.2	20.1	19.1

Nitrate-N Mass Loading

In year 1, there were differences in cumulative NO₃-N mass flux in response to the interaction of grass × N rate (Table 2). In St. Augustinegrass, there were no differences in N mass flux at N rates up to 49.0 kg N ha⁻¹, with greatest N loading from application of 98.0 kg N ha⁻¹. Zoysiagrass had greatest loading from the two highest N rates. Zoysiagrass had no differences in NO₃-N loading between control treatments and up to 12.2 kg N ha⁻¹.

In year 2, cumulative NO₃-N loads differed in response to main effects of grass and N rate (Table 2). Cumulative loads were 5.2 vs. 14.2 kg N ha⁻¹ for St. Augustinegrass and zoysiagrass, respectively. There were no differences in loading from 0 to 49.0 kg N ha⁻¹, with greatest loading resulting from application of 98.0 kg N ha⁻¹.

In year 3, cumulative leaching differed due to the interaction of grass × N rate (Table 2). Similar to year 1 results, loading from St. Augustinegrass was greatest from the highest N application rate, with no differences between the other rates. Highest loads in zoysiagrass occurred at the two highest N rates, with no differences between the lower rates.

Table 115. Analysis of variance and means for NO₃-N mass flux in response to N rate during winter months in St. Augustinegrass and zoysiagrass over a 3-year trial in Citra, FL.

Grass	Monthly N rate -----kg N ha ⁻¹ 1---	Cumulative Nitrate N Mass Flux -----kg N ha ⁻¹ -----		
		Year 1	Year 2	Year 3
St. Augustinegrass				
	98.0	45.5 a†		18.7 a
	49.0	17.0 b		2.8 b
	24.5	8.0 b		0.9 b
	12.2	8.3 b		1.4 b
	6.1	6.1 b		0.9 b
	0	5.0 b		1.0 b
Zoysiagrass				
	98.0	113.7 a		29.3 a
	49.0	107.7 a		27.2 a
	24.5	53.5 b		3.7 b
	12.2	42.2 bc		3.7 b
	6.1	36.8 bc		2.0 b
	0	22.5 c		2.7 b
St. Augustinegrass			5.2 b	
Zoysiagrass			14.2 a	
	98.0		30.2 a	
	49.0		14.0 b	
	24.5		4.9 b	
	12.2		3.3 b	
	6.1		3.0 b	
	0		2.7 b	
ANOVA				
Grass (G)		**	*	*
Nitrogen (N)		***	***	***
G x N		**	NS	**

† Within columns, means followed by different letters differ significantly at $P = 0.05$.

*, **, *** Significant at the 0.05, 0.01, and 0.001 probability levels, respectively.

NS Not significant at the 0.05 probability level.

Nitrate-N loads were compared for the interaction of grass, N rate, and month of application. In years 1 and 3, there were significant 3 way interactions (Table 3). In year 2, there were differences due to grass and the interaction of N rate × month.

Table 116. Analysis of variance for NO₃-N mass flux in response to grass, N rate and month of application over a 3-year trial in Citra, FL.

ANOVA	Year 1	Year 2	Year 3
Grass (G)	**	*	*
Nitrogen (N)	***	***	***
Month (M)	***	***	***
G x N	**	NS	**
G x M	***	NS	**
N x M	***	***	***
G x N x M	***	NS	**

*, **, *** Significant at the 0.05, 0.01, and 0.001 probability levels, respectively.

NS Not significant at the 0.05 probability level.

In year 1, St. Augustinegrass had no differences in NO₃-N loading between months at the highest N rate (Table 4). At 49.0 kg N ha⁻¹, greatest loading occurred Nov-Feb. At the lower rates, loading was greatest in Nov or Nov and Dec at the 6.1 kg N ha⁻¹ rate only. In zoysiagrass, greatest N loading at the 4 highest rates rate occurred in Dec, Jan and Mar. At the 6.1 kg N ha⁻¹ rate, greatest loading was in Dec.

Table 117. Nitrate-N mass flux in response to nitrogen rate and month in year 1 in St. Augustinegrass and zoysiagrass in Citra, FL.

Month	Nitrate N Mass Flux					
	-----kg N ha ⁻¹ -----					
	0	6.1	12.2	24.5	49.0	98.0
	<u>St. Augustinegrass</u>					
Nov 06	2.7 a†	2.9 a	4.0 a	3.8 a	5.6 a	5.1
Dec 06	1.2 b	1.4 ab	1.7 b	1.6 b	4.4 ab	10.2
Jan 07	0.7 b	0.9 b	1.4 b	0.7 b	1.6 ab	13.4
Feb 07	0.3 b	0.5 b	0.5 b	1.2 b	5.3 a	12.7
Mar 07	0.2 b	0.3 b	0.7 b	0.7 b	0.1 b	4.2
	<u>Zoysiagrass</u>					
Nov 06	4.4 ab	5.9 c	6.7 bc	6.8 b	7.7 c	7.5 b
Dec 06	5.4 a	10.8 a	10.8 ab	12.9 a	23.4 ab	21.9 ab
Jan 07	4.6 a	7.8 b	7.8 a-c	12.7 a	30.8 a	35.6 a
Feb 07	3.1 b	4.0 c	5.1 c	6.9 b	12.1 bc	12.6 b
Mar 07	4.9 a	8.3 b	11.8 a	14.3 a	33.7 a	36.1 a

† Within columns, means followed by different letters differ significantly at $P = 0.05$.

In year 2, there were differences between months at the two highest application rates only (Table 5). Lowest NO₃-N loading occurred in Dec and Jan at the 98.0 kg N ha⁻¹ rate. At the 49.0 kg N ha⁻¹ rate, loading was significantly greater in Mar than in Dec.

Table 118. Nitrate-N mass flux in response to nitrogen rate and month in year 2 in St. Augustinegrass and zoysiagrass in Citra, FL.

Month	Nitrate N Mass Flux					
	-----kg N ha ⁻¹ -----					
	0	6.1	12.2	24.5	49.0	98.0
Dec 07	0.6	0.7	0.6	0.8	0.6 b†	1.0 c
Jan 08	0.8	0.5	0.7	1.2	2.8 ab	3.7 bc
Feb 08	0.5	0.7	0.6	0.9	3.9 ab	9.8 ab
Mar 08	0.8	1.1	1.4	2.0	6.6 a	15.8 a

† Within columns, means followed by different letters differ significantly at $P = 0.05$.

In year 3, there were differences in loading from St. Augustinegrass between months at all N rates except for the 49.0 kg N ha⁻¹ rate (Table 6). At the highest N rate, loading was greatest in Feb and Mar. At rates of 24.5 and 6.1 kg N ha⁻¹, greatest loading occurred in Jan-Mar. At 12.2 kg N ha⁻¹, greatest loads occurred Dec-Mar. Zoysiagrass loading was greatest at the two highest N rates in Jan and Feb. At application rates of 12.2 and 24.5 kg N ha⁻¹, loading was greatest Jan-Mar and in Feb and Mar at the 6.1 kg N ha⁻¹ application rate.

Table 119. Nitrate-N mass flux in response to nitrogen rate and month in year 3 in St. Augustinegrass and zoysiagrass in Citra, FL.

Month	Nitrate N Mass Flux					
	-----kg N ha ⁻¹ -----					
	0	6.1	12.2	24.5	49.0	98.0
St. Augustinegrass						
Nov 08	0.04 c†	0.04 c	0.05 b	0.03 b	0.1	0.04 b
Dec 08	0.1 c	0.1 bc	0.1 ab	0.1 b	0.1	0.1 b
Jan 09	0.2 b	0.3 a	0.6 a	0.3 a	0.5	2.7 b
Feb 09	0.2 b	0.2 ab	0.4 ab	0.3 a	1.6	11.0 a
Mar 09	0.4 a	0.3 a	0.3 ab	0.1 ab	0.5	4.9 ab
Zoysiagrass						
Nov 08	0.2	0.1 cd	0.2 b	0.2 b	0.1 c	0.3 c
Dec 08	0.3	0.1 d	0.1 b	0.3 b	0.2 c	0.3 c
Jan 09	0.9	0.4 bc	1.0 ab	1.4 a	9.1 b	7.2 b
Feb 09	0.5	0.5 ab	0.8 ab	0.8 ab	14.2 a	15.0 a
Mar 09	0.7	0.7 a	0.9 ab	0.9 ab	3.6 c	6.2 bc

† Within columns, means followed by different letters differ significantly at $P = 0.05$.

In all years, where there were differences due to grass, less NO₃-N leached from St. Augustinegrass. For year 1, cumulative leaching load totaled 15.0 vs. 62.7 kg ha⁻¹ from St. Augustinegrass and zoysiagrass, respectively, averaged over N treatments (data not shown). Previous research has similarly reported reduced NO₃-N leached from St. Augustinegrass than from other species investigated. Erickson et al. (2001) observed a cumulative annual NO₃-N load of 4.1 kg ha⁻¹ from St. Augustinegrass compared to 48.3 kg ha⁻¹ from a mixed landscape planting. Trenholm et al. (in press) reported average annual mass flux of 1.4 vs. 10.1 and 3.8 vs. 61.2 kg ha⁻¹ from St. Augustinegrass and zoysiagrass, respectively, for two subsequent years.

Turf Quality and Color

Turf quality scores differed due to the interaction of grass $\times$ N rate in year 1 in Dec, Jan and Mar (Table 7). St. Augustinegrass had increased quality in response to N from Dec-Mar, although scores were largely below acceptable from Jan-Mar. Turf quality in zoysiagrass was less responsive to N rate and quality scores were below acceptable from Jan-Mar. There was an interaction of grass $\times$ N rate for color scores in year 1 in Nov and Mar and differences due to main effects of both grass and N rate in the other months. Color scores were below acceptable at all treatment levels in both grasses for each month, with the exception of St. Augustinegrass in Dec that received N at rates $> 12.2 \text{ kg N ha}^{-1}$.

Table 120. Average turf quality and color of St. Augustinegrass and zoysiagrass in response to nitrogen rate in year 1 (2006-07) in Citra, FL. Turf quality was based on a scale of 1 to 9, where 1 = dead, brown turf and 9 = optimal healthy, green turf.

	Monthly N Rate ---kg N ha ⁻¹ ---	Turf quality					Turf color				
		Nov	Dec	Jan	Feb	Mar	Nov	Dec	Jan	Feb	Mar
<u>St. Augustinegrass</u>	98.0	6.5	7.5 a†	5.3 a	3.6 a	6.0 a	5.9	7.6 a	5.1 a	2.9 a	5.6 a
	49.0	6.5	7.2 b	5.0 b	3.2 ab	5.5 b	5.7	7.0 b	4.6 b	2.3 ab	5.2 ab
	24.5	6.5	6.6 c	4.8 c	2.8 bc	5.4 bc	5.7	6.4 c	4.2 bc	2.0 bc	4.9 bc
	12.2	6.5	6.5 c	4.7 c	2.4 cd	5.1 c	5.7	6.1 d	4.1 c	1.6 cd	4.6 cd
	6.1	6.5	6.5 c	4.4 d	2.6 bc	4.6 d	5.6	5.9 d	3.6 d	1.9 bc	4.3 d
	0	6.5	6.2 d	3.8 e	2.0 d	4.1 e	5.1	5.4 e	2.8 e	1.2 d	3.6 e
<u>Zoysiagrass</u>	98.0	6.5	6.5	4.1 a	2.1 a	4.4 a	4.0	4.8 a	3.1 a	1.2 a	3.8 ab
	49.0	6.5	6.5	3.9	1.9 ab	4.4 a	4.0	4.6 a	2.8 ab	1.1 ab	3.9 ab
	24.5	6.5	6.4	ab 3.9	1.9 a-c	4.4 a	4.0	4.4 ab	2.8 ab	1.0 b	4.0 a
	12.2	6.5	6.5	4.0 a	1.9 a-c	4.2 ab	4.0	4.3 ab	2.6 ab	1.0 b	3.5 ab
	6.1	6.5	6.5	3.6	1.7 bc	3.9 b	4.0	3.9 ab	2.1 bc	1.0 b	3.4 b
	0	6.5	6.4	bc 3.4 c	1.6 c	3.4 c	4.0	3.4 b	1.6 c	1.0 b	2.9 c
<u>ANOVA</u>											
Grass (G)		NS	**	**	*	*	***	**	**	**	NS
N Rate (N)		NS	***	***	***	***	*	***	***	***	***
G $\times$ N		NS	***	**	NS	*	*	NS	NS	NS	*

† Within columns, means followed by different letters differ significantly at $P = 0.05$.

*, **, *** Significant at the 0.05, 0.01, and 0.001 probability levels, respectively.

NS Not significant at the 0.05 probability level.

In year 2, TQ had minor differences due to grass and N rate, with increased TQ as N increased in both grasses in Dec and Jan (Table 8). Quality scores for both grasses were below acceptable in all months. Color scores responded to the interaction of N $\times$ grass in all months in year 2. Color scores were less than acceptable, with the exception of St. Augustinegrass at the highest N rate in Jan and Feb and N at $24.5 \text{ kg N ha}^{-1}$ or greater in Mar.

Table 121. Average turf quality and color of St. Augustinegrass and zoysiagrass in response to nitrogen rate (N rate) in year 2 (2007-08) in Citra, FL. Turf quality was based on a scale of 1 to 9, where 1 = dead, brown turf and 9 = optimal healthy, green turf.

	Monthly N Rate ----kg N ha ⁻¹ ----	Turf quality				Turf color			
		Dec	Jan	Feb	Mar	Dec	Jan	Feb	Mar
<u>St. Augustinegrass</u>	98.0	5.8 a†	5.5 a	4.7	5.5	5.6 a	6.0 a	6.4 a	6.5 a
	49.0	5.5 b	5.2 b	4.6	5.5	5.4 a	5.6 ab	5.9 ab	6.3 a
	24.5	5.2 c	5.0 c	4.7	5.3	4.9 b	5.3 bc	5.0 bc	6.0 b
	12.2	5.0 cd	4.9 c	5.0	5.4	4.7 bc	4.9 cd	4.9 c	5.5 b
	6.1	4.9 cd	4.8 cd	4.6	4.9	4.6 bc	4.8 cd	4.3 c	5.2 b
	0	4.8 d	4.6 d	4.5	4.8	4.4 c	4.5 d	4.0 c	5.1 b
<u>Zoysiagrass</u>	98.0	5.7 a	5.0 a	4.2	4.0	4.6 a	4.7 a	4.9 a	4.3 ab
	49.0	5.7 a	4.9 ab	4.6	4.4	4.4 b	4.6 ab	4.8 a	4.6 ab
	24.5	5.5 ab	4.8 ab	4.7	4.7	4.3 bc	4.6 ab	4.6 a	5.0 a
	12.2	5.3 bc	4.7 b	4.7	4.6	4.2 cd	4.4 ab	4.6 a	4.9 a
	6.1	5.1 cd	4.7 b	4.6	4.6	4.1 d	4.3 b	4.4 ab	4.7 ab
	0	4.9 d	4.5 c	4.3	4.3	3.9 e	4.0 c	3.6 b	4.1 b
<u>ANOVA</u>									
Grass (G)		NS	**	NS	**	***	**	*	**
N Rate (N)		***	***	NS	NS	***	***	***	**
G × N		NS	NS	NS	NS	**	*	*	**

† Within columns, means followed by different letters differ significantly at $P = 0.05$.

*, **, *** Significant at the 0.05, 0.01, and 0.001 probability levels, respectively.

NS Not significant at the 0.05 probability level.

Turf quality was below acceptable at all ratings in year 3 for both grasses, with grass × N interactions in Nov, Dec and Jan (Table 9). Color scores differed in response to the interaction of grass × N in all months except for Mar. Scores were below acceptable, with the exception of St. Augustinegrass in Nov at the two highest N rates.

Table 122. Average turf quality and color of St. Augustinegrass and zoysiagrass in response to nitrogen rate (N rate) in year 3 (2008-09) in Citra, FL. Turf quality was based on a scale of 1 to 9, where 1 = dead, brown turf and 9 = optimal healthy, green turf.

St.	Monthly N Rate	Turf quality					Turf color				
	--kg N ha ⁻¹ --	Nov	Dec	Jan	Feb	Mar	Nov	Dec	Jan	Feb	Mar
<u>St. Augustinegrass</u>	98.0	5.9 a†	5.4 a	4.3 a	3.0 a	5.2 a	6.6 a	5.0 a	3.9 a	3.1 a	5.3 a
	49.0	5.3 ab	4.8 ab	3.9 b	2.6 a	4.4 a	6.1 ab	4.6 ab	3.3 ab	2.3 b	4.8 a
	24.5	4.5 b	3.9 bc	2.8 c	1.8 b	2.9 b	5.1 bc	3.5 cd	2.3 c	1.6 c	3.4 b
	12.2	4.3 bc	3.4 cd	2.2 d	1.4 b	2.4 bc	5.0 bc	3.9 bc	2.5 bc	1.4 cd	2.8 bc
	6.1	3.1 d	2.6 d	2.1 d	1.6 b	2.2 bc	3.3 d	2.6 d	2.0 c	1.1 d	2.4 cd
	0	3.3 cd	2.6 d	1.8 e	1.1 b	1.5 c	3.8 cd	2.8 d	1.9 c	1.4 cd	1.8 d
<u>Zoysiagrass</u>	98.0	5.6 a	4.5 a	3.4 a	3.5 a	5.1 a	5.0 a	3.8 ab	2.8 ab	1.9 a	5.3 a
	49.0	5.4 a	4.5 a	3.4 a	3.5 a	5.1 a	5.1 a	4.0 a	2.9 a	1.9 a	5.1 a
	24.5	5.3 ab	4.0 b	3.0 b	3.0 b	3.6 b	5.1 a	3.6 bc	2.8 ab	1.8 ab	3.7 b
	12.2	5.1 ab	3.8 b	2.9 bc	2.5 c	2.9 c	4.3 b	3.3 c	2.5 ab	1.5 a- c	3.1 c
	6.1	4.6 bc	3.6 bc	2.8 bc	2.4 c	2.8 c	4.3 b	3.5 bc	2.4 b	1.4 bc	2.8 c
	0	4.3 c	3.3 c	2.6 c	1.6 d	2.2 d	3.8 c	2.8 d	1.9 c	1.1 c	2.0 d
<u>ANOVA</u>											
Grass (G)		**	NS	NS	***	*	NS	NS	NS	NS	NS
N Rate (N)		***	***	***	***	***	***	***	***	***	***
G × N		*	*	***	NS	NS	*	**	**	***	NS

† Within columns, means followed by different letters differ significantly at $P = 0.05$.

*, **, *** Significant at the 0.05, 0.01, and 0.001 probability levels, respectively.

NS Not significant at the 0.05 probability level.

Conclusions

Application of low rates ($< 24.5 \text{ kg N ha}^{-1}$) of N during winter months to St. Augustinegrass or zoysiagrass did not result in $\text{NO}_3\text{-N}$ fluxes greater than those of control plots, but also did not enhance TQ or TC, as would be expected with dormant or semi-dormant grass. At higher N rates, greater $\text{NO}_3\text{-N}$ loading was likely and, while TQ and TC may have increased slightly, in 2 of the 3 years, TQ and TC were below acceptable quality at any N rate. Additionally, the high rates would result in N application in excess of the currently recommended N rates (Sartain, 2007). There was a trend towards greater $\text{NO}_3\text{-N}$ leaching in the winter and early spring months prior to spring green-up, a time when commercial lawn care services are often beginning annual lawn maintenance services. If an additional N application were needed due to contractual obligations or due to summer fertilizer restrictions, these results suggest that N application in the late fall months would be preferable to winter or early spring application to reduce the potential for $\text{NO}_3\text{-N}$ mass loading.

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Statewide Analysis of Effect of N Rate on Nitrate-N Leaching in Established Grasses

Introduction

Irrigation and nitrogen fertilization are essential components of turfgrass maintenance programs that provide healthy, good quality St. Augustinegrass lawns. Applied at the appropriate rates as suggested by current IFAS guidelines, N and irrigation have been shown to improve turfgrass quality, color, health and vigor. However, excess N from over-fertilization in combination with over-irrigation can potentially increase $\text{NO}_3\text{-N}$ leaching and contribute to degradation of ground and surface water quality. There are currently increased restrictions on fertilization of home lawns due to these concerns, but the precise $\text{NO}_3\text{-N}$ loading that might be expected from fertilization of a lawn grass has not been precisely quantified. Nor is there relevant published literature available on the quantity of N or irrigation needed to produce acceptable turfgrass quality and health for home lawns throughout Florida. The objective of this experiment was to determine the effects of two irrigation regimes, four N rates (ranging from sub-optimal to excess fertilization) and location on N leaching from St. Augustinegrass at each of three geographic locations in Florida. The information provided from this research will help in the development of Best Management Practices (BMPs) that improve water quality and conservation while providing healthy turf systems.

Materials and Methods

The research was conducted at the Ft. Lauderdale Research and Education Center, the Plant Science Research and Education Unit in Citra, and the West Florida Research and Education Center in Jay. St. Augustinegrass cv. 'Floritam' was planted in each location and allowed to establish prior to initiation of treatments. Plots were 4 m x 4 m with a lysimeter in the center of each plot as previously described in this report.

Nitrogen rates for each location are listed in Table 1 and were designed to provide sub-optimal, medium, and excess rates for each of the three locations, based on existing IFAS recommendations for fertilization of St. Augustinegrass. Treatment application in Ft Lauderdale began 12 October, 2006 and continued every other month after that for a total of 12 fertilizer cycles. Main blocks (8 x 4 m) consisted of one of two irrigation regimes: 2.5 mm daily (low) except when daily precipitation > 6.4 mm (irrigation turned off), and 13 mm three times weekly (high). In Citra, sod was established in spring of 2005 and treatments began in July 2005. There were 2 treatment applications in 2005 and 4 each in 2006 and 2007 for a total of 10 fertilizer cycles. Irrigation treatments consisted of 13 mm applied twice weekly or 25 mm applied weekly. When rainfall met or exceeded these amounts, irrigation was suspended. In Jay, fertilizer and irrigation treatments began in summer 2005 through 2007 for a total of 10 fertilizer cycles. Irrigation treatments consisted of 13 mm applied twice weekly or 25 mm applied weekly.

In all locations, the N source used was soluble urea (46-0-0) and applied as a spray for all treatment applications. Irrigation regimes were based on local estimates of evapotranspiration (ET).

Lysimeters were evacuated and samples taken as previously described in this report twice a week during this study period. Any $\text{NO}_3\text{-N}$ concentration that was lower than the minimum detection limit (MDL) of 0.05 mg L^{-1} was corrected to the MDL value. Visual turf ratings, closely linked to turf health and vigor, were based on a scale of 1-9 (9 = healthy, growing uniform turf, 1 = dead turf and 6 = minimally acceptable turf) and were made bi-weekly.

Experimental design in each location was a split plot with 4 replications. For the analysis that included location, the design was a split-split plot, with locations as whole plots, irrigation as sub plots and NR as sub-sub plots.

Following correction for outliers, all data were analyzed with PROC GLM or PROC REG (SAS Institute, 1999) Significance was determined at the 5% probability level.

To compare data between the three locations, 8 fertilizer cycles were analyzed over a 3-year period. Total NO₃-N leaching data are reported for the 3-yr period and annually and percent of applied N leached is reported by year.

Table 123. Treatment annual rates by location.

Location	Annual N Rates (kg ha ⁻¹)
Ft. Lauderdale	98
	196
	294
	588
Citra	49
	196
	343
	490
Jay	49
	98
	196
	294

Results

Hydrology

Rainfall data are displayed in Fig 34 a-c for each of the locations over the trial period. Events that produced greater than 25 mm in a day are considered excessive.

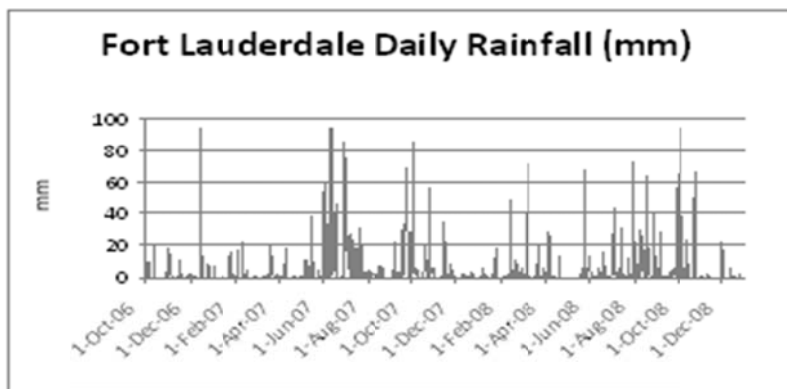
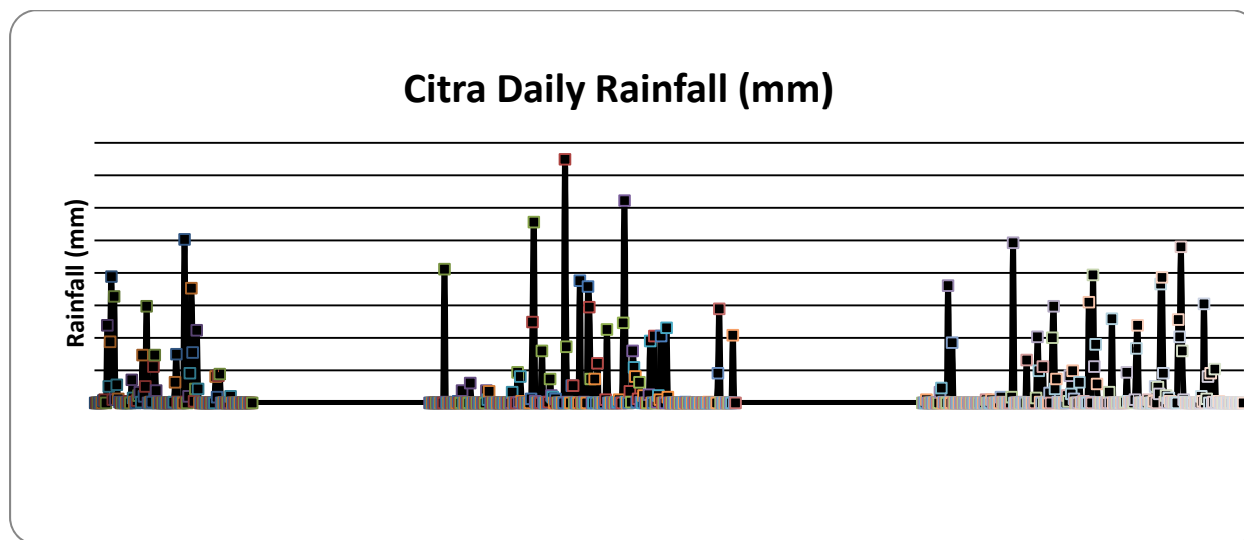


Fig. 1 Daily rainfall (mm) in Ft. Lauderdale during the study period.



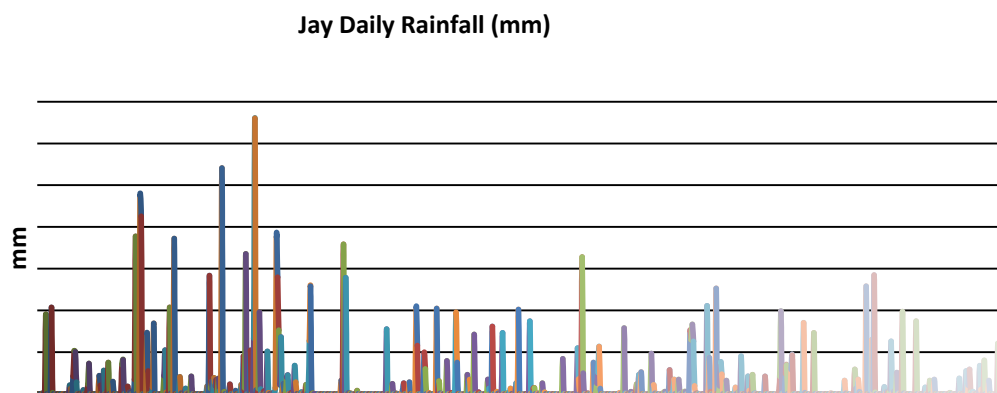


Fig. 34a-c. Rainfall in the 3 test locations throughout the trial period.

Total Nitrate-N Leached

Differences in total annual NO₃-N leached occurred due to location in years 1 and 3 and for the cumulative 3-yr period (Table x). Highest loading was in the Jay location, with no differences between Ft. Lauderdale and Citra (Table 124). In year 2, the only difference was due to N rate (Table 124), with greatest loading coming from the plots that received 490 kg N ha⁻¹. There were no interactions for total NO₃-N loading for any of the combined analyses.

Amount of nitrate-N leached differed due to the interaction of location (L) * nitrogen rate (NR) in yr 1 and by L in yr 1 and 3 and when totaled over the 3 yrs. In yr 2, there was a difference due to NR. There were no responses to irrigation (I). Means of nitrate-N leaching values for all locations by NR and year are shown in Table 125.

Table 124. Analysis of variance of main effects and interactions on NO₃-N leaching and single degree of freedom contrasts between NRs.

Source of variation	TN Yr1	TN Yr2	TN Yr3	TN Yr1-3	PC N Yr1	PCN Yr2	PCN Yr3
	-----kg ha ⁻¹ -----						
Location (L)	**	NS	*	**	**	NS	NS
Nitrogen Rate (NR)	NS	*	NS	NS	***	***	NS
L*NR	NS	NS	NS	NS	**	NS	NS
Irrigation (I)	NS	NS	NS	NS	NS	NS	NS
L*I	NS	NS	NS	NS	NS	*	NS
NR*I	NS	NS	NS	NS	NS	NS	NS
L*NR*I	NS	NS	NS	NS	NS	NS	NS
Contrasts - NR							
196 vs 49 kg ha ⁻¹	NS	NS	*	NS			
196 vs 98 kg ha ⁻¹	NS	NS	NS	NS			
196 vs 294 kg ha ⁻¹	NS	NS	NS	NS			
196 vs 343 kg ha ⁻¹	NS	NS	NS	NS			
196 vs 490 kg ha ⁻¹	NS	***	NS	NS			
196 vs 588 kg ha ⁻¹	NS	NS	NS	NS			

TN= Total nitrate-N leached (kg ha⁻¹). PC N = Percent of applied N leached.

***, **, * Significant at $P = 0.001$, 0.01 , and 0.05 levels, respectively. NS = not significant.

Greater NO₃-N loading at Jay in year 1 is attributed to heavy rainfall volumes (> 1350 mm) throughout the trial period in year 1 due to Hurricane Dennis. In year 3, Jay also experienced heavy rainfall (536 mm) and additionally had decreased turf quality and density in response to winterkill from the winter months preceding year 3. Turf that is not healthy and is not growing or providing adequate root and shoot cover results in greater potential for NO₃-N leaching because it has less probability of intercepting the fertilizer. The ability of damaged turf to assimilate N is not as well documented as other factors related to NO₃-N leaching, but similar findings were reported in Floratam that had sustained loss of density due to insect damage in a study conducted in tubs in a greenhouse. Sharma et al. (2009) reported that NO₃-N leaching from grass with insect damage did not exceed 0.7 % of the applied N, but was higher than from previous cycles when the grass was not damaged and provided better cover.

Although not statistically significant at 0.05%, means breakdown for NO₃-N loading by location for year 2 indicated that leaching was greater in Citra than in Ft. Lauderdale (Table 125).

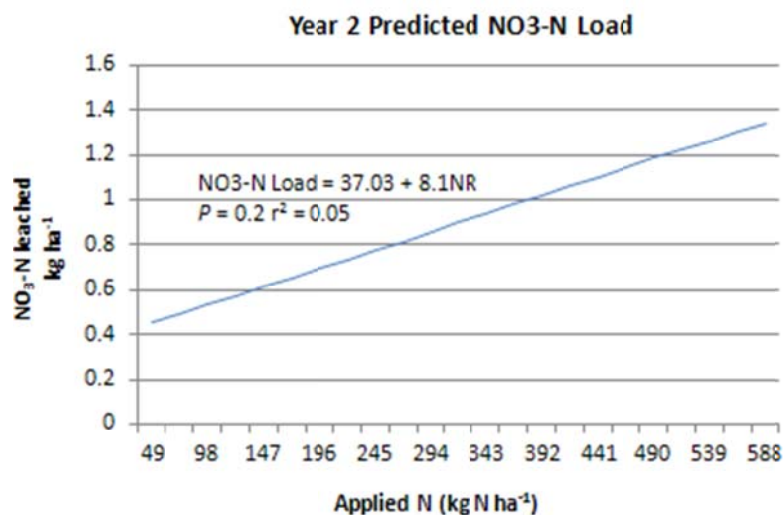
Single degree of freedom contrasts between NRs are displayed in Table 2. In year 1 and over the 3-year study period, there were no differences in NO₃-N leaching between 196 kg N ha⁻¹ (common to all 3 locations and part of IFAS current fertilizer recommendations for all 3 geographical locations) and all other NRs. In year 2, there was a significant difference between 196 and 490 kg N ha⁻¹. This is associated with the higher NO₃-N leached at Citra in this year at the 490 kg ha⁻¹ NR, as previously discussed. The 490 kg ha⁻¹ rate did not differ from either the 98 or the 343 kg ha⁻¹ NR. In year 3, there was a contrast between 196 and 49 kg ha⁻¹, averaged over all Jay and Citra locations. Although analysis of variance did not detect differences in leaching between any rates in either Citra or Jay in this year, there was approximately a 53% reduction in nitrate-N leaching at Jay from plots that received N at 49 vs. those that received 196 kg ha⁻¹. This increased leaching at Jay in year 3 is related to the decreased turf density in response to winterkill from the previous year.

Table 125. Means of nitrate- N leaching values and percent of applied N leached at 3 locations in response to NR. Means are averages of 4 replications per location over a 3-yr period.

Nitrogen Rate (kg ha ⁻¹)	Nitrate-N Leaching (kg ha ⁻¹)				Percent of Applied N Leached		
	Yr 1	Yr 2	Yr 3	Total	Yr 1	Yr 2	Yr 3
588	1.7 c†	0.6 b	0.9	3.2 b	0.9 c	0.2 d	0.3
490	2.4 c	2.3 a	0.6	5.3 b	0.7 c	0.6 bc	0.2
343	1.8 c	1.3 b	0.8	3.9 b	0.8 c	0.5 b-d	0.3
294	5.9 a	0.6 b	12.0	18.5 a	3.1 bc	0.3 cd	4.2
196	2.6 bc	0.6 b	6.7	9.8 ab	2.3 bc	0.4 cd	3.6
98	4.3 a-c	0.5 b	4.8	9.7 ab	6.9 b	0.8 b	5.4
49	5.6 ab	0.6 b	4.4	10.5 ab	17.1 a	1.3 a	9.1
Location							
Ft L	0.8 b	0.5 b	1.0 b	2.4 b	0.9 b	0.5	1.1 b
Citra	1.9 b	1.1 a	0.6 b	3.6 b	1.8 b	0.6	0.5 b
Jay	8.6 a	0.7 ab	14.5 a	23.8 a	13.0 a	0.6	10.7 a

† Within columns, means followed by different letters differ significantly at $P = 0.05$.

Regression analysis for St. Augustinegrass loading over the 3 locations showed a linear relationship between NR and NO₃-N leached in year 2 only (Fig 35), with no association in the other years or for the cumulative total. This indicates that in 2 out of 3 years, even at the range of NRs applied in each location, NO₃-N leaching did not increase in a linear fashion with NR.



There were no other significant responses to NR throughout this study period. Previous research has documented the ability of St. Augustinegrass to take up applied nitrogen in a healthy turf system. In a greenhouse study, Bowman et al. (2002) reported volume-weighted NO₃-N totals of 0.9 to 8.0 mg L⁻¹ lost from ‘Raleigh’ St. Augustinegrass and ‘Meyer’ zoysiagrass (*Zoysia japonica* Steud), respectively. Percentages of applied N leached ranged from 0.9 to 17.6% in Raleigh and Meyer, respectively. Erickson et al. (2001) reported

annual inorganic-N loss of 4.1 kg ha⁻¹ from Floratam and concluded that St. Augustinegrass was a more effective filter for leachate reduction than a mixed landscape planting.

Previous research on other turf species has documented the effects of NR on NO₃-N leaching. Frank et al. (2006) reported higher total NO₃-N losses when N was applied at annual rates of 245 rather than 98 kg N ha⁻¹ to Kentucky bluegrass (*Poa pratensis* L.). The authors concluded that application of the low NR provided minimal potential for groundwater pollution, but that the high rate, particularly when applied as a single dose, water soluble N source, may result in NO₃-N levels in excess of the USEPA safe levels of 10 mg NO₃-N L⁻¹. Morton et al. (1988) reported greatest annual flow-weighted nitrate concentration (4.02 mg L⁻¹) in Kentucky bluegrass that received high N (244 kg N ha⁻¹ yr⁻¹) and excessive irrigation (3.75 cm wk⁻¹ regardless of rainfall), well below the USEPA safe water standards. Annual NO₃-N losses for this treatment totaled 32 kg NO₃-N ha⁻¹. The authors concluded that inorganic N leaching losses from appropriate home lawn care practices would not contribute to ground water contamination, but that care should be used when fertilizing lawns in coastal watersheds.

In addition to NR, other factors have also been studied with respect to their influence on NO₃-N leaching. The influence of NR and irrigation, while not significant in this research, has been shown to strongly influence nitrate-N movement in some published reports. Snyder et al. (1984) reported significantly less NO₃-N leached from bermudagrass (*Cynodon dactylon* L. x *C. transvaalensis* Burt-Davy) that received sensor-based irrigation treatments than from plots receiving a daily irrigation regime. Brown et al. (1977), also working with bermudagrass, reported that NO₃-N losses were a function of NR and applied irrigation, with minimal losses from inorganic N sources when irrigation was matched with evapotranspiration (ET). Clearly, proper irrigation management is critical for both reduction of potential leaching losses and for maintenance of a healthy turf.

Other factors reported to influence NO₃-N leaching include N source (Easton and Petrovic, 2004; Guillard and Kopp, 2004; Saha et al., 2007). Some published reports have noted differences in NO₃-N leached in response to N source, while others report few differences. We chose a highly soluble N source for this research to represent a worst-case scenario in representing NO₃-N leaching. Maturity of the grass has been noted by numerous researchers as impacting NO₃-N leaching (Bowman et al., 2002; Easton and Petrovic, 2004; Erickson et al., 2001; Geron et al., 1993), as well as root architecture (Bowman et al., 1998). Nitrate-N levels reported here are much lower than those reported on newly established turf (Trenholm et al. 2012) due to the ability of St. Augustinegrass to provide dense root and shoot cover when established.

Percent of Applied N Leached

The percent of applied N that leached differed due to an interaction of L*NR in year 1 only and due to main effect of NR in year 2 (Table 124). In year 1, Ft. Lauderdale observed no response to NR, while in both Citra and Jay, highest percentage leached was from turf that received the lowest NR of 49 kg ha⁻¹ (Table 125). This is a typical response from lower NRs, as low levels of applied NO₃⁻-N can result in high percentages leached given the small amount applied.

In year 2, there was a response to NR across locations. The low rate of 49 kg ha⁻¹ resulted in the highest percentage of leached nitrate-N (Table 6). Percentages at all other NRs were below 1% of applied N. There were no responses to irrigation in any year.

Conclusions

Results of this research indicate that there is little difference in NO₃-N loading from healthy, established St. Augustinegrass due to NR. On a statewide basis, NO₃-N leaching had few responses to NR in Floratam St. Augustinegrass. Exceptions to this were found in turf that had suffered damage due to winterkill in Jay, due to reduced root and shoot growth and ability to intercept the fertilizer, or when there was excessive rainfall, such as from a hurricane.

Regression analysis likewise showed no association with applied NR and NO₃-N leached in 2 of 3 years. These results indicate that water soluble nitrogen could potentially be applied at higher than currently allowed rates to healthy turfgrass without causing increased NO₃-N loading. In spite of the documented ability for N uptake demonstrated by St. Augustinegrass, there are many other factors that may also contribute to NO₃-N leaching. Due to these other factors and due to the complex dynamics of N cycling in turf, it is recommended that the N application rates currently recommended by IFAS be maintained, although the single application amounts for water soluble N sources could be reviewed.

For optimal reduction of NO₃-N movement from lawns, it is critical to address proper cultural practices, including irrigation and mowing height. Presence of biotic and abiotic stresses must also be considered, as these can lead to reduced cover and increased potential for nitrate-N leaching.

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COMPARISON OF SAMPLE PRESERVATION METHODS

Samples were collected from the Winter Fertilization Study and sampled with one of four preservation methods:

1. Acidified and analyzed within 28 days
2. Frozen and analyzed within 48 days
3. Frozen and analyzed within 111 days
4. Frozen and analyzed within 179 days

Data were analyzed for effects of timing, N rate and their interaction.

Table 126. Preservation method analysis.

ANOVA	NO ₃ -N (ppm)
Preservation	NS
N Rate	**
P*NR	NS
Means	
Preservation Method	
4	0.01667 a
3	0.00083 a
2	0.02125 a
1	0.00792 a
N Rate (kg ha ⁻¹)	
98.0	0.00063 b
49.0	-0.02875 b
24.5	-0.02938 b
12.25	0.06188 a
6.12	0.00750 b
0	-0.03188 b

† Within columns, means followed by different letters differ significantly at $P = 0.05$.

** Significant at the 0.01 probability level.

NS Not significant at the 0.05 probability level.

There were no differences found due to preservation method or timing in the NO₃-N concentration reported by the Analytical Research Lab for the samples analyzed.

JAY PROJECTS – DR. J. BRYAN UNRUH

Nitrate Leaching During Establishment

Nitrogen Effects on Centipedegrass Establishment After Seeding Seedling Establishment - 2005

There was no effect of nitrogen application date or rate on centipedegrass seedling population seeded on 16 May 2005 (Table 127).

Table 127. Nitrogen application date and rate effects on Centipedegrass seedling establishment in 2005.

	Average Seedlings/m ² 29 Jun 05
Application date	
PTS (16 May)	82.9
30DAS (16 June) ...	73.2
<i>P(F)</i>	NS
Rate (kg/ha)	
12.25	80.7
24.50	75.3
49.00	78.6
<i>P(F)</i>	NS
<i>App. x Rate</i>	NS

PTS= nitrogen application made Prior To Seeding
30DAS =nitrogen application made 30 Days After Seeding. NS = $P>0.05$.

Turf Quality, Color, and Density – 2005-2006 Seeded Centipedegrass quality was unaffected by fertilizer application timing in both runs of the experiment with the exception of the initial rating where fertilizer applied 30DAS (June) resulted in slightly better quality (Table 128). Fertilizer applied 30DAS (June) generally resulted in better turfgrass color, especially during the initial months of each study (Table 129). Similar quality and color scores were obtained regardless of the rate of nitrogen applied. On August 2005 the nitrogen rate of 49.0 kg/ha also slightly increased quality. Centipedegrass has a low fertility requirement which may explain the minimal response to nitrogen fertilization.

In 2005, nitrogen applied 30DAS (June) produced greater density on nearly all rating dates compared to Centipedegrass fertilized immediately prior to seeding (PTS) in May (Table 130). This trend was not observed in the second run of the trial (Table 130). Rate of applied nitrogen had no effect on Centipedegrass density.

Table 128. Nitrogen timing and rate effect on centipede turf quality following seeding in 2005 and 2006.

	<u>2005</u>					<u>2006</u>			
	Jun 05	Jul 05	Aug 05	Sep 05	Oct 05	Mar 06	Jul 06	Aug 06	Sep 06
Application date									
PTS (May)	6.7 b	6.6	6.9	6.3	6.0	.	7.9	8.5	8.0
30DAS (June)	7.0 a	6.7	7.1	6.4	6.0	.	8.1	8.5	8.0
<i>P(F)</i>	***	NS	NS	NS	NS		NS	NS	NS
Rate (kg/ha)									
12.5	6.9	6.5	6.9 b	6.3	6.0	.	7.9	8.5	8.0
24.0	6.9	6.6	6.9 b	6.3	6.0	.	8.1	8.5	8.0
49.0	6.9	6.8	7.3 a	6.4	6.0	.	8.1	8.5	8.0
<i>P(F)</i>	NS	NS	**	NS	NS		NS	NS	NS
<i>App.x Rate</i>	NS	NS	NS	NS	NS		NS	NS	NS

Applications made on 16 May and 8 June in 2005 and 3 May and 2 June in 2006. PTS= nitrogen application made Prior To Seeding, 30DAS =nitrogen application made 30 Days After Seeding. Quality visually rated on a scale of 1 to 9 where 9=best. Data pooled for each month. Means in each column followed by the same letter(s) are not significantly different according to Fisher's Protected LSD ($P=0.05$). ***= $P < 0.001$ and NS= $P > 0.05$.

Table 129. Nitrogen timing and rate effect on centipede turf color following seeding in 2005 and 2006.

	<u>2005</u>					<u>2006</u>			
	Jun 05	Jul 05	Aug 05	Sep 05	Oct 05	Mar 06	Jul 06	Aug 06	Sep 06
Application date									
PTS (May)	6.2 b	6.2 b	6.4 a	6.0	5.5	.	8.0 b	8.5	7.8
30DAS (June)	6.8 a	6.5 a	6.2 b	6.0	5.5	.	8.2 a	8.5	7.8
<i>P(F)</i>	****	*	**	NS	NS		**	NS	NS
Rate (kg/ha)									
12.5	6.5	6.2 b	6.4	6.0	5.5	.	7.9	8.5	7.8
24.0	6.5	6.3 b	6.3	6.0	5.5	.	8.1	8.5	7.8
49.0	6.6	6.6 a	6.4	6.0	5.5	.	8.1	8.5	7.8
<i>P(F)</i>	NS	*	NS	NS	NS		NS	NS	NS
<i>App.x Rate</i>	NS	NS	NS	NS	NS		NS	NS	NS

Applications made on 16 May and 8 June in 2005 and 3 May and 2 June in 2006. PTS= nitrogen application made Prior To Seeding, 30DAS =nitrogen application made 30 Days After Seeding. Color visually rated on a scale of 1 to 9 where 9=best. Data pooled for each month. Means in each column followed by the same letter(s) are not significantly different according to Fisher's Protected LSD ($P=0.05$). *, **, **** = $P < 0.05$, $P < 0.01$, and $P < 0.0001$, respectively. NS= $P > 0.05$.

Table 130. Nitrogen timing and rate effect on centipede turf density following seeding in 2005 and 2006.

	<u>2005</u>					<u>2006</u>			
	Jun 05	Jul 05	Aug 05	Sep 05	Oct 05	Mar 06	Jul 06	Aug 06	Sep 06
Application date									
PTS (May)	2.0	2.9 b	4.2 b	5.0 b	5.6 b	6.0 b	2.6	3.5	5.5
30DAS (June)	2.1	3.8 a	5.1 a	5.7 a	6.4 a	6.8 a	2.8	4.1	5.6
<i>P(F)</i>	NS	**	**	**	**	**	NS	NS	NS
Rate (kg/ha)									
12.5	2.1	3.2	4.4	5.2	5.8	6.3	2.7	3.8	5.7
24.0	2.2	3.5	4.7	5.3	5.9	6.3	2.4	3.6	5.2
49.0	2.3	3.8	4.9	5.6	6.4	6.8	2.8	4.0	5.7
<i>P(F)</i>	NS	NS	NS	NS	NS	NS	NS	NS	NS
<i>App x Rate</i>	NS	NS	NS	NS	NS	NS	NS	NS	NS

Applications made on 16 May and 8 June in 2005 and 3 May and 2 June in 2006. PTS= nitrogen application made Prior To Seeding, 30DAS =nitrogen application made 30 Days After Seeding. Density visually rated on a scale of 1 to 9 where 9=best. Data pooled for each month. Means in each column followed by the same letter(s) are not significantly different according to Fisher's Protected LSD ($P=0.05$). **= $P < 0.01$ and NS= $P > 0.05$.

Nitrogen Effects on Centipedegrass Establishment After Seeding – Nitrate Leaching – 2005 – Trial 1

Individual samples from each time period were added together in the monthly summaries. Sampling events prior to the initiation of the trial confirmed that no differences existed between any of the plots (Table 131). No differences in nitrogen leaching could be attributed to application timing or rate throughout the first 60d of the study. Differences due to application timing were detected at three sampling dates (17 Oct, 20 Oct, and 25 Oct) which correlated to five and four months after the May (PTS) and June (30DAS) fertilizer application dates (data not presented). At the conclusion of the study, greater nitrogen leaching was observed in the plots receiving nitrogen at the time of seeding (PTS) (Table 131) and a rate response was observed with higher applied nitrogen resulting in greater leaching (Table 131). These differences, however, are not statistically significant. The amount of nitrate leached into the soil seems to spike following major rain events for all three rates in 2005 (Figure 35).

Table 131. Seeded Centipedegrass Establishment Study total N value (MDL) leached by month in 2005.

	Total N (kg/ha)							Total Post
	Pre	T1	T2	T3	T4	T5	T6	
Application date								
PTS (16 May) ...	0.072	5.015	0.621	3.985	0.242	0.074	0.049	9.986
30DAS(16 June)	0.048	3.766	0.397	3.597	0.113	0.077	0.039	7.929
<i>P</i> (F)	NS	NS	NS	NS	NS	NS	NS	NS
Rate (kg/ha)								
12.5	0.048	3.164	0.526	3.084	0.167	0.073	0.045	7.059
24.0	0.075	3.758	0.653	4.243	0.141	0.067	0.033	8.893
49.0	0.057	6.160	0.348	4.046	0.227	0.087	0.054	10.920
<i>P</i> (F)	NS	NS	NS	NS	NS	NS	NS	NS
<i>App. x Rate</i>	NS	NS	NS	NS	NS	NS	NS	NS

PTS= nitrogen application made Prior To Seeding, 30DAS =nitrogen application made 30 Days After Seeding. Data corrected for MDL if data ≤ 0.148 then =0.148. No significant interactions between application date and rate, therefore only means for main effects of application date and rate are presented. Means followed by the same letter(s) in a column are not significantly different according to Duncan's Multiple Range Test ($P=0.05$). NS = $P>0.05$. Pre= 6 May-12 May, T1=17 May- 16 Jun, T2=20 Jun-18 Jul, T3=21 Jul-18 Aug, T4=22 Aug-19 Sep, T5=22 Sep-20 Oct, T6=25 Oct- 7 Nov, Total post =accumulated N post 16 May treatment.

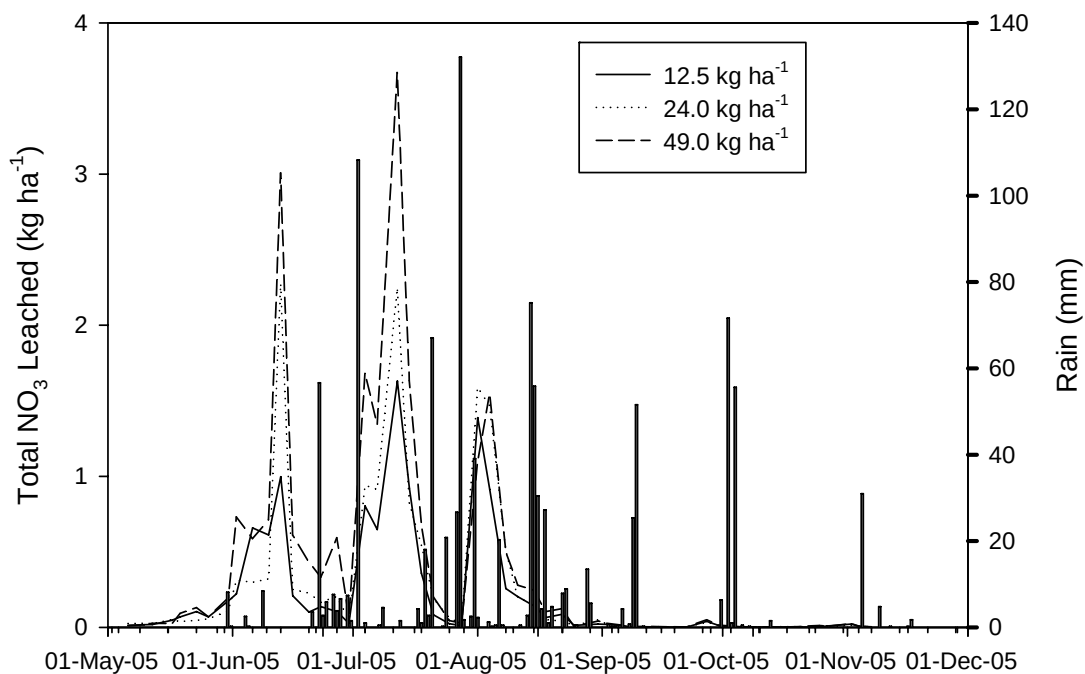


Figure 35: Total NO₃ leached from nitrogen applied in 2005 seeded centipedegrass and the corresponding rainfall.

Nitrogen Effects on Centipedegrass Establishment After Seeding – Nitrate Leaching – 2006 – Trial 2

Individual samples from each time period were added together in the monthly summaries. Sampling events prior to the initiation of the trial confirmed that no differences existed between any of the plots (Table 132). In the first 30d of the 2006 run of the seeded Centipedegrass study showed no differences in nitrate leaching regardless of when the nitrogen was applied or the rate applied (Table 132).

Similar results were noted in the second 30d time period up until 57d after the 16 May 2006 application date (29 June 2006). On this sampling date, more nitrogen leached from plots receiving fertilizer applied at the time of seeding (PTS) than when applied 30 DAS (data not presented). This effect was observed on sampling dates through 10 July (Table 132). No significant rainfall events occurred during this period of time. A nitrogen rate response was observed on only one sampling date (10 July 2006). No differences between application timing and nitrogen rate were detected during the period following the 60d designated sampling period following the 30 DAS fertilizer application (10 Aug – 9 Oct) (Table 6). There were no significant differences between the total nitrate leached regardless of when the nitrogen was applied or the rate applied (Table 132). The amount of nitrate leached into the soil seems to spike following major rain events for all three rates in 2006 (Figure 36).

Table 132. Seeded Centipedegrass Establishment Study total N value (MDL) leached by month in 2006.

	Total N (kg/ha)						Total Post
	Pre	T1	T2	T3	T4	T5	
Application date							
PTS (3 May)....	0.079	0.069	2.103	4.183	6.102	0.804	13.261
30DAS(2 June)	0.078	0.085	0.902	1.721	7.278	0.401	10.387
<i>P</i> (F)	NS	NS	NS	NS	NS	NS	NS
Rate (kg/ha)							
12.5.....	0.081	0.078	1.211	2.029	3.416	0.550	7.284
24.0.....	0.069	0.069	0.967	2.990	7.907	0.466	12.399
49.0.....	0.085	0.085	2.330	3.837	8.746	0.791	15.790
<i>P</i> (F)	NS	NS	NS	NS	NS	NS	NS
<i>App. x Rate</i>	NS	NS	NS	NS	NS	NS	NS

PTS= nitrogen application made Prior To Seeding, 30DAS =nitrogen application made 30 Days After Seeding. Data corrected for MDL if data ≤ 0.148 then =0.148. No significant interactions between application date and rate, therefore only means for main effects of application date and rate are presented. Means followed by the same letter(s) in a column are not significantly different according to Duncan's Multiple Range Test ($P=0.05$). NS = $P>0.05$. Pre= 14 Apr-1 May, T1=5 May- 1 Jun, T2=5 Jun- 3 Jul, T3=6 Jul-3 Aug, T4=7 Aug-5 Sep, T5=8 Sep- 9 Oct, Total post=accumulated N since 3 May treatment.

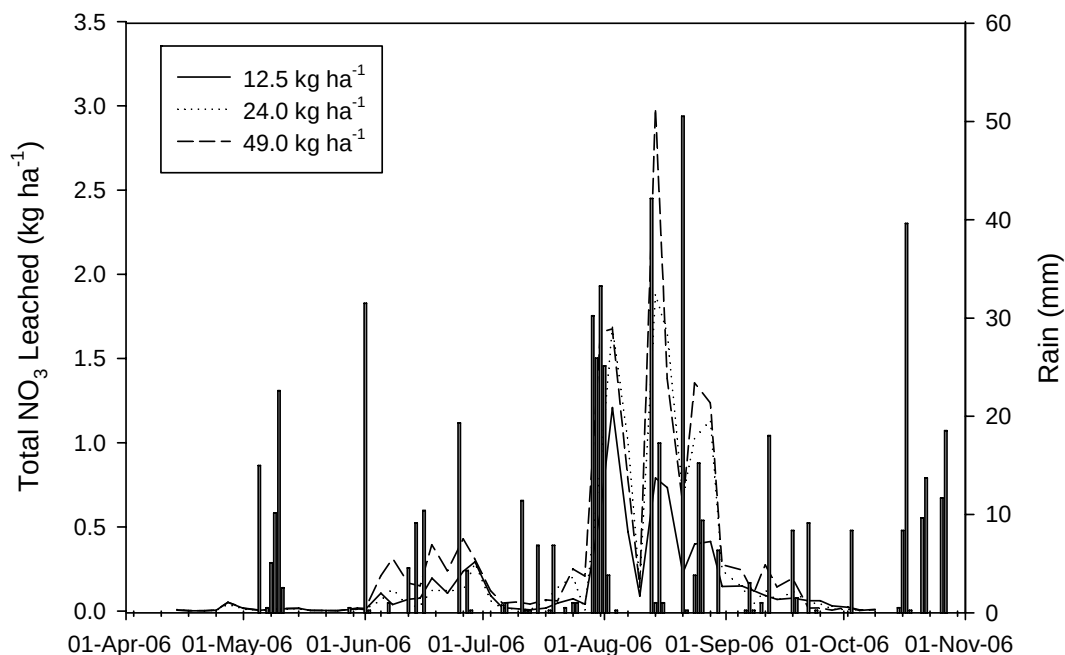


Figure 36: Total NO₃ leached from nitrogen applied in 2006 seeded centipedegrass and the corresponding rainfall.

Nitrogen Effects on Centipedegrass Establishment After Seeding – Nitrate Leaching –Combined Analysis

There were no significant effects of application date or rate on nitrate leaching across both studies (Table 133). The only differences detected were between the 2005 and 2006 trials for nitrate leaching prior to seeding of the centipedegrass where the 2006 trial showed slightly higher nitrate (Table 133). During the first month of sampling the 2005 showed significantly higher leaching, but this difference was not detected in the remaining periods (Table 133).

Table 133. Seeded Centipedegrass Establishment Study total N value (MDL) leached by month combined across years.

	Total N (kg/ha)						Total Post
	Pre	T1	T2	T3	T4	T5	
Year							
2005	0.060	4.361					
	b	a	0.509	3.791	0.178	0.076	8.957
2006	0.079	0.077					
	a	b	1.503	2.952	6.690	0.603	11.824
<i>P(F)</i>	***	*	NS	NS	NS	NS	NS
Application date							
PTS (May)	0.076	2.542	1.362	4.084	3.172	0.439	11.624
30DAS (June) ...	0.063	1.895	0.650	2.659	3.696	0.239	9.158
<i>P(F)</i>	NS	NS	NS	NS	NS	NS	NS
Rate (kg/ha)							
12.5	0.065	1.621	0.869	2.557	1.791	0.312	7.171
24.0	0.072	1.913	0.810	3.616	4.024	0.267	10.646
49.0	0.071	3.122	1.339	3.941	4.486	0.439	13.355
<i>P(F)</i>	NS	NS	NS	NS	NS	NS	NS
<i>Year x App</i>	NS	NS	NS	NS	NS	NS	NS
<i>Year x Rate</i>	NS	NS	NS	NS	NS	NS	NS
<i>App. x Rate</i>	NS	NS	NS	NS	NS	NS	NS
<i>Year x App x Rate</i> ..	NS	NS	NS	NS	NS	NS	NS

PTS= nitrogen application made Prior To Seeding, 30DAS =nitrogen application made 30 Days After Seeding. Data corrected for MDL if data ≤ 0.148 then =0.148. No significant interactions between year, application date and rate, therefore only means for main effects of year, application date and rate are presented. Means followed by the same letter(s) in a column are not significantly different according to Duncan's Multiple Range Test ($P=0.05$). NS = $P>0.05$.

Nitrogen Effects on Centipedegrass Establishment After Seeding – Nitrate Leaching –% applied 2005 and 2006

The percentage of nitrogen applied that was leached was determined for each monthly time period. In 2005 % of nitrogen leached from application was highest at the 12.5 kg/ha rate at T2 (60 DAA) and T5 (150 DAA), no other differences were detected between the rates or application date (Table 134). In the 2006 trial the 12.5 kg/ha rate was only significantly higher during T1 (30 DAA) (Table 135). The total % leached for 12.5, 24.0, and 49.0 kg/ha was 56.5, 37.0 and 22.3 % in 2005 respectively and 58.3, 51.7, and 32.2 % respectively (Tables 134 and 135). When both years were combined the only differences detected occurred during the pre planting sampling and there were no significant interactions between year, application date, and rate (Table 136).

Table 134. Seeded Centipedegrass Establishment Study % of nitrogen from application leached by month in 2005.

	% Nitrogen applied							Total Post
	Pre	T1	T2	T3	T4	T5	T6	
Application date								
PTS(16 May)	0.34	20.14	3.13	16.43	0.99	0.33	0.22	41.24
30DAS(16 June)	0.20	15.55	1.96	17.31	0.60	0.36	0.19	35.97
<i>P</i> (F)	NS	NS	NS	NS	NS	NS	NS	NS
Rate (kg/ha)								
12.5	0.38	25.31	4.21 a	24.67	1.33	0.59 a	0.36	56.47
24.0	0.32	15.66	2.72 ab	17.68	0.59	0.28 b	0.14	37.06
49.0	0.12	12.57	0.71 b	8.26	0.46	0.18 b	0.11	22.29
<i>P</i> (F)	NS	NS	*	NS	NS	*	NS	NS
<i>App. x Rate</i>	NS	NS	NS	NS	NS	NS	NS	NS

PTS= nitrogen application made Prior To Seeding, 30DAS =nitrogen application made 30 Days After Seeding. Pre= 6 May-12 May, T1=17 May- 16 Jun, T2=20 Jun-18 Jul, T3=21 Jul-18 Aug, T4=22 Aug-19 Sep, T5=22 Sep-20 Oct, T6=25 Oct- 7 Nov, Total post = accumulated N since 16 May treatment. Data corrected for MDL if data ≤ 0.148 then =0.148. No significant interactions between application date and rate, therefore only means for main effects of application date and rate are presented. Means followed by the same letter(s) in a column are not significantly different according to Duncan's Multiple Range Test ($P=0.05$). *= $P<0.05$ and NS = $P>0.05$.

Table 135. Seeded Centipedegrass Establishment Study % of nitrogen from application leached by month in 2006.

	% Nitrogen applied						Total Post
	Pre	T1	T2	T3	T4	T5	
Application date							
PTS (3 May)	0.37	0.34	8.52	16.69	24.64	4.10	54.30
30DAS (2 June)	0.37	0.38	3.79	7.66	27.44	1.20	40.48
<i>P</i> (F)	NS	NS	NS	NS	NS	NS	NS
Rate (kg/ha)							
12.5	0.65 a	0.62 a	9.69	16.23	27.33	4.40	58.27
24.0	0.29 b	0.29 b	4.03	12.46	32.95	1.94	51.66
49.0	0.17 b	0.17 b	4.76	7.83	17.85	1.62	32.22
<i>P</i> (F)	*	*	NS	NS	NS	NS	NS
<i>App. x Rate</i>	NS	NS	NS	NS	NS	NS	NS

PTS= nitrogen application made Prior To Seeding, 30DAS =nitrogen application made 30 Days After Seeding. Pre= 14 Apr-1 May, T1=5 May- 1 Jun, T2=5 Jun- 3 Jul, T3=6 Jul-3 Aug, T4=7 Aug-5 Sep, T5=8 Sep- 9 Oct, Total post = accumulated N since 3 May treatment. Data corrected for MDL if data ≤ 0.148 then =0.148. No significant interactions between application date and rate, therefore only means for main effects of application date and rate are presented. Means followed by the same letter(s) in a column are not significantly different according to Duncan's Multiple Range Test ($P=0.05$). *= $P<0.05$ and

NS = $P > 0.05$.

Table 136 Seeded Centipedegrass Establishment Study % of nitrogen from application leached by month combined across years.

	% Nitrogen applied						Total Post
	Pre	T1	T2	T3	T4	T5	
Year							
2005	0.27 b	17.85	2.54	16.87	0.79	0.35	38.60
2006	0.37 a	0.36	8.16	12.17	26.04	2.65	47.39
<i>P(F)</i>	*	NS	NS	NS	NS	NS	NS
Application date							
PTS (3 May)	0.36	10.24	5.82	16.56	12.81	2.22	47.77
30DAS(2 June) .	0.29	7.97	2.88	12.48	14.02	0.78	38.22
<i>P(F)</i>	NS	NS	NS	NS	NS	NS	NS
Rate (kg/ha)							
12.5	0.52 a	12.97	6.95	20.45	14.33	2.49	57.37
24.0	0.30 b	7.97	3.37	15.07	16.77	1.11	44.36
49.0	0.14 b	6.37	2.73	8.04	9.16	0.90	27.26
<i>P(F)</i>	***	NS	NS	NS	NS	NS	NS
<i>Year x App</i>	NS	NS	NS	NS	NS	NS	NS
<i>Year x Rate</i>	NS	NS	NS	NS	NS	NS	NS
<i>App. x Rate</i>	NS	NS	NS	NS	NS	NS	NS
<i>Year x App x Rate</i> ..	NS	NS	NS	NS	NS	NS	NS

PTS= nitrogen application made Prior To Seeding, 30DAS =nitrogen application made 30 Days After Seeding. Data corrected for MDL if data ≤ 0.148 then =0.148. No significant interactions between year, application date and rate, therefore only means for main effects of year, application date and rate are presented. Means followed by the same letter(s) in a column are not significantly different according to Duncan's Multiple Range Test ($P=0.05$).

* and ***= $P < 0.05$ and $P < 0.001$, respectively. NS = $P > 0.05$.

Nitrogen Effects on Centipedegrass Establishment After Sodding

Root and Shoot Growth- 2007

Root growth as measured by dry weight, ash and % ash of centipede grass s was not affected by nitrogen application date or rate (Table 137). Nitrogen application date and rate did not have any effect centipede root dry weight, ash or % ash. Differences were only detected between trials which may be due to the time of year trials were initiated with the first trial having increased root weight and the second trial increase % ash (Table 137). Centipedegrass shoot weight was increased by increasing application of nitrogen in study 1 and in study 2 by 6 November (Tables 138and 139). Application date had no effect in trial 1, but in trial 2 the 30DAS application increased shoot growth on 26 Sep, 11 Oct, and 6 Nov (Table 139).

Table 137. Nitrogen application date and rate effect on sodded centipedegrass root growth.

	Root dry weight (g)	Ash (g)	Ash (%)
Trial			
Trial 1	0.451 a	0.035	7.50 b
Trial 2	0.306 b	0.034	11.05 a
<i>P(F)</i>	*	NS	**
Application date			
PTS	0.389	0.036	9.52
30DAS	0.368	0.032	9.03
<i>P(F)</i>	NS	NS	NS
Rate (kg/ha)			
12.5	0.399	0.037	9.59
24.0	0.375	0.034	9.12
49.0	0.361	0.032	9.12
<i>P(F)</i>	NS	NS	NS
<i>Trial X App.</i>	NS	NS	NS
<i>Trial X Rate</i>	NS	NS	NS
<i>App. x Rate</i>	NS	NS	NS
<i>Trial x App. x Rate</i>	NS	NS	NS

PTS= nitrogen application made Prior To Sodding, 30DAS =nitrogen application made 30 Days After Sodding. *, * = $P < 0.05$ and $P < 0.01$, respectively. NS = $P > 0.05$.

Table 138. Nitrogen timing and rate effect on sodded centipedegrass shoot growth, study 1.

	Shoot dry weight (g)
	3 Jul
Application date	
PTS (17 April)	5.24
30DAS (16 May)	5.49
<i>P</i> (<i>F</i>)	NS
Rate (kg/ha)	
12.5	3.33 b
24.0	5.16 ab
49.0	7.61 a
<i>P</i> (<i>F</i>)	**
<i>App. x Rate</i>	NS

PTS= nitrogen application made Prior To Sodding,
30DAS =nitrogen application made 30 Days After Sodding.

** = $P < 0.01$. NS = $P > 0.05$.

Table 139. Nitrogen timing and rate effect on sodded centipede shoot growth, study 2.

	Shoot dry weight (g)			
	26 Sep	4 Oct	11 Oct	6 Nov
Application date				
PTS (21 August)	17.14 b	16.38	11.72 b	14.57 b
30DAS (21 September)	20.03 a	17.54	18.14 a	18.03 a
<i>P</i> (<i>F</i>)	*	NS	***	*
Rate (kg/ha)				
12.5	16.97	14.30	12.81	13.15b
24.0	19.51	19.61	15.06	16.38ab
49.0	19.28	16.98	16.92	19.37a
<i>P</i> (<i>F</i>)	NS	NS	NS	*
<i>App. x Rate</i>	NS	NS	NS	NS

PTS= nitrogen application made Prior To Sodding, 30DAS =nitrogen application made 30 Days After Sodding. *** and * = $P < 0.001$ and $P < 0.05$, respectively. NS = $P > 0.05$.

Nitrogen Effects on Centipedegrass Establishment After Sodding – Turf Quality, Color, and Density – 2007

Centipedegrass established from sod showed a slight improvement in turf quality when fertilized 30 DAS versus at the time of sodding (PTS) during the first run of the experiment (Table 140). This effect was not noted during the second run of the experiment (Table 140). A dose response was also observed with higher nitrogen rates producing higher turf quality during Trial 1 and to a lesser extent in Trail 2 (Table 140). However, the lowest level of nitrogen yielded acceptable turf quality. Similar results were observed for turf color (Tables 141). Centipedegrass density was largely unaffected by nitrogen timing or nitrogen rate in both runs of the experiment (Tables 16).

Table 140. Nitrogen timing and rate effect on centipede turf quality following sodding in 2007.

	Trial 1							Trial 2		
	15 May	23 May	6 Jun	14 Jun	24 Sep	5 Oct	15 Oct	24 Sep	5 Oct	15 Oct
Application date										
PTS	7.4	7.5	7.5	7.3	7.5	7.3	7.6	7.5	7.3	7.6
			b	b		a			a	
30DAS	7.2	7.8	7.9	7.8	7.3	7.0	7.8	7.3	7.0	7.8
			a	a		b			b	
<i>P(F)</i>	NS	NS	*	*	NS	*	NS	NS	*	NS
Rate (kg/ha)										
12.5	7.1	7.3	7.2	7.1	7.4	7.1	7.6	7.4	7.1	7.6
		b	b	b			ab			ab
24.0	7.4	7.8	7.8	7.6	7.3	7.1	7.5	7.3	7.1	7.5
		a	a	ab			b			b
49.0	7.3	7.9	8.0	7.9	7.4	7.1	7.9	7.4	7.1	7.9
		a	a	a			a			a
<i>P(F)</i>	NS	*	**	*	NS	NS	*	NS	NS	*
<i>App.x Rate</i>	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

PTS= nitrogen application made Prior To Sodding, 30DAS =nitrogen application made 30 Days After Sodding. Applications made on 17 April and 16 May in 2007 for study 1 and 21 August and 21 September 2007 in study 2. Quality visually rated on a scale of 1 to 9 where 9=best.

Means in each column followed by the same letter(s) are not significantly different according to Fisher's Protected LSD ($P=0.05$). *, **= $P < 0.05$ and $P < 0.01$, respectively and NS = $P > 0.05$.

Table 141. Nitrogen timing and rate effect on centipede turf color following sodding in 2005 and 2006.

	Trial 1							Trial 2		
	15 May	23 May	6 Jun	14 Jun	24 Sep	5 Oct	15 Oct	24 Sep	5 Oct	15 Oct
Application date										
PTS	7.6 a	7.6 b	7.4 b	7.3	7.6 a	7.2 a	7.4	7.6 a	7.2 a	7.4
30DAS	7.2 b	8.0 a	8.0 a	7.8	7.1 b	6.7 b	7.5	7.1 b	6.7 b	7.5
<i>P(F)</i>	*	*	**	NS	**	*	NS	**	*	NS
Rate (kg/ha)										
12.5	7.3	7.3 b	7.2 b	6.9 b	7.5	7.1	7.3 b	7.5	7.1	7.3 b
24.0	7.5	7.9 a	7.8 a	7.6 a	7.2	6.9	7.3 b	7.2	6.9	7.3 b
49.0	7.4	8.2 a	8.1 a	8.1 a	7.3	6.8	7.8 a	7.3	6.8	7.8 a
<i>P(F)</i>	NS	**	***	**	NS	NS	**	NS	NS	**
<i>App.x Rate</i>	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

PTS= nitrogen application made Prior To Sodding, 30DAS =nitrogen application made 30 Days After Sodding. Applications made on 17 April and 16 May in 2007 for study 1 and 21 August and 21 September 2007 in study 2. Color visually rated on a scale of 1 to 9 where 9=best. Means in each column followed by the same letter(s) are not significantly different according to Fisher's Protected LSD ($P=0.05$). *, **, *** = $P<0.05$, $P<0.01$, and $P<0.001$, respectively. NS= $P>0.05$.

Table 142. Nitrogen timing and rate effect on centipede turf density following sodding in 2005 and 2006.

	Trial 1							Trial 2		
	15 May	23 May	6 Jun	14 Jun	24 Sep	5 Oct	15 Oct	24 Sep	5 Oct	15 Oct
Application date										
PTS	7.3	7.4	7.3	7.3	7.8	7.0	7.6 b	7.8	7.0	7.6 b
30DAS	7.2	7.6	7.7	7.7	7.7	7.2	7.9 a	7.7	7.2	7.9 a
<i>P(F)</i>	NS	NS	NS	NS	NS	NS	**	NS	NS	**
Rate (kg/ha)										
12.5	7.1	7.1	7.1	7.2	7.7	7.1	7.7	7.7	7.1	7.7
24.0	7.4	7.8	7.6	7.5	7.7	7.1	7.7	7.7	7.1	7.7
49.0	7.2	7.6	7.8	7.8	7.8	7.1	7.9	7.8	7.1	7.9
<i>P(F)</i>	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
<i>App.x Rate</i>	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

PTS= nitrogen application made Prior To Sodding, 30DAS =nitrogen application made 30 Days After Sodding. Applications made on 17 April and 16 May in 2007 for study 1 and 21 August and 21 September 2007 in study 2. Density visually rated on a scale of 1 to 9 where 9=best. Data pooled for each month. Means in each column followed by the same letter(s) are not significantly different according to Fisher's Protected LSD ($P=0.05$). ** = $P<0.01$ and NS= $P>0.05$.

Nitrogen Effects on Centipedegrass Establishment after Sodding – Nitrate Leaching – 2007

Trial 1: In the first run of the experiment, no differences in nitrogen leaching were attributed to nitrogen application timing or rate (Table 143). During the 60d trial, 4.02” of rainfall fell during this period. During this same time period, the total evapotranspiration (ET) was 8.83”. Though supplemental irrigation was applied, significant leaching events were not prevalent during this run of the experiment (Figure 37).

Trial 2: In the first 30d after the 21 August 2007 fertilizer application, no differences in nitrogen leaching (application timing or rate) were observed (Table 144). Abnormally high leaching events were observed on 4 Sep 2007, 20-24 Sep 2007, and 19-23 Oct 2007. Each of these leaching events can be attributed to rainfall events that occurred within one week of the sampling period. The week prior to 4 Sep 2007 produced 1.45” of rainfall. Similarly, during 18-24 Sep 2007, 2.70” of rainfall fell. Similarly, 7.03” of rainfall fell during the week preceding the 19-23 Oct 2007 sampling dates. Rainfall exceeded ET by nearly 2:1 during this run of the experiment (Figure 38).

During the first 30d following the initial application, no differences in nitrogen leaching due to application rates were noted (Table 144). A fertilizer rate response was observed in only 5 of the 22 sampling events in 2007 (data not presented). The highest rate of applied nitrogen (49.0 kg/ha) resulted in the greatest nitrogen leaching. Minimal differences in leaching between 12.5 and 24.0 kg/ha were observed on any given sampling event. During the 31-60d time period, a rate response was noted with the most nitrogen leaching from plots receiving 49.0 kg/ha; 26% less on plots receiving 24.0 kg/ha; and 48% less for plots receiving 12.5 kg/ha (Table 144). Over the duration of the study, more nitrogen leached from plots receiving 49.0 kg/ha; 25% less on plots receiving 24.0 kg/ha; and 45% less for plots receiving 12.5 kg/ha (Table 144).

During the first 30d following the initial application, no differences in nitrogen leaching due to application timing were noted (Table 144). During the 31-60d time period, 41% more nitrogen leached from the plots receiving fertilizer PTS (Table 144). This is likely attributed to the longer time period in which the fertilizer had been on the ground. Over the entire duration of the study, 37% more N leached from the plots receiving nitrogen PTS versus plots receiving nitrogen 30 DAS (Table 144).

Table 143. Establishment of sodded centipedegrass study total N value by month trial 1.

	Total N (kg/ha)				
	Pre	T1	T2	T3	Total Post
Application date					
PTS (17 April) ..	0.010	0.34	0.009	0.09	0.45
30DAS (16 May)	0.005	0.25	0.004	0.10	0.38
<i>P(F)</i>	NS	NS	NS	NS	NS
Rate (kg/ha)					
12.5	0.005	0.16	0.004	0.10	0.28
24.0	0.010	0.36	0.010	0.06	0.45
49.0	0.009	0.36	0.005	0.11	0.52
<i>P(F)</i>	NS	NS	NS	NS	NS
<i>App. x Rate</i>	NS	NS	NS	NS	NS

PTS= nitrogen application made Prior To Sodding, 30DAS =nitrogen application made 30 Days After Sodding. Data corrected for MDL if data ≤ 0.148 then =0.148. No significant interactions between application date and rate, therefore only means for main effects of application date and rate are presented. Means followed by the same letter(s) in a column are not significantly different according to Duncan's Multiple Range Test ($P=0.05$). NS = $P>0.05$. Pre= 14 Apr-16 Apr, T1=19 Apr-14 May, T2=17 May-14 Jun, T3=18 Jun-16 Jul, Total post =accumulated N post 17 April treatment.

Table 144. Establishment of sodded centipedegrass study total N value by month trial 2.

	Total N (kg/ha)				
	Pre	T1	T2	T3	Total Post
Application date					
PTS (17 April) ..	0.02	12.56	33.86 a	1.90	48.34a
30DAS (16 May)	0.05	9.26	24.10 b	1.92	35.32b
<i>P(F)</i>	NS	NS	*	NS	*
Rate (kg/ha)					
12.5	0.02	8.81	20.10 b	1.05	29.98b
24.0	0.04	11.19	28.39 ab	1.45	41.07ab
49.0	0.05	12.73	38.46 a	3.22	54.46a
<i>P(F)</i>	NS	NS	**	NS	*
<i>App. x Rate</i>	NS	NS	NS	NS	NS

PTS= nitrogen application made Prior To Sodding, 30DAS =nitrogen application made 30 Days After Sodding. Data corrected for MDL if data ≤ 0.148 then =0.148. No significant interactions between application date and rate, therefore only means for main effects of application date and rate are presented. Means followed by the same letter(s) in a column are not significantly different according to Duncan's Multiple Range Test ($P=0.05$). *= $P<0.05$ and NS = $P>0.05$. Pre= 16 Aug-20 Aug, T1=23 Aug-20 Sep, T2=24 Sep-23 Oct, T3=25 Oct-5 Nov, Total post =accumulated N post 21 August treatment.

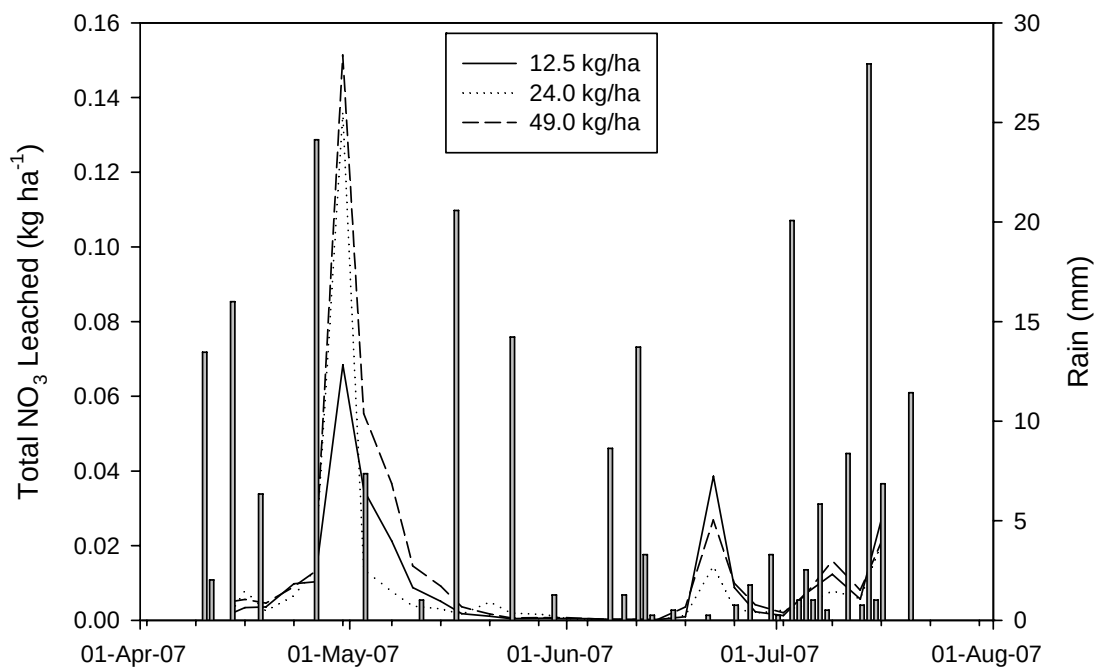


Figure 37: Total NO_3 leached from nitrogen applied in 2007 trial 1 sodding of centipedegrass and corresponding rainfall that occurred.

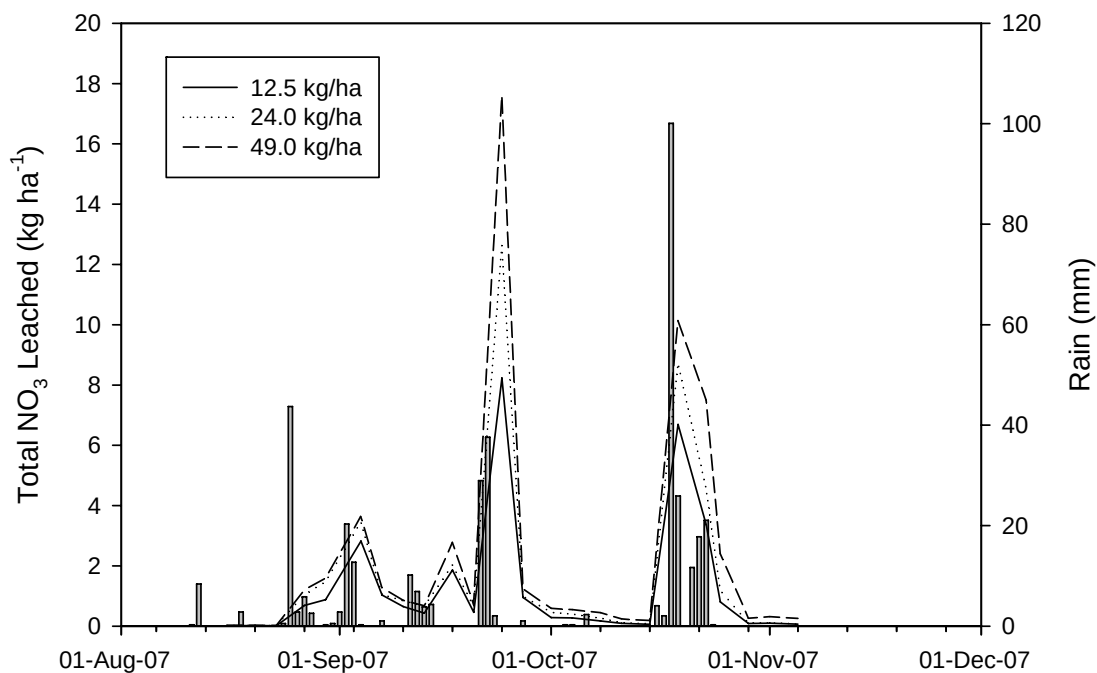


Figure 38: Total NO_3 leached from nitrogen applied in 2007 trial 2 sodding of centipedegrass and corresponding rainfall that occurred.

Nitrogen Effects on Centipedegrass Establishment after Sodding – Nitrate Leaching – Combined Analysis – 2007

Trial 2 had significantly more leaching of nitrate verses Trial 1 in all sampling dates following sodding. During 31-60 days following sodding and application across both trials the 30 DAS showed lower levels of nitrate and is likely attributed to the longer time period in which the fertilizer had been on the ground (Table 145). This time period also showed differences in nitrogen rate with the highest leaching occurring at the 49.0 kg/ha rate, this is again evident for the total accumulated. The 49.0 kg/ha rate resulted in the highest leaching, with the 24.0 kg/ha rate with 24.5% less and the 12.5 kg/ha rate with 45% less when combined across both trials in 2007 (Table 145).

Table 145. Establishment of sodded centipedegrass study total N value (MDL) by month combined across trials.

	Total N (kg/ha)				
	Pre	T1	T2	T3	Total Post
Trial					
Trial 1	0.008	0.296 b	0.006 b	0.093 b	0.416 b
Trial 2	0.035	10.909 a	28.981 a	1.907 a	41.833 a
<i>P(F)</i>	NS	**	***	*	***
Application date					
PTS	0.017	6.451	16.935 a	0.991	24.397 a
30 DAS	0.026	4.754	12.052 b	1.009	17.852 b
<i>P(F)</i>	NS	NS	*	NS	*
Rate (kg/ha)					
12.5	0.014	4.484	10.051 b	0.576	15.126 b
24.0	0.023	5.776	14.198 b	0.758	20.759 ab
49.0	0.028	6.548	19.232 a	1.666	27.488 a
<i>P(F)</i>	NS	NS	**	NS	**
<i>Trial x App.</i>	NS	NS	*	NS	*
<i>Trial x Rate</i>	NS	NS	**	NS	*
<i>App. x Rate</i>	NS	NS	NS	NS	*
<i>Trial x App x Rate</i> .	NS	NS	NS	NS	*

PTS= nitrogen application made Prior To Sodding, 30DAS =nitrogen application made 30 Days After Sodding. Data corrected for MDL if data ≤ 0.148 then =0.148. No significant interactions between year, application date and rate, therefore only means for main effects of year, application date and rate are presented. Means followed by the same letter(s) in a column are not significantly different according to Duncan's Multiple Range Test ($P=0.05$).

*, **, *** = $P < 0.05$, $P < 0.01$, $P < 0.001$, respectively and NS = $P > 0.05$.

Nitrogen Effects on Centipedegrass Establishment after Sodding – Nitrate Leaching –% of Applied Individual Trials and Combined Analysis – 2007

Trial 1: In the first run of the experiment, no differences in % nitrogen leached were attributed to nitrogen application date or rate, except during the 61-90 day period (T3), where the 12.5 kg/ha rate had the highest percentage of nitrogen leaching verses the other two rates. This percentage was very minimal since very little nitrogen leached in this trial (Table 146).

Trial 2: In the second run no differences in nitrogen leaching were attributed to nitrogen application timing. Differences were detected for nitrogen rates during the first 60 day and the total accumulation of nitrogen. The 12.5 kg/ha rate had the highest percentage of leaching compared to the other rates. All rates had more nitrogen leached than what was applied and this is probably due to nitrogen fertilizer present in the sod prior to planting (Table 147).

When combined across both trials significant differences in % nitrogen leaching were detected between the two trials (Table 148). The combined analysis did show that rate had a significant effect, but there was a significant interaction between rate and trial due to the extreme differences in the amount of nitrate leached from each trial (Table 148).

Table 146. Establishment of sodded centipedegrass study % nitrogen applied by month trial 1.

	% nitrogen applied				
	Pre	T1	T2	T3	Total Post
Application date					
PTS (17 April) ..	0.045	1.506	0.039	0.461	2.076
30DAS (16 May)	0.023	0.859	0.017	0.419	1.362
<i>P(F)</i>	NS	NS	NS	NS	NS
Rate (kg/ha)					
12.5	0.042	1.297	0.033	0.831 a	2.217
24.0	0.041	1.504	0.040	0.263 b	1.880
49.0	0.019	0.747	0.011	0.227 b	1.061
<i>P(F)</i>	NS	NS	NS	*	NS
<i>App. x Rate</i>	NS	NS	NS	NS	NS

PTS= nitrogen application made Prior To Sodding, 30DAS =nitrogen application made 30 Days After Sodding. Data corrected for MDL if data ≤ 0.148 then =0.148. No significant interactions between application date and rate, therefore only means for main effects of application date and rate are presented. Means followed by the same letter(s) in a column are not significantly different according to Duncan's Multiple Range Test ($P=0.05$). NS = $P>0.05$. Pre= 14 Apr-16 Apr, T1=19 Apr-14 May, T2=17 May-14 Jun, T3=18 Jun-16 Jul, Total post =% accumulated N post 17 April treatment.

Table 147. Establishment of sodded centipedegrass study % nitrogen applied by month trial 2.

	% nitrogen applied				
	Pre	T1	T2	T3	Total Post
Application date					
PTS (17 April) ..	0.104	49.052	131.667	6.173	186.996
30DAS (16 May)	0.182	46.320	106.696	7.839	161.036
<i>P(F)</i>	NS	NS	NS	NS	NS
Rate (kg/ha)					
12.5	0.180				239.800
		70.449 a	160.779 a	8.392	a
24.0	0.152	46.628 ab	118.277 b	6.055	171.113
					ab
49.0	0.096	25.981 b	78.488 b	6.571	111.136
					b
<i>P(F)</i>	NS	*	**	NS	**
<i>App. x Rate</i>	NS	NS	NS	NS	NS

PTS= nitrogen application made Prior To Sodding, 30DAS =nitrogen application made 30 Days After Sodding. Data corrected for MDL if data ≤ 0.148 then =0.148. No significant interactions between application date and rate, therefore only means for main effects of application date and rate are presented. Means followed by the same letter(s) in a column are not significantly different according to Duncan's Multiple Range Test ($P=0.05$). *= $P < 0.05$ and NS = $P > 0.05$. Pre= 16 Aug-20 Aug, T1=23 Aug-20 Sep, T2=24 Sep-23 Oct, T3=25 Oct-5 Nov, Total post =% accumulated N post 21 August treatment.

Table 148. Establishment of sodded centipedegrass study % of nitrogen leached by month combined across trials.

	% Nitrogen applied				
	Pre	T1	T2	T3	Total Post
Trial					
Trial 1			0.028		
	0.034	1.183 b	b	0.440 b	1.719 b
Trial 2			119.182		
	0.143	47.686 a	a	7.006 a	174.016 a
<i>P(F)</i>	<i>NS</i>	**	****	**	****
Application date					
PTS	0.075	25.279	65.853	3.317	94.536
30 DAS	0.102	23.590	53.356	4.129	81.200
<i>P(F)</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>
Rate (kg/ha)					
12.5	0.111	35.873 a	80.406 a	4.611	121.008 a
24.0	0.097	24.066 ab	59.159 b	3.159	86.496 ab
49.0	0.057	13.364 b	39.249 c	3.399	56.098 b
<i>P(F)</i>	<i>NS</i>	*	***	<i>NS</i>	**
<i>Trial x App.</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>
<i>Trial x Rate</i>	<i>NS</i>	*	***	<i>NS</i>	**
<i>App. x Rate</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>
<i>Trial x App x Rate</i> .	<i>NS</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>

PTS= nitrogen application made Prior To Sodding, 30DAS =nitrogen application made 30 Days After Sodding. Data corrected for MDL if data ≤ 0.148 then =0.148. Means followed by the same letter(s) in a column are not significantly different according to Duncan's Multiple Range Test ($P=0.05$). *, **, ***, ****= $P < 0.05$, $P < 0.01$, $P < 0.001$, and $P < 0.0001$, respectively and *NS* = $P > 0.05$.

PROJECT: EFFECTS OF IRRIGATION AND NITROGEN APPLICATION RATES ON NITROGEN LEACHING FROM ESTABLISHED CENTIPEDE AND ST. AUGUSTINEGRASS TURF

Root and Shoot Growth (2005, 2006 and 2007)

Centipede turf had greater root dry weight and ash than St. Augustine turf in all three years (Tables 149- 151). Irrigation rate had no effect on root, ash and % ash across both grasses in 2005 and 2007, but in 2006 root dry weight and ash were greatest at the lower irrigation rate of 1.27 cm (Tables 149-151). In 2005 nitrogen applied at 65.17 kg/ha rate improved root growth over other nitrogen treatments, but no differences in rate were detected for ash or % ash (Table 149). In 2006 the nitrogen rate of 32.83 kg/ha had significantly increased root growth over the 16.17 and 98.00 kg/ha rates (Table 150). Ash was increased by the 32.83 and 65.17 kg/ha rates (Table 150). No differences in nitrogen rate on root and ash were detected in 2007 (Table 151).

St. Augustine turf had greater shoot growth than centipede turf in July 2005, August 2006, and September 2006. Centipede turf had increased shoot growth May 2006 and August 2007, no differences between the turf types were detected for the other sample dates (Table 152-154). There was no effect of irrigation on shoot growth in all three years (Table 152-154). In 2005, nitrogen rate only affected shoot growth in Centipede turf, as the rate of nitrogen applied increased the amount of centipede shoot growth increased, there was no effect of rate on St. Augustine turf shoot growth in 2005 (Table 152). In both 2006 and 2007 both St. Augustine and centipede turf shoot growth increased as the rate of nitrogen applied increased (Table 152-154).

Table 149. Established turf, irrigation and rate effect on root growth in 2005.

	Root dry weight (g)	Ash (g)	Ash (%)
Turf			
St. Augustine.....	0.138 b	0.023 b	15.88
Centipede	0.239 a	0.035 a	14.44
P(F)	*	*	NS
Irrigation			
1.27 cm.....	0.192	0.030	15.36
2.54 cm.....	0.185	0.028	14.97
P(F)	NS	NS	NS
Rate (kg/ha)			
16.17.....	0.196 ab	0.028	14.06
32.83.....	0.155 b	0.023	15.46
65.17.....	0.217 a	0.032	14.61
98.00.....	0.185 ab	0.033	16.51
P(F)	*	NS	NS
Turf x Irrigation	*	NS	NS
Turf x Rate.....	NS	NS	NS
Irrigation x Rate.....	NS	NS	NS
Turf x Irr. X rate.....	NS	NS	NS

Means followed by the same letter(s) in a column are not significantly different according to Duncan's Multiple Range Test ($P=0.05$). * = $P<0.05$, NS = not significant.

Table 150. Established turf, irrigation and rate effect on root growth in 2006.

	Root dry weight (g)	Ash (g)	Ash (%)
Turf			
St. Augustine.....	0.258 b	0.034 b	11.73
Centipede	0.361 a	0.055 a	13.64
<i>P</i> (F)	**	**	NS
Irrigation			
1.27 cm.....	0.361 a	0.055 a	13.29
2.54 cm.....	0.258 b	0.034 b	12.09
<i>P</i> (F)	*	**	NS
Rate (kg/ha)			
16.17.....	0.278 b	0.034 b	11.14
32.83.....	0.355 a	0.053 a	12.87
65.17.....	0.308 ab	0.046 a	13.30
98.00.....	0.297 b	0.044 ab	13.44
<i>P</i> (F)	*	*	NS
<i>Turf</i> x <i>Irrigation</i>	NS	NS	NS
<i>Turf</i> x <i>Rate</i>	NS	NS	NS
<i>Irrigation</i> x <i>Rate</i>	NS	NS	NS
<i>Turf</i> x <i>Irr.</i> x <i>Rate</i>	NS	NS	NS

Means followed by the same letter(s) in a column are not significantly different according to Duncan's Multiple Range Test ($P=0.05$). ** and * = $P<0.01$ and $P<0.05$, respectively. NS = not significant.

Table 151. Established turf, irrigation and rate effect on root growth in 2007.

	Root dry weight (g)	Ash (g)	Ash (%)
Turf			
St. Augustine.....	0.264 b	0.036 b	13.59
Centipede	0.486 a	0.064 a	13.20
<i>P</i> (F)	***	**	NS
Irrigation			
1.27 cm.....	0.389	0.054	13.65
2.54 cm.....	0.361	0.046	13.15
<i>P</i> (F)	NS	NS	NS
Rate (kg/ha)			
16.17.....	0.355	0.048	13.41
32.83.....	0.389	0.050	12.80
65.17.....	0.409	0.053	12.95
98.00.....	0.348	0.050	14.43
<i>P</i> (F)	NS	NS	NS
<i>Turf</i> x <i>Irrigation</i>	NS	NS	*
<i>Turf</i> x <i>Rate</i>	NS	NS	NS
<i>Irrigation</i> x <i>Rate</i>	NS	NS	NS
<i>Turf</i> x <i>Irr.</i> x <i>Rate</i>	NS	NS	NS

Means followed by the same letter(s) in a column are not significantly different according to Duncan's Multiple Range Test ($P=0.05$). *** and ** = $P<0.001$ and $P<0.01$, respectively. NS = not significant.

Table 152. Irrigation and nitrogen rate effect on established turf shoot growth in 2005.

	Average monthly shoot weight (g)							
	Jul		Aug		Sep		Oct	
Turf								
St. Augustine.....	7.78	a	6.95		7.05		7.58	
Centipede	6.78	b	7.22		7.19		7.36	
P(F).....	*		NS		NS		NS	
Irrigation								
1.27 cm.....	7.28		7.13		7.13		7.58	
2.54 cm.....	7.28		7.05		7.11		7.36	
P(F).....	NS		NS		NS		NS	
Rate (kg/ha)	<u>St. Aug</u>	<u>Cent</u>	<u>St. Aug</u>	<u>Cent</u>	<u>St. Aug</u>	<u>Cent</u>	<u>St. Aug</u>	<u>Cent</u>
16.17.....	7.88	6.13 c	6.94	6.81 c	7.00	6.56 c	7.44	6.94 c
32.83.....	7.75	6.63 bc	6.88	7.00 bc	7.00	6.88 c	7.63	7.06 bc
65.17.....	8.00	6.88 b	6.94	7.19 b	7.13	7.38 b	7.75	7.44 b
98.00.....	7.50	7.50 a	7.06	7.88 a	7.06	7.94 a	7.50	8.00 a
P(F).....	NS	***	NS	****	NS	****	NS	***
Turf x Irrigation	NS		NS		NS		NS	
Turf x Rate.....	****		**		***		***	
Irrigation x Rate.....	NS		NS		NS		NS	
Turf x Irr. X rate.....	NS		NS		NS		NS	

Nitrogen application dates 8 June 2005 and 9 August 2005. Means for rate separated by turf since significant Turf x Rate interaction. St. Aug= St. Augustinegrass and Cent = Centipedegrass. ****, ***, ** and * = $P < 0.0001$, $P < 0.001$, $P < 0.01$, and $P < 0.05$, respectively. NS = not significant.

Table 153. Irrigation and nitrogen rate effect on established turf shoot growth in 2006.

Average monthly shoot weight (g)												
	May		Jun		Jul		Aug		Sep		Oct	
Turf												
St. Augustine....	1.95 b		3.62		11.49		17.11 a		27.91 a		4.86	
Centipede	4.65 a		5.56		14.46		11.66b		21.12 b		5.78	
P(F).....	*		NS		NS		*		*		NS	
Irrigation												
1.27 cm.....	3.65		4.40		11.33		13.63		25.42		5.45	
2.54 cm.....	2.95		4.78		14.62		15.15		23.61		5.19	
P(F)	NS		NS		NS		NS		NS		NS	
Rate (kg/ha)	<u>St.</u>	<u>Cent</u>	<u>St.</u>	<u>Cent</u>	<u>St.</u>	<u>Cent</u>	<u>St.</u>	<u>Cent</u>	<u>St.</u>	<u>Cent</u>	<u>St.</u>	<u>Cent</u>
	<u>Aug</u>		<u>Aug</u>		<u>Aug</u>		<u>Aug</u>		<u>Aug</u>		<u>Aug</u>	
16.17.....	1.41b	5.06ab	1.47d	5.40ab	2.31c	10.95	2.95c	9.41b	6.02d	12.78	1.54b	5.26b
					b				c			
32.83.....	1.59b	1.96b	2.54c	3.02b	4.59c	9.16b	7.31c	6.53b	15.33	10.51	2.92b	4.12b
									c	c		
65.17.....	2.32a	3.06b	4.58b	4.63b	12.39	14.03	23.66	10.94	38.52	20.36	7.04a	5.15b
					b	b	b	b	b	b		
98.00.....	2.47a	8.53a	5.90a	9.18a	26.68	23.68	34.53	19.78	51.76	40.81	7.94a	8.59a
					a	a	a	a	a	a		
P(F).....	****	*	****	NS	****	***	****	***	****	****	****	**
Turf x	NS		NS		NS		NS		NS		NS	
Irrigation.....												
Turf x Rate	*		NS		*		****		****		**	
Irrigation x	NS		NS		NS		NS		NS		NS	
Rate												
Turf x Irr. X	NS		NS		NS		NS		NS		NS	
rat.....												

Nitrogen application dates 14 May 2006, 14 June 2006 and 11 August 2006. Means for rate separated by turf since significant Turf x Rate interaction. St. Aug= St. Augustinegrass and Cent = Centipede grass. ****, ***, ** and * = $P < 0.0001$, $P < 0.001$, $P < 0.01$, and $P < 0.05$, respectively. NS = not significant.

Table 154. Irrigation and nitrogen rate effect on established turf shoot growth in 2007.

Average monthly shoot weight (g)						
	Aug		Sep		Oct	
Turf						
St. Augustine.....	3.07	b	1.09		5.05	
Centipede	6.04	a	3.25		7.42	
<i>P</i> (F)	**		NS		NS	
Irrigation						
1.27 cm.....	4.87		2.57		5.72	
2.54 cm.....	4.23		1.77		6.75	
<i>P</i> (F)	NS		NS		NS	
Rate (kg/ha)	<u>St. Aug</u>	<u>Cent</u>	<u>St. Aug</u>	<u>Cent</u>	<u>St. Aug</u>	<u>Cent</u>
16.17.....	1.88	b	0.99	b	1.86	d
32.83.....	2.53	b	0.86	b	3.54	c
65.17.....	3.81	a	1.20	a	6.45	b
98.00.....	4.04	a	1.31	a	8.36	a
<i>P</i> (F)	****	***	***	NS	****	**
Interactions						
<i>Turf</i> x <i>Irrigation</i>	NS		NS		NS	
<i>Turf</i> x <i>Rate</i>	***		NS		NS	
<i>Irrigation</i> x <i>Rate</i>	NS		NS		NS	
<i>Turf</i> x <i>Irr. X rate</i>	NS		NS		NS	

Nitrogen application dates 16 May 2007, 14 June 2007 and 14 August 2007. Means for Rate separated by turf since significant Turf x Rate interaction. St. Aug= St. Augustinegrass and Cent = Centipedegrass. ****, ***, and ** = $P < 0.0001$, $P < 0.001$, and $P < 0.01$, respectively. NS = not significant.

Effects of Irrigation and Nitrogen Application Rates on Nitrogen Leaching From Established St. Augustinegrass Turf

Quality, Color, and Density (2005 – 2007)

Irrigation Frequency: On only one rating date over the three year study did irrigation influence a visual turf rating. On the last rating date following the second fertilizer application in 2006, 0.5” of irrigation applied twice weekly yielded better turf color than the same quantity of irrigation applied once per week (Table 159). Though not statistically significant, 2X week irrigation yielded slight improvements on all rating dates.

Nitrogen Rate: No rate effect on turf quality and color was observed during the initial treatment cycle starting June, 2005. This is likely due to the residual nutrients that were applied as fertilizer during production of the sod (Tables 155 and 156). Slightly higher density was observed with increasing nitrogen rates (Table 157). In 2005 and 2006, increasing nitrogen rate produced better turf quality, color, and density (Tables 155-160). By the end of the 2006 growing season, good turf quality was obtained with single application rates $\leq 98.00 \text{ kg ha}^{-1}$. Plots receiving 16.17 kg ha^{-1} had quality slightly below an acceptable level (Table 158). Winter 2006 through spring 2007 produced an appreciable level of winter injury. Acceptable recovery did not occur until 1 September 2007 after receiving three applications of fertilizer (Tables 161-163).

Table 155: Effect of irrigation and N-application rate on established St. Augustine turf quality in 2005.

	Nitrogen application date								8 Oct 6 DAA
	8 Jun				9 Aug				
	9 DAA	27 DAA	36 DAA	50 DAA	3 DAA	17 DAA	31 DAA	52 DAA	
Irrigation									
1.27 cm.....	7.8	7.0	7.0	7.7	7.9	8.3	7.7	7.5	6.7
2.54 cm.....	7.8	6.9	7.1	7.5	7.8	8.0	7.7	7.2	6.4
P(F)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Rate (kg/ha)									
16.17.....	7.9	6.9	7.0	7.4	7.9 a	7.8 c	7.3 b	7.2 bc	6.1 b
32.83.....	7.8	6.9	7.0	7.6	7.9 a	8.0 bc	7.5 b	7.0 c	6.4 b
65.17.....	8.0	6.9	7.1	7.8	8.0 a	8.2 b	7.9 a	7.5 ab	6.8 a
98.00.....	7.5	7.1	7.1	7.5	7.6 b	8.4 a	8.0 a	7.8 a	6.9 a
P(F)	NS	NS	NS	NS	*	****	***	**	**
Irr. x Rate	NS	NS	NS	NS	NS	NS	NS	NS	NS

Quality visually rated on scale 1 to 9 where 9=best. Means in each column followed by the same letter(s) are not significantly different according to Fisher's Protected LSD ($P=0.05$). ****, ***, **, and * = $P<0.0001$, $P<0.001$, $P<0.01$, and $P<0.05$, respectively. NS = not significant.

Table 156: Effect of irrigation and N-application rate on established St. Augustine turf color in 2005.

	Nitrogen application date								8 Oct 6 DAA
	8 Jun				9 Aug				
	9 DAA	27 DAA	36 DAA	50 DAA	3 DAA	17 DAA	31 DAA	52 DAA	
Irrigation									
1.27 cm.....	7.7	7.5	7.0	7.3	7.7	7.8	7.5	7.2	6.6
2.54 cm.....	7.6	7.6	6.8	7.1	7.7	7.6	7.4	6.8	6.4
<i>P(F)</i>	NS	NS	NS	NS	NS	NS	NS	NS	NS
Rate (kg/ha)									
16.17.....	7.6	7.1 c	6.9	7.1	7.8	7.4 b	7.1 b	6.8 b	6.2 b
32.83.....	7.8	7.5	6.8	7.1	7.6	7.6 b	7.2 b	6.9 b	6.3 b
		bc							
65.17.....	7.8	7.6	6.9	7.3	7.8	7.9 a	7.6 a	7.1	6.6 ab
		ab						ab	
98.00.....	7.5	7.9 a	7.0	7.3	7.6	8.0 a	7.9 a	7.3 a	6.9 a
<i>P(F)</i>	NS	**	NS	NS	NS	***	***	*	*
<i>Irr. x Rate</i>	NS	NS	NS	NS	NS	NS	NS	NS	NS

Color visually rated on scale 1 to 9 where 9=best. Means in each column followed by the same letter(s) are not significantly different according to Fisher's Protected LSD ($P=0.05$). ***and * = $P<0.001$ and $P<0.05$, respectively. NS = not significant.

Table 157: Effect of irrigation and N-application rate on established St. Augustine turf density in 2005.

	Nitrogen application date								8 Oct 6 DAA
	8 Jun				9 Aug				
	9 DAA	27 DAA	36 DAA	50 DAA	3 DAA	17 DAA	31 DAA	52 DAA	
Irrigation									
1.27 cm.....	8.2	8.6	8.6	8.6	8.9	9.0	9.0	9.0	9.0
2.54 cm.....	8.5	8.5	8.3	8.4	8.9	9.0	9.0	9.0	9.0
<i>P(F)</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>
Rate (kg/ha)									
16.17.....	8.4	8.2	8.3	8.3	8.8	8.9	9.0	9.0	9.0
32.83.....	8.4	b		b	8.8	9.0	9.0	9.0	9.0
65.17.....	8.4	ab		ab	9.0	9.0	9.0	9.0	9.0
98.00.....	8.3	a		a	8.9	9.0	9.0	9.0	9.0
<i>P(F)</i>	<i>NS</i>	**	<i>NS</i>	*	<i>NS</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>
<i>Irr. x Rate</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>

Density visually rated on scale 1 to 9 where 9=best. Means in each column followed by the same letter(s) are not significantly different according to Fisher's Protected LSD ($P=0.05$). **and * = $P<0.01$ and $P<0.05$, respectively. NS = not significant.

Table 158: Effect of irrigation and N-application rate on established St. Augustine turf quality in 2006.

	Nitrogen application date									
	14 Apr				14 Jun			11 Aug		
	13 DAA	28 DAA	42 DAA	56 DAA	16 DAA	37 DAA	51 DAA	8 DAA	28 DAA	42 DAA
Irrigation										
1.27 cm.....	7.4	6.5	6.1	6.3	7.5	7.4	8.1	8.6	8.7	7.3
2.54 cm.....	7.2	6.6	5.8	6.2	7.4	7.3	7.9	8.3	8.6	7.3
P(F)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Rate (kg/ha)										
16.17.....	6.7 c	5.7 d	5.4 b	5.4 c	6.1 d	6.5 d	7.0 c	7.4 c	7.9 c	6.4 c
32.83.....	7.2 b	6.3 c	5.9 a	5.9 b	7.1 c	7.1 c	7.8 b	8.3 b	8.6 b	7.0 b
65.17.....	7.4 b	6.9 b	6.2 a	6.7 a	8.1 b	7.8 b	8.4 a	8.9 a	9.0 a	7.7 a
98.00.....	7.9 a	7.4 a	6.3 a	7.0 a	8.6 a	8.1 a	8.7 a	8.9 a	9.0 a	7.9 a
P(F)	****	****	**	****	****	****	****	****	****	****
Irr. x Rate ...	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Quality visually rated on scale 1 to 9 where 9=best. Means in each column followed by the same letter(s) are not significantly different according to Fisher's Protected LSD ($P=0.05$). **** and ** = $P<0.0001$ and $P<0.01$, respectively. NS = not significant.

Table 159: Effect of irrigation and N-application rate on established St. Augustine turf color in 2006.

	Nitrogen application date									
	14 Apr				14 Jun			11 Aug		
	13 DAA	28 DAA	42 DAA	56 DAA	16 DAA	37 DAA	51 DAA	8 DAA	28 DAA	42 DAA
Irrigation										
1.27 cm.....	7.7	6.9	6.2	6.5	7.7	7.5	8.2 a	8.3	8.7	7.4
2.54 cm.....	7.5	6.8	5.8	6.8	7.2	7.5	7.6 b	8.4	8.7	7.3
P(F)	NS	NS	NS	NS	NS	NS	***	NS	NS	NS
Rate (kg/ha)										
16.17.....	6.6 d	6.0 d	5.3 d	5.8 d	5.9 d	6.6 d	7.1 c	7.5 d	8.1 c	6.6 c
32.83.....	7.4 c	6.6 c	5.6 c	6.3 c	7.2 c	7.2 c	7.6 b	8.2 c	8.7 b	6.9 c
65.17.....	8.0 b	7.1 b	6.3 b	7.0 b	8.1 b	7.8 b	8.3 a	8.6 b	9.0 a	7.7 b
98.00.....	8.4 a	7.6 a	6.9 a	7.4 a	8.6 a	8.3 a	8.6 a	9.0 a	9.0 a	8.1 a
P(F)	****	****	****	****	****	****	****	****	****	****
Irr. x Rate ...	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Color visually rated on scale 1 to 9 where 9=best. Means in each column followed by the same letter(s) are not significantly different according to Fisher's Protected LSD ($P=0.05$). **** and *** = $P<0.0001$ and $P<0.001$, respectively. NS = not significant.

Table 160: Effect of irrigation and N-application rate on established St. Augustine turf density in 2006.

	Nitrogen application date									
	14 Apr				14 Jun			11 Aug		
	13 DAA	28 DAA	42 DAA	56 DAA	16 DAA	37 DAA	51 DAA	8 DAA	28 DAA	42 DAA
Irrigation										
1.27 cm.....	7.0	7.2	7.4	7.8	8.0	8.4	8.6	8.8	8.8	8.8
2.54 cm.....	6.7	7.1	7.5	7.8	8.0	8.3	8.5	8.7	8.7	8.7
P(F)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Rate (kg/ha)										
16.17.....	6.1 b	6.6 d	6.9 d	7.3 c	7.4 c	7.8 d	8.0 c	8.3 c	8.4 c	8.2 c
32.83.....	6.9 a	6.9 c	7.3 c	7.7 b	7.8 b	8.3 c	8.5 b	8.7 b	8.7 b	8.8 b
65.17.....	7.1 a	7.3 b	7.6 b	8.0 a	8.3 a	8.6 b	8.9 a	9.0 a	8.9 a	9.0 a
98.00.....	7.3 a	7.8 a	8.0 a	8.0 a	8.4 a	8.9 a	8.9 a	9.0 a	9.0 a	9.0 a
P(F)	****	****	****	****	****	****	****	****	****	****
Irr. x Rate ...	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Density visually rated on scale 1 to 9 where 9=best. Means in each column followed by the same letter(s) are not significantly different according to Fisher's Protected LSD ($P=0.05$). **** = $P<0.0001$. NS = not significant.

Table 161: Effect of irrigation and N-application rate on established St. Augustine turf quality in 2007.

	Nitrogen application date														
	12 May		16 May		14 Jun		14 Aug				13 Oct				
	-10 DAA	3 DAA	21 DAA	29 DAA	29 DAA	35 DAA	41 DAA	10 DAA	16 DAA	24 DAA	31 DAA	41 DAA	52 DAA	2 DAA	
Irrigation															
1.27 cm.....	2.1	2.6	3.9	4.7	4.3	4.6	6.2	5.8	5.6	5.9	7.2	7.2	7.7	7.1	7.2
2.54 cm.....	2.6	3.4	4.4	5.1	4.8	5.3	5.5	6.3	5.7	5.5	6.9	6.9	7.4	6.9	7.1
P(F)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Rate (kg/ha)															
16.17.....	2.4	3.3	4.6	5.4	4.8	4.6	5.5	5.4 b	5.0	4.6 c	6.1 b	6.1 b	6.9 c	6.4 b	6.7
32.83.....	2.4	3.1	4.3	4.8	4.6	5.1	5.7	5.9 ab	5.6	5.6 b	6.6 b	6.6 b	7.4 bc	6.7 b	6.9
65.17.....	2.4	3.0	4.1	4.6	4.4	5.4	6.3	6.5 a	6.0	6.3 a	7.6 a	7.6 a	7.9 ab	7.4 a	7.6
98.00.....	2.1	2.8	3.8	4.7	4.4	4.9	6.0	6.6 a	5.8	6.3 a	7.9 a	7.9 a	8.0 a	7.4 a	7.4
P(F)	NS	NS	NS	NS	NS	NS	NS	**	NS	****	****	***	*	*	NS
Irr. x Rate	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Quality visually rated on scale 1 to 9 where 9=best. Means in each column followed by the same letter(s) are not significantly different according to Fisher's Protected LSD ($P=0.05$). ****, ***, **, and * = $P<0.0001$, $P<0.001$, $P<0.01$, and $P<0.05$, respectively. NS = not significant

Table 162. Effect of irrigation and N-application rate on established St. Augustine turf color in 2007.

	Nitrogen application date														
	12 May		16 May		14 Jun		14 Aug				13 Oct				
	-10 DAA	3 DAA	7 DAA	21 DAA	29 DAA	29 DAA	35 DAA	41 DAA	10 DAA	16 DAA	24 DAA	31 DAA	41 DAA	52 DAA	2 DAA
Irrigation															
1.27 cm.....	3.2	6.6	5.0	6.3	5.9	6.6	6.4	6.9	7.4	7.7	7.4	7.4	7.8	7.1	7.2
2.54 cm.....	3.3	7.2	6.2	6.3	6.2	6.8	6.8	7.2	7.3	7.7	7.3	7.3	7.8	7.0	7.1
<i>P</i> (F)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Rate (kg/ha)															
16.17.....	3.1	7.0	5.8	6.4	5.9	6.6	6.4	6.5 b	6.6 b	6.9 b	6.4 b	6.4 b	7.4 b	6.5 c	7.0
32.83.....	3.3	6.8	5.8	6.3	5.9	6.5	6.4	6.9 ab	6.9 b	7.3 b	6.9 b	6.9 b	7.4 b	6.8 bc	7.0
65.17.....	3.4	6.9	5.8	6.5	6.2	6.8	6.8	7.2 a	7.9 a	8.3 a	7.8 a	7.8 a	8.1 a	7.4 ab	7.3
98.00.....	3.1	6.8	5.1	5.8	6.2	6.9	6.9	7.5 a	8.1 a	8.4 a	8.2 a	8.2 a	8.3 a	7.4 a	7.3
<i>P</i> (F)	NS	NS	NS	NS	NS	NS	NS	*	****	****	****	****	**	*	NS
<i>Irr. x Rate</i>	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Color visually rated on scale 1 to 9 where 9=best. Means in each column followed by the same letter(s) are not significantly different according to Fisher's Protected LSD ($P=0.05$). ****, **, and * = $P<0.0001$, $P<0.01$, and $P<0.05$, respectively. NS = not significant

Table 163: Effect of irrigation and N-application rate on established St. Augustine turf density in 2007.

	Nitrogen application date														
	12 May		16 May		14 Jun			14 Aug				13 Oct			
	-10 DAA	3 DAA	7 DAA	21 DAA	29 DAA	29 DAA	35 DAA	41 DAA	10 DAA	16 DAA	24 DAA	31 DAA	41 DAA	52 DAA	2 DAA
Irrigation															
1.27 cm.....	4.1	3.1	4.3	4.7	4.0	4.8	6.4	6.6	6.4	6.7	7.2	7.3	7.5	7.1	7.3
2.54 cm.....	4.6	3.7	5.1	5.4	5.1	5.6	5.8	6.9	6.4	6.7	6.5	7.0	7.1	6.9	7.4
P(F)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Rate (kg/ha)															
16.17.....	4.5	3.8	5.1	5.5	5.0 a	4.9	5.8	5.9	6.2	5.9	6.1	6.3	6.4	6.4	6.7
								b		c				c	c
32.83.....	4.4	3.4	4.8	5.1	4.8 a	5.3	6.0	6.8	6.3	6.5	6.4	6.6	7.3	6.7	7.1
								a		bc				bc	bc
65.17.....	4.4	3.4	4.6	4.8	4.4	5.7	6.4	7.1	6.6	7.4	7.5	7.8	7.8	7.5	7.9
					ab			a		a				a	a
98.00.....	4.1	3.0	4.2	4.8	4.0 b	5.0	6.3	7.1	6.4	6.9	7.5	8.0	7.7	7.4	7.7
								a		ab				ab	ab
P(F)	NS	NS	NS	NS	*	NS	NS	**	NS	*	**	****	**	*	*
Irr. x Rate	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Density visually rated on scale 1 to 9 where 9=best. Means in each column followed by the same letter(s) are not significantly different according to Fisher's. ****, **, and * = $P<0.0001$, $P<0.01$, and $P<0.05$, respectively.

NS = not significant

Effects of Irrigation and Nitrogen Application Rates on Nitrogen Leaching From Established St. Augustinegrass Turf – Nitrate Leaching – 2006

Irrigation Frequency: The effect of irrigation frequency was significant on seven sampling dates in 2006. In general, the 2X week irrigation regime resulted in greater nitrate leaching (Tables 164).

Nitrogen Rate: Nitrogen applied at 98 kg ha⁻¹ (single application) yielded greater nitrate leaching compared to rates ≤ 65.17 kg ha⁻¹ (single application) (Tables 169 and 171). This increased level of nitrate leaching was evident in all three fertilization cycles in 2005 and 2007. Though the analysis suggests these data are not significant. Notable leaching events occurred on 8 May, 11 May, and 15 May following the 14 April application in 2007 (Figure 41). These three elevated leaching events are tied to rainfall events producing 2.2" of precipitation during this period of time. Similarly, elevated leaching events during the second fertilizer cycle were noted on 31 Jul and 3 Aug, these also are linked to rainfall events producing 4.67" of rain during this period of time. Finally, 24 Aug, 28 Aug, and 5 Sep had high leaching events during the third fertilizer cycle. Likewise, these were tied to a single rainfall event on 21 Aug that generated 1.99" of total precipitation (Figure 41).

When comparing the percentage of applied nitrogen between nitrogen application Rates, the 0.33 lb 1,000 ft⁻² consistently leaching 0.7%; 0.67 and 1.33 lb 1,000 ft⁻² leached ~ 0.2% of applied nitrogen; and recovery from the 2.0 lb 1,000 ft⁻² treatments ranged from 0.6 to 2.7% of applied over the three cycles.

Table 164. Effect of irrigation and N-application rate on total N (MDL) on St. Augustine turf in 2005.

	Total N (kg/ha)						Total Post
	Pre	T1	T2	T3	T4	T5	
Irrigation							
1.27 cm.....	16.804	6.327	2.832	0.194	0.068	0.052	10.633
2.54 cm.....	13.785	5.552	4.037	0.181	0.063	0.046	10.658
<i>P</i> (F).....	NS	NS	NS	NS	NS	NS	NS
Rate (kg/ha)							
16.17.....	13.288 ab	5.200	4.208	0.331	0.091	0.059	10.597
32.83.....	17.939 a	5.420	3.407	0.204	0.061	0.043	9.704
65.17.....	9.848 b	4.036	1.025	0.030	0.035	0.035	5.175
98.00.....	20.103 a	9.102	5.096	0.184	0.074	0.061	17.106
<i>P</i> (F).....	*	NS	NS	NS	NS	NS	NS
<i>Irrigation x Rate...</i>	NS	NS	NS	NS	NS	NS	NS

Nitrogen applications made on 8 June and 9 August 2005. Pre= 6 May -6 Jun, T1=10 Jun- 7 Jul, T2=12 Jul- 8 Aug, T3=11 Aug – 8 Sep, T4=12 Sep – 10 Oct, T5=13 Oct – 7 Nov. Total post =accumulated N post 8 Jun treatment. Data corrected for MDL if data ≤ 0.148 then =0.148. No significant interactions between application date and rate, therefore only means for main effects of application date and rate are presented. Means followed by the same letter(s) in a column are not significantly different according to Duncan's Multiple Range Test ($P=0.05$). *= $P < 0.05$ and NS = $P > 0.05$.

Table 165. Effect of irrigation and N-application rate on total N (MDL) on St. Augustinegrass turf in 2006.

	Total N (kg/ha)							Total Post
	Pre	T1	T2	T3	T4	T5	T6	
Irrigation								
1.27 cm.....	0.011	0.193	0.058	0.062	0.163	0.250	0.118	0.828
2.54 cm.....	0.011	0.094	0.055	0.040	0.117	0.172	0.055	0.532
<i>P</i> (F).....	NS	NS	NS	NS	NS	NS	NS	NS
Rate (kg/ha)								
16.17.....	0.009	0.143	0.073	0.047	0.166	0.186	0.102	0.717
32.83.....	0.011	0.107	0.054	0.052	0.115	0.129	0.073	0.531
65.17.....	0.012	0.186	0.052	0.052	0.157	0.219	0.085	0.750
98.00.....	0.012	0.140	0.047	0.052	0.122	0.316	0.087	0.724
<i>P</i> (F).....	NS	NS	NS	NS	NS	NS	NS	NS
<i>Irrigation x Rate...</i>	NS	NS	NS	NS	NS	NS	NS	NS

Nitrogen applications made on 14 April, 14 June and 11 August 2006. Pre= 14 Apr, T1=17 Apr -11 May, T2=15 May – 12 Jun, T3=15 Jun – 13 Jul, T4=17 Jul – 10 Aug, T5=14 Aug – 11 Sep, T6=14 Sep – 9 Oct. Total post =accumulated N post 14 Apr treatment. Data corrected for MDL if data ≤ 0.148 then =0.148. No significant interactions between application date and rate, therefore only means for main effects of application date and rate are presented. Means followed by the same letter(s) in a column are not significantly different according to Duncan's Multiple Range Test ($P=0.05$). NS = $P > 0.05$.

Table 166. Effect of irrigation and N-application rate on total N (MDL) on St. Augustinegrass turf in 2007.

	Total N (kg/ha)							
	Pre	T1	T2	T3	T4	T5	T6	Total Post
Irrigation								
1.27 cm.....	0.816	3.367	3.280	6.917	0.662	0.129a	0.128	14.483
2.54 cm.....	0.495	2.467	3.064	7.366	0.460	0.078b	0.096	13.532
P(F)	NS	NS	NS	NS	NS	*	NS	NS
Rate (kg/ha)								
16.17.....	0.675	2.368	1.832	3.524	0.174	0.102	0.126	8.126
32.83.....	0.498	1.657	1.627	3.256	1.139	0.085	0.089	7.852
65.17.....	0.725	3.314	3.672	9.632	0.596	0.091	0.098	17.404
98.00.....	0.723	4.330	5.557	12.154	0.335	0.136	0.135	22.648
P(F)	NS	NS	NS	NS	NS	NS	NS	NS
Irrigation x Rate...	NS	NS	NS	NS	NS	NS	NS	NS

Nitrogen applications made on 16 April, 14 June and 14 August 2006. Pre= 12 Apr - 16 Apr, T1=19 Apr -14 May, T2=17 May – 14 Jun, T3=18 Jun – 16 Jul, T4=19 Jul – 13 Aug, T5=16 Aug – 13 Sep, T6=17 Sep – 15 Oct. Total post =accumulated N post 16 Apr treatment. Data corrected for MDL if data ≤ 0.148 then =0.148. No significant interactions between application date and rate, therefore only means for main effects of application date and rate are presented. Means followed by the same letter(s) in a column are not significantly different according to Duncan's Multiple Range Test ($P=0.05$). *= $P<0.05$ and NS = $P>0.05$.

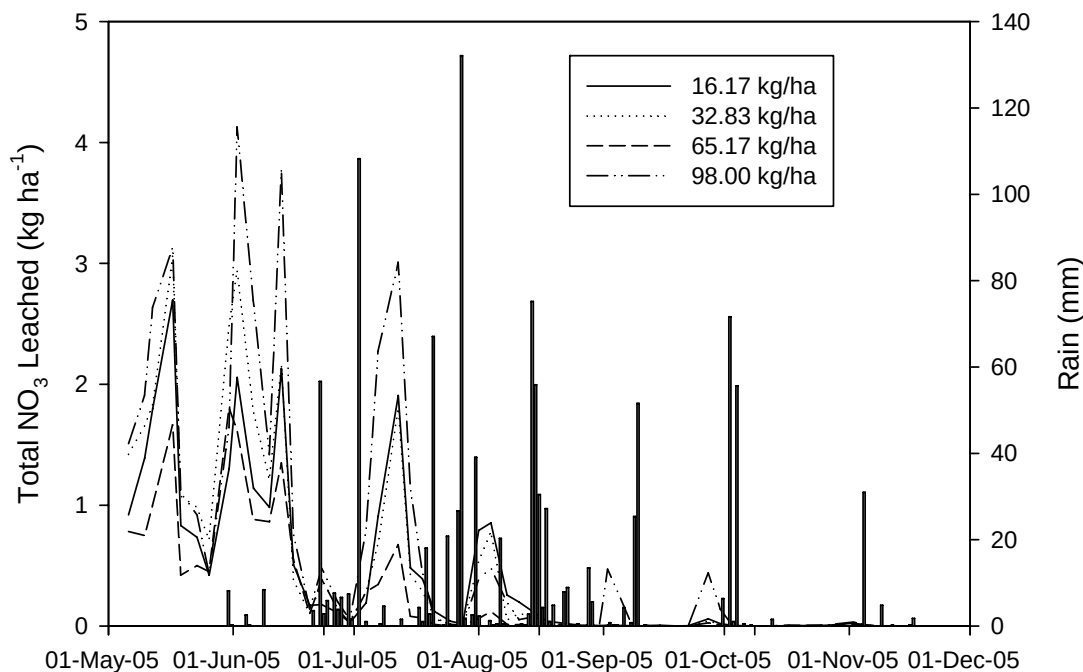


Figure 39: Total NO₃ leached from different nitrogen rates applied to established St. Augustinegrass in 2005 and the corresponding rainfall that occurred.

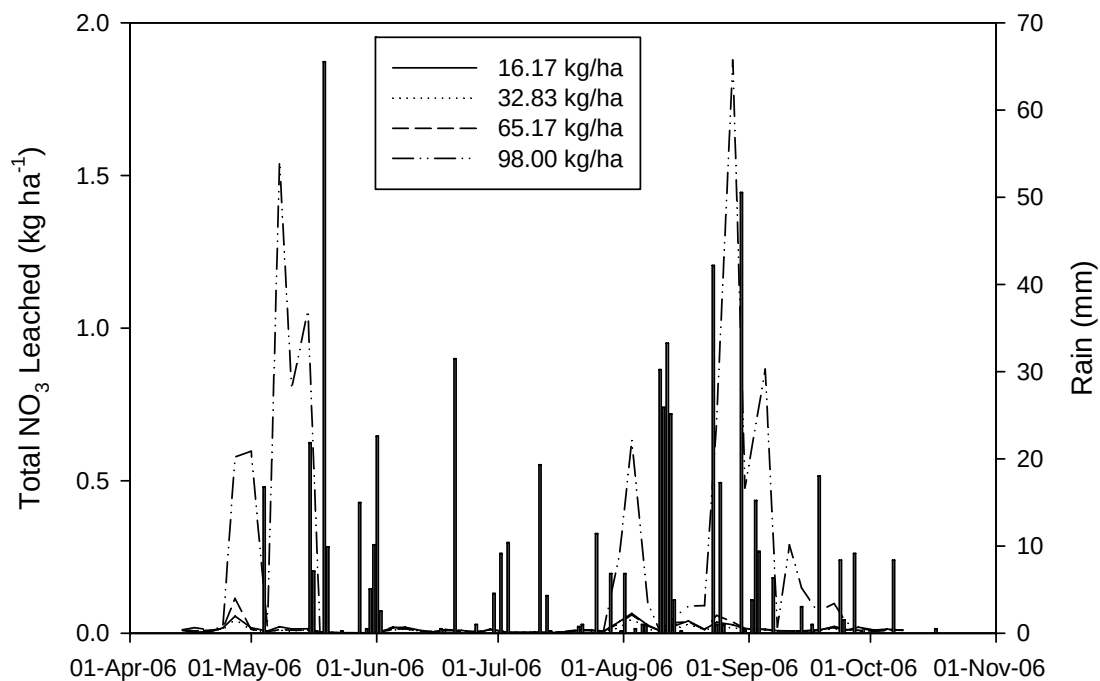


Figure 40: Total NO_3 leached from different nitrogen rates applied to established St. Augustinegrass in 2006 and the corresponding rainfall that occurred.

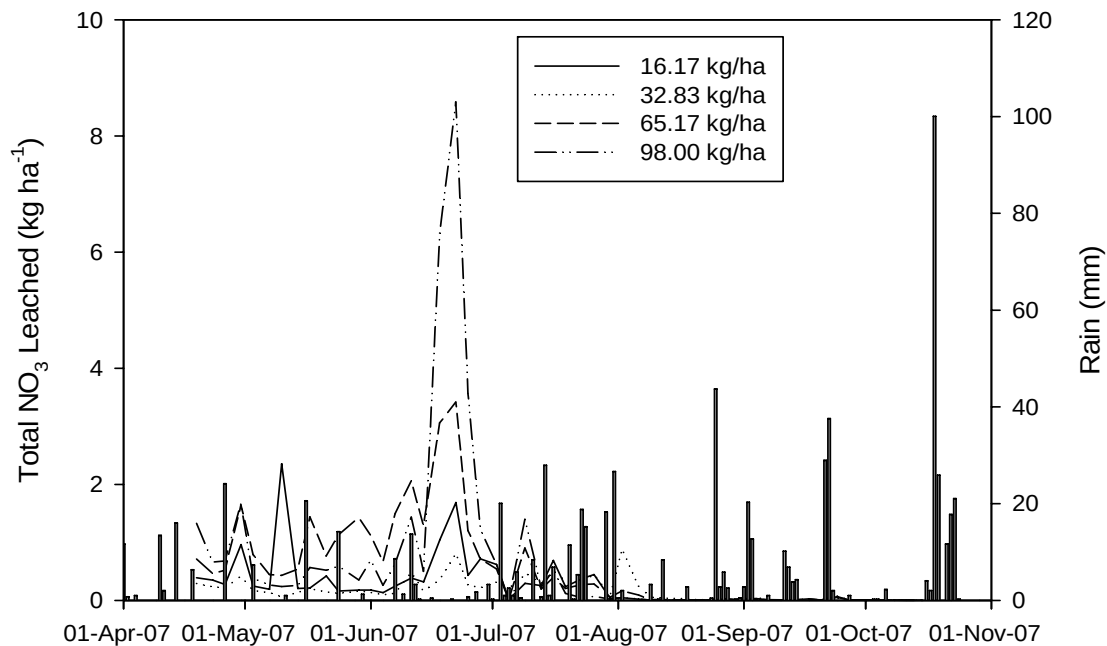


Figure 41: Total NO_3 leached from different nitrogen rates applied to established St. Augustinegrass in 2007 and the corresponding rainfall that occurred.

Table 167. Effect of irrigation and N-application rate on total N (MDL) on St. Augustinegrass turf.

	Total N (kg/ha)							
	Pre	T1	T2	T3	T4	T5	T6	Total Post
Year								
2005.....	15.294 a	-	-	5.940 a	3.434	0.187	0.065 b	10.645 a
2006.....	0.011 b	0.144	0.056	0.051 b	0.140	0.209	0.087 b	0.680 b
2007.....	0.655 b	2.917	3.172	7.142 a	0.561	0.103	0.122 a	14.007 a
<i>P</i> (F).....	**	NS	*	**	NS	NS	**	*
Irrigation								
1.27 cm.....	5.877	1.780	1.670	4.435	1.219	0.190	0.105 b	8.648
2.54 cm.....	4.763	1.281	1.560	4.319	1.538	0.143	0.071 a	8.241
<i>P</i> (F).....	NS	NS	NS	NS	NS	NS	*	NS
Rate (kg/ha)								
16.17.....	4.657 ab	1.256	0.952	2.924	1.516	0.206	0.106 a	6.480
32.83.....	6.149 a	0.882	0.841	2.909	1.554	0.139	0.074 bc	6.029
65.17.....	3.528 b	1.750	1.862	4.573	0.593	0.113	0.073 c	7.776
98.00.....	6.946 a	2.235	2.812	7.103	1.851	0.208	0.099 ab	13.493
<i>P</i> (F).....	*	NS	NS	NS	NS	NS	*	NS
<i>Year x Irr.</i>	NS	NS	NS	NS	NS	NS	NS	NS
<i>Year x Rat.</i>	**	NS	NS	NS	*	NS	NS	NS
<i>Irr. x Rate</i>	NS	NS	NS	NS	NS	NS	NS	NS
<i>Year x Irr.x Rate...</i>	NS	NS	NS	NS	NS	NS	NS	NS

Data corrected for MDL if data ≤ 0.148 then =0.148. Means followed by the same letter(s) in a column are not significantly different according to Duncan's Multiple Range Test ($P=0.05$).

**, * = $P < 0.01$ and $P < 0.05$, respectively. NS = $P > 0.05$.

Table 168. Effect of irrigation and N-application rate on total N (MDL) on St. Augustinegrass turf.

	% applied nitrogen							
	Pre	T1	T2	T3	T4	T5	T6	Total Post
Year								
2005.....	43.11 a	-	-	16.04 a	10.79	0.72	0.22 b	30.12
2006.....	0.03 b	0.41	0.19	0.15 b	0.44	0.57	0.27 ab	1.98
2007.....	1.89 b	7.30	6.90	14.72 a	1.45	0.29	0.33 a	31.00
P(F)	***	NS	NS	*	NS	NS	*	NS
Irrigation								
1.27 cm.....	15.98	4.91	4.89	12.08	3.40	0.56	0.31	23.39
2.54 cm.....	14.04	2.80	2.20	8.52	5.05	0.50	0.24	18.67
P(F)	NS	NS	NS	NS	NS	NS	NS	NS
Rate (kg/ha)								
16.17.....	28.80a	7.76	5.89	18.08	9.38 a	1.28 a	0.66 a	40.07
32.83.....	18.73a	2.69	2.56	8.86	4.73 ab	0.42 b	0.23 b	18.36
65.17.....	5.41b	2.69	2.86	7.02	0.91 b	0.17 b	0.11 c	11.93
98.00.....	7.09b	2.28	2.86	7.25	1.89 b	0.25 b	0.10 c	13.77
P(F)	****	NS	NS	NS	**	****	****	NS
Year x Irr.....	NS	NS	NS	NS	NS	NS	NS	NS
Year x Rat.....	****	NS	NS	NS	**	NS	NS	NS
Irr. x Rate	NS	NS	NS	NS	NS	NS	NS	NS
Year x Irr.x Rate...	****	NS	NS	NS	NS	NS	NS	NS

Data corrected for MDL if data ≤ 0.148 then =0.148. Means followed by the same letter(s) in a column are not significantly different according to Duncan's Multiple Range Test ($P=0.05$).

****, ***, ** and * = $P<0.0001$, $P<0.001$, $P<0.01$ and $P<0.05$, respectively. NS = $P>0.05$.

Effects of Irrigation and Nitrogen Application Rates on Nitrogen Leaching From Established Centipedegrass Turf

Quality, Color, and Density (2005 – 2007)

Irrigation Frequency: Centipedegrass quality, color, and density were not influenced by irrigation frequency in 2005 and 2006 (Tables 169-174). However, a single, weekly irrigation event yielded a slight improvement in color and quality in May 2007 (Table 175-177).

Nitrogen Rate: A notable quality, color, and density response was observed in all three years of the study (Tables 169-177). All rates of applied nitrogen produced acceptable turf quality. Unlike St. Augustinegrass, the deterioration in turf quality in 2007 was not as pronounced in centipedegrass (Table 175). The lower nitrogen rates resulted in poorer turf color during spring green-up in 2006 and 2007 (Tables 173 and 176, respectively). Turf density waned over the three years and was most negatively affected by low nitrogen ($\leq 12.25 \text{ kg ha}^{-1}$) in spring 2007 (Table 177).

Table 169: Effect of irrigation and N-application rate on established centipede turf quality in 2005.

	Nitrogen application date								
	8 Jun				9 Aug				8 Oct
	9 DAA	27 DAA	36 DAA	50 DAA	3 DAA	17 DAA	31 DAA	52 DAA	6 DAA
Irrigation									
1.27 cm.....	6.8	7.2	7.3	7.5	7.8	8.3	8.3	7.8	7.8
2.54 cm.....	6.8	7.2	7.1	7.3	7.7	8.1	8.0	7.6	7.6
<i>P</i> (F)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Rate (kg/ha)									
6.13.....	6.1 c	6.8 c	6.6 c	6.9 c	7.4 c	7.7 c	7.6 c	7.2 c	7.3 c
12.25.....	6.6	7.0	6.9 c	7.1	7.6	7.9 c	7.9 c	7.4 c	7.4
	bc	bc		bc	bc				bc
24.50.....	6.9 b	7.2 b	7.4 b	7.4 b	7.9	8.3 b	8.3 b	7.9 b	7.8 b
					ab				
49.00.....	7.5 a	7.9 a	7.9 a	8.0 a	8.1 a	8.8 a	8.8 a	8.5 a	8.3 a
<i>P</i> (F)	**	****	****	***	**	****	****	****	****
<i>Irr. x Rate</i>	NS	NS	NS	NS	NS	NS	NS	NS	NS

Quality visually rated on scale 1 to 9 where 9=best. Means in each column followed by the same letter(s) are not significantly different according to Fisher's Protected LSD ($P=0.05$). ****, ***, and ** = $P<0.0001$, $P<0.001$, and $P<0.01$, respectively. NS = not significant.

Table 170: Effect of irrigation and N-application rate on established centipede turf color in 2005.

	Nitrogen application date								
	8 Jun				9 Aug				8 Oct
	9 DAA	27 DAA	36 DAA	50 DAA	3 DAA	17 DAA	31 DAA	52 DAA	6 DAA
Irrigation									
1.27 cm.....	7.1	7.0	6.8	7.1	7.5	7.7	7.9	7.5	7.8
2.54 cm.....	7.0	7.0	7.1	7.2	7.6	7.6	7.8	7.5	7.4
<i>P</i> (F)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Rate (kg/ha)									
6.13.....	6.3 c	6.6 c	6.4 c	6.9 b	7.4	7.1 d	7.2 d	7.1 c	7.3 b
12.25.....	6.8	6.8 c	6.8 b	7.0 b	7.6	7.5 c	7.6 c	7.1 c	7.4 b
	bc								
24.50.....	7.1 b	7.0 b	6.9 b	7.1 b	7.6	7.8 b	8.1 b	7.6 b	7.6 b
49.00.....	8.0 a	7.6 a	7.6 a	7.6 a	7.7	8.2 a	8.6 a	8.1 a	8.1 a
<i>P</i> (F)	****	****	****	****	NS	****	****	****	****
<i>Irr. x Rate</i>	NS	NS	NS	NS	NS	NS	NS	NS	NS

Color visually rated on scale 1 to 9 where 9=best. Means in each column followed by the same letter(s) are not significantly different according to Fisher's Protected LSD ($P=0.05$). ****= $P<0.0001$. NS = not significant.

Table 171: Effect of irrigation and N-application rate on established centipede turf density in 2005.

	Nitrogen application date								
	8 Jun				9 Aug				8 Oct
	9 DAA	27 DAA	36 DAA	50 DAA	3 DAA	17 DAA	31 DAA	52 DAA	6 DAA
Irrigation									
1.27 cm.....	7.6	7.6	7.6	7.7	8.1	8.4	8.7	8.8	9.0
2.54 cm.....	6.9	7.3	7.4	7.5	8.1	8.4	8.6	8.8	9.0
<i>P</i> (F)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Rate (kg/ha)									
6.13.....	6.9 b	7.1 b	7.2 b	7.4 b	7.7 c	8.1 c	8.3 c	8.5 c	9.0
12.25.....	7.1	7.3 b	7.3 b	7.4 b	7.9 c	8.2 c	8.6 b	8.7 b	9.0
	ab								
24.50.....	7.5 a	7.7 a	7.7 a	7.6 b	8.2 b	8.4 b	8.9 a	9.0 a	9.0
49.00.....	7.6 a	7.9 a	7.9 a	8.0 a	8.5 a	8.8 a	8.9 a	9.0 a	9.0
<i>P</i> (F)	*	***	**	**	****	****	****	****	NS
<i>Irr. x Rate</i>	NS	NS	NS	NS	NS	NS	NS	NS	NS

Density visually rated on scale 1 to 9 where 9=best. Means in each column followed by the same letter(s) are not significantly different according to Fisher's Protected LSD ($P=0.05$). ****, ***, **, and * = $P<0.0001$, $P<0.001$, $P<0.01$, and $P<0.05$, respectively. NS = not significant.

Table 172: Effect of irrigation and N-application rate on established centipede turf quality in 2006.

	Nitrogen application date									
	14 Apr				14 Jun			11 Aug		
	13 DAA	28 DAA	42 DAA	56 DAA	16 DAA	37 DAA	51 DAA	8 DAA	28 DAA	42 DAA
Irrigation										
1.27 cm.....	7.3	6.7	7.3	7.0	7.6	7.6	7.8	7.8	8.1	7.4
2.54 cm.....	7.4	6.6	7.1	7.0	7.3	7.5	7.6	7.7	8.3	7.4
<i>P</i> (F)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Rate (kg/ha)										
6.13.....	6.9 c	6.1 b	6.9 b	6.6 b	6.6 d	7.0 c	7.3 c	7.1 c	7.6 c	6.8 c
12.25.....	7.1 bc	6.3 b	6.9 b	6.6 b	7.1 c	7.2 bc	7.4 bc	7.4 c	7.8 c	7.1 c
24.50.....	7.5 b	6.5 b	7.2 b	6.9 b	7.6 b	7.6 b	7.8 b	8.0 b	8.4 b	7.5 b
49.00.....	8.0 a	7.6 a	7.8 a	7.8 a	8.4 a	8.3 a	8.4 a	8.6 a	8.9 a	8.3 a
<i>P</i> (F)	***	**	**	**	****	***	***	****	****	****
<i>Irr. x Rate</i>	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Quality visually rated on scale 1 to 9 where 9=best. Means in each column followed by the same letter(s) are not significantly different according to Fisher's Protected LSD ($P=0.05$). ****, *** and ** = $P<0.0001$, $P<0.001$, and $P<0.01$, respectively. NS = not significant.

Table 173: Effect of irrigation and N-application rate on established centipede turf color in 2006.

	Nitrogen application date									
	14 Apr				14 Jun			11 Aug		
	13 DAA	28 DAA	42 DAA	56 DAA	16 DAA	37 DAA	51 DAA	8 DAA	28 DAA	42 DAA
Irrigation										
1.27 cm.....	7.3	6.7	7.3	6.8	7.6	7.5	7.8	7.8	8.2	7.6
2.54 cm.....	7.4	7.1	7.2	6.9	7.7	7.5	7.6	7.8	8.3	7.5
<i>P</i> (F)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Rate (kg/ha)										
6.13.....	7.0 b	6.4 c	7.1 b	6.7	7.0 d	7.2 bc	7.3 c	7.1 d	7.7 b	7.1 c
12.25.....	7.0 b	6.7 bc	6.9 b	6.6	7.4 c	7.1 c	7.4 bc	7.4 c	7.9 b	7.3 c
24.50.....	7.4 b	7.0 ab	7.1 b	6.8	7.8 b	7.5 b	7.8 b	8.1 b	8.5 a	7.6 b
49.00.....	7.9 a	7.4 a	7.7 a	7.3	8.4 a	8.2 a	8.3 a	8.6 a	8.9 a	8.2 a
<i>P</i> (F)	**	**	*	NS	****	****	***	****	****	****
<i>Irr. x Rate</i>	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Color visually rated on scale 1 to 9 where 9=best. Means in each column followed by the same letter(s) are not significantly different according to Fisher's Protected LSD ($P=0.05$). ****, ***, **, and * = $P<0.0001$, $P<0.001$, $P<0.01$, and $P<0.05$, respectively. NS = not significant.

Table 174: Effect of irrigation and N-application rate on established centipede turf density in 2006.

	Nitrogen application date									
	14 Apr				14 Jun			11 Aug		
	13 DAA	28 DAA	42 DAA	56 DAA	16 DAA	37 DAA	51 DAA	8 DAA	28 DAA	42 DAA
Irrigation										
1.27 cm.....	8.1	8.1	8.1	8.2	8.2	8.4	8.5	8.7	8.5	8.5
2.54 cm.....	8.2	7.9	8.0	8.2	8.2	8.4	8.5	8.7	8.6	8.5
<i>P</i> (F)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Rate (kg/ha)										
6.13.....	8.0	7.8 c	7.8	7.9 c	7.9 c	7.9 c	8.2 c	8.4 c	8.2 c	8.2 c
12.25.....	8.1	7.9 bc	7.9	8.1 bc	8.0 bc	8.1 c	8.3 bc	8.5 c	8.4 c	8.4 b
24.50.....	8.2	8.1 ab	8.1	8.3 ab	8.3 ab	8.6 b	8.5 b	8.8 b	8.7 b	8.5 b
49.00.....	8.4	8.3 a	8.3	8.5 a	8.6 a	8.9 a	8.9 a	9.0 a	8.9 a	8.8 a
<i>P</i> (F)	NS	*	NS	**	**	****	****	***	****	***
<i>Irr. x Rate</i>	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Density visually rated on scale 1 to 9 where 9=best. Means in each column followed by the same letter(s) are not significantly different according to Fisher's Protected LSD ($P=0.05$). ****, ***, **, and * = $P<0.0001$, $P<0.001$, $P<0.01$, and $P<0.05$, respectively. NS = not significant.

Table 175: Effect of irrigation and N-application rate on established centipede turf quality in 2007.

	Nitrogen application date														
	12 May		16 May			14 Jun			14 Aug				3 Oct		
	10 DAA	3 DAA	7 DAA	21 DAA	29 DAA	29 DAA	35 DAA	41 DAA	10 DAA	16 DAA	24 DAA	31 DAA	41 DAA	52 DAA	2 DAA
Irrigation															
1.27 cm.....	5.6	6.9	6.6	6.6	6.3	7.2	7.0	6.9	7.1	7.6	7.5	7.5	7.8	7.3	7.5
	b		b	b											
2.54 cm.....	6.1	7.0	6.9	6.9	6.3	7.2	6.8	7.0	7.3	7.8	7.7	7.7	7.6	7.3	7.7
	a		a	a											
P(F)	*	NS	*	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Rate (kg/ha)															
6.13.....	5.1	6.4	6.2	6.2	6.0	6.2	6.1	6.0	6.1	6.8	6.6	6.6	6.9	6.6	6.9
	c	c	c	c	b	d	c	c	d	c	d	d	d	d	c
12.25.....	5.5	6.4	6.4	6.4	6.1	6.6	6.3	6.3	6.6	7.1	7.1	7.1	7.3	6.9	7.0
	c	c	c	c	b	c	c	c	c	c	c	c	c	c	c
24.50.....	6.0	6.9	6.7	6.7	6.3	7.5	7.1	7.2	7.7	8.1	8.1	8.1	8.1	7.4	7.8
	b	b	b	b	b	b	b	b	b	b	b	b	b	b	b
49.00.....	6.6	8.0	7.8	7.8	7.1	8.5	8.1	8.3	8.3	8.7	8.5	8.5	8.6	8.2	8.7
	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a
P(F)	****	****	****	****	****	****	****	****	****	****	****	****	****	****	****
Irr. x Rate	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Quality visually rated on scale 1 to 9 where 9=best. Means in each column followed by the same letter(s) are not significantly different according to Fisher's Protected LSD ($P=0.05$). **** and * = $P<0.0001$ and $P<0.05$, respectively. NS = not significant.

Table 176. Effect of irrigation and N-application rate on established centipede turf color in 2007.

	Nitrogen application date														
	12 May		16 May			14 Jun			14 Aug				13 Oct		
	-10 DAA	3 DAA	7 DAA	21 DAA	29 DAA	29 DAA	35 DAA	41 DAA	10 DAA	16 DAA	24 DAA	31 DAA	41 DAA	52 DAA	2 DAA
Irrigation															
1.27 cm.....	7.1	6.8	6.6b	6.6b	6.2	6.8	6.9	6.8	7.0	7.7	7.3	7.3	7.7	7.2	7.4
2.54 cm.....	7.1	7.1	6.9a	6.9a	6.3	7.1	6.8	6.9	7.2	7.8	7.5	7.5	7.6	7.3	7.6
P(F)	NS	NS	*	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Rate (kg/ha)															
6.13.....	6.4b	6.4c	6.2c	6.2c	6.0b	6.0c	6.3c	5.9d	6.1d	6.8c	6.4d	6.4d	6.9c	6.6c	6.9c
12.25.....	6.8b	6.4c	6.3c	6.3c	6.1b	6.1c	6.3c	6.2c	6.5c	7.1c	6.8c	6.8c	7.1c	6.9c	7.0c
24.50.....	6.8b	7.1b	6.7b	6.7b	6.1b	7.3b	6.9b	7.0b	7.4b	8.2b	8.0b	8.0b	7.9b	7.3b	7.6b
49.00.....	8.4a	7.9a	7.7a	7.7a	6.7a	8.4a	8.1a	8.3a	8.3a	8.8a	8.5a	8.5a	8.6a	8.2a	8.4a
P(F)	**	****	****	****	****	****	****	****	****	****	****	****	****	****	****
Irr. x Rate	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Color visually rated on scale 1 to 9 where 9=best. Means in each column followed by the same letter(s) are not significantly different according to Fisher's Protected LSD ($P=0.05$). ****, **, and * = $P<0.0001$, $P<0.01$, and $P<0.05$, respectively. NS = not significant.

Table 177: Effect of irrigation and N-application rate on established centipede turf density in 2007.

	Nitrogen application date														
	12 May		16 May			14 Jun			14 Aug					13 Oct	
	-10 DAA	3 DAA	7 DAA	21 DAA	29 DAA	29 DAA	35 DAA	41 DAA	10 DAA	16 DAA	24 DAA	31 DAA	41 DAA	52 DAA	2 DAA
Irrigation															
1.27 cm	6.0	7.3	6.7	6.7	6.5	7.3	7.0	7.0	7.1	7.6	7.6	7.5	7.8	7.3	7.5
2.54 cm	6.3	7.3	6.8	6.8	6.3	7.2	6.9	6.9	7.2	7.7	7.7	7.5	7.6	7.3	7.7
P(F).....	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Rate (kg/ha)															
6.13	5.6c	6.9c	6.2c	6.2c	6.0c	6.1d	6.1c	6.0c	6.1c	6.7c	6.9d	6.5d	6.9d	6.6d	6.9c
12.25	6.1b	7.1bc	6.4bc	6.4bc	6.0c	6.6c	6.3c	6.3c	6.6b	7.1c	7.3c	7.1c	7.3c	7.0c	7.0c
24.50	6.0bc	7.3b	6.7b	6.7b	6.4b	7.8b	7.2b	7.3b	7.8a	8.1b	8.0b	8.0b	8.0b	7.4b	7.9b
49.00	6.8a	8.0a	7.7a	7.7a	7.3a	8.4a	8.3a	8.3a	8.1a	8.6a	8.5a	8.5a	8.6a	8.3a	8.7a
P(F).....	**	****	****	****	****	****	****	****	****	****	****	****	****	****	****
Irr. x Rate	NS	NS	NS	NS	NS	0.0314	NS	NS	NS	NS	NS	NS	NS	NS	NS

Density visually rated on scale 1 to 9 where 9=best. Means in each column followed by the same letter(s) are not significantly different according to Fisher's Protected LSD ($P=0.05$). **** and ** = $P<0.0001$ and $P<0.01$, respectively. NS = not significant.

Effects of Irrigation and Nitrogen Application Rates on Nitrogen Leaching From Established Centipedegrass Turf – Nitrate Leaching – 2006

Irrigation Frequency: The effect of irrigation frequency was not significant in 2005, 2006 and 2007 or when analyzed across years (Tables 178-181). The number of leaching events in centipedegrass equals that of St. Augustinegrass; however, only two of the dates coincide with each other. Nitrate leaching from centipedegrass, unlike St. Augustinegrass, is greater (though not statistically significant) when the turf is irrigated weekly as opposed to the 2X week irrigation regime.

Nitrogen Rate: During 2005 and 2007, no differences in nitrate leaching from centipedegrass due to nitrogen rate were observed (Tables 178 and 180). In 2006, following the first fertilizer cycle nitrate leaching was highest following the 6.13 kg ha⁻¹ application, but this effect was not seen the rest of the season (Table 179). The combined yearly analysis only found significant differences between years and a rate effect 30 days after the initial fertilization treatment with the lowest rate having the highest nitrate leaching (Table 181). The percentage of applied nitrogen that leached averaged only 0.0098% over the three fertilizer cycles suggesting that the rates of applied nitrogen were sufficiently low to not producing nitrate leaching and that the centipedegrass appears to be very efficient at using the applied nitrogen.

Table 178. Effect of irrigation and N-application rate on total N (MDL) on centipede turf in 2005.

	Total N (kg/ha)						Total Post
	Pre	T1	T2	T3	T4	T5	
Irrigation							
1.27 cm.....	13.407	5.396	3.570	0.270	0.073	0.066	9.734
2.54 cm.....	10.727	3.769	3.099	0.282	0.154	0.036	7.910
<i>P</i> (F)	NS	NS	NS	NS	NS	NS	NS
Rate (kg/ha)							
6.13.....	13.299	4.620	4.097	0.292	0.120	0.070	9.870
12.25.....	11.002	4.061	3.895	0.222	0.051	0.025	9.050
24.50.....	12.805	5.238	3.568	0.373	0.157	0.041	9.549
49.00.....	11.163	4.410	1.777	0.218	0.125	0.068	6.820
<i>P</i> (F)	NS	NS	NS	NS	NS	NS	NS
<i>Irrigation x Rate</i>	NS	NS	NS	NS	NS	NS	NS

Nitrogen applications made on 8 June and 9 August 2005. Pre= 6 May -6 Jun, T1=10 Jun- 7 Jul, T2=12 Jul- 8 Aug, T3=11 Aug – 8 Sep, T4=12 Sep – 10 Oct, T5=13 Oct – 7 Nov. Total post =accumulated N post 8 Jun treatment. Data corrected for MDL if data ≤ 0.148 then =0.148. No significant interactions between application date and rate, therefore only means for main effects of application date and rate are presented. Means followed by the same letter(s) in a column are not significantly different according to Duncan's Multiple Range Test ($P=0.05$). NS = $P>0.05$.

Table 179. Effect of irrigation and N-application rate on total N (MDL) on centipede turf in 2006.

	Total N (kg/ha)							Total Post
	Pre	T1	T2	T3	T4	T5	T6	
Irrigation								
1.27 cm.....	0.008	0.127	0.053	0.061	0.157	0.177	0.111	0.686
2.54 cm.....	0.010	0.131	0.088	0.055	0.128	0.141	0.073	0.617
<i>P</i> (F)	NS	NS	NS	NS	NS	NS	NS	NS
Rate (kg/ha)								
6.13.....	0.011	0.203 a	0.129 a	0.084	0.178	0.193	0.117	0.905
12.25.....	0.007	0.077 b	0.044 b	0.046	0.108	0.142	0.073	0.490
24.50.....	0.010	0.090 b	0.041 b	0.049	0.130	0.098	0.063	0.471
49.00.....	0.009	0.147 ab	0.069 ab	0.053	0.154	0.201	0.115	0.739
<i>P</i> (F)	NS	*	*	NS	NS	NS	NS	NS
<i>Irrigation x Rate</i> ...	NS	NS	NS	NS	NS	NS	NS	NS

Nitrogen applications made on 14 April, 14 June and 11 August 2006. Pre= 14 Apr, T1=17 Apr -11 May, T2=15 May – 12 Jun, T3=15 Jun – 13 Jul, T4=17 Jul – 10 Aug, T5=14 Aug – 11 Sep, T6=14 Sep – 9 Oct. Total post =accumulated N post 14 Apr treatment. Data corrected for MDL if data ≤ 0.148 then =0.148. No significant interactions between application date and rate, therefore only means for main effects of application date and rate are presented. Means followed by the same letter(s) in a column are not significantly different according to Duncan's Multiple Range Test ($P=0.05$). NS = $P>0.05$.

Table 180. Effect of irrigation and N-application rate on total N (MDL) on centipede turf in 2007.

	Total N (kg/ha)							
	Pre	T1	T2	T3	T4	T5	T6	Total Post
Irrigation								
1.27 cm.....	0.054	0.095	0.081	0.248	0.182	0.144	0.128	0.877
2.54 cm.....	0.108	0.258	0.088	0.204	0.151	0.115	0.127	0.943
<i>P(F)</i>	NS	NS	NS	NS	NS	NS	NS	NS
Rate (kg/ha)								
6.13.....	0.077	0.143	0.125	0.300	0.227	0.172	0.151	1.116
12.25.....	0.039	0.085	0.079	0.201	0.159	0.116	0.113	0.753
24.50.....	0.032	0.049	0.060	0.138	0.115	0.085	0.102	0.549
49.00.....	0.175	0.429	0.073	0.266	0.166	0.144	0.144	1.222
<i>P(F)</i>	NS	NS	NS	NS	NS	NS	NS	NS
<i>Irrigation x Rate...</i>	NS	NS	NS	NS	NS	NS	NS	NS

Nitrogen applications made on 16 April, 14 June and 14 August 2006. Pre= 12 Apr - 16 Apr, T1=19 Apr -14 May, T2=17 May – 14 Jun, T3=18 Jun – 16 Jul, T4=19 Jul – 13 Aug, T5=16 Aug – 13 Sep, T6=17 Sep – 15 Oct. Total post =accumulated N post 16 Apr treatment. Data corrected for MDL if data ≤ 0.148 then =0.148. No significant interactions between application date and rate, therefore only means for main effects of application date and rate are presented. Means followed by the same letter(s) in a column are not significantly different according to Duncan's Multiple Range Test ($P=0.05$). NS = $P>0.05$.

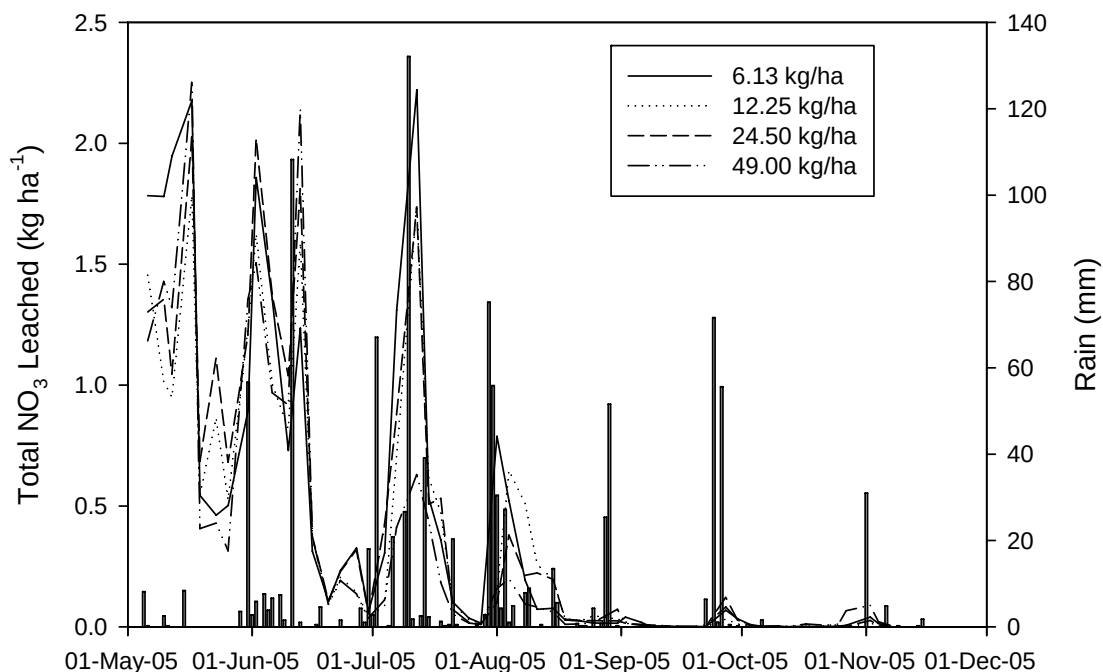


Figure 42: Total NO₃ leached from different nitrogen rates applied to established St. Augustinegrass in 2005 and the corresponding rainfall that occurred.

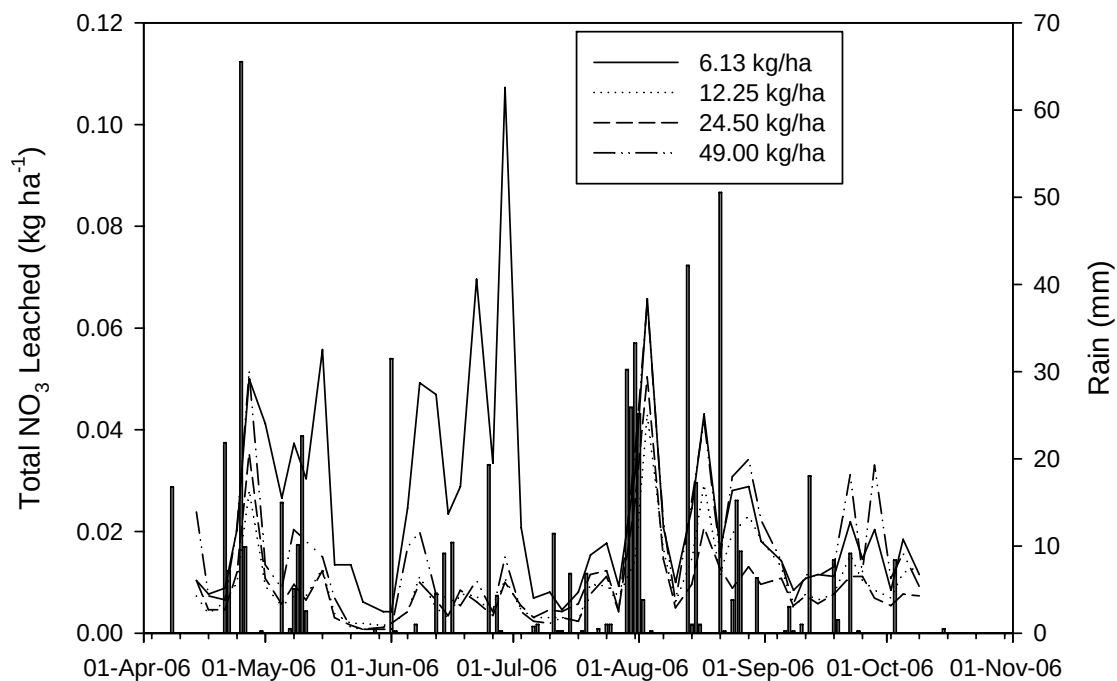


Figure 43: Total NO₃ leached from different nitrogen rates applied to established centipedegrass in 2006 and the corresponding rainfall that occurred.

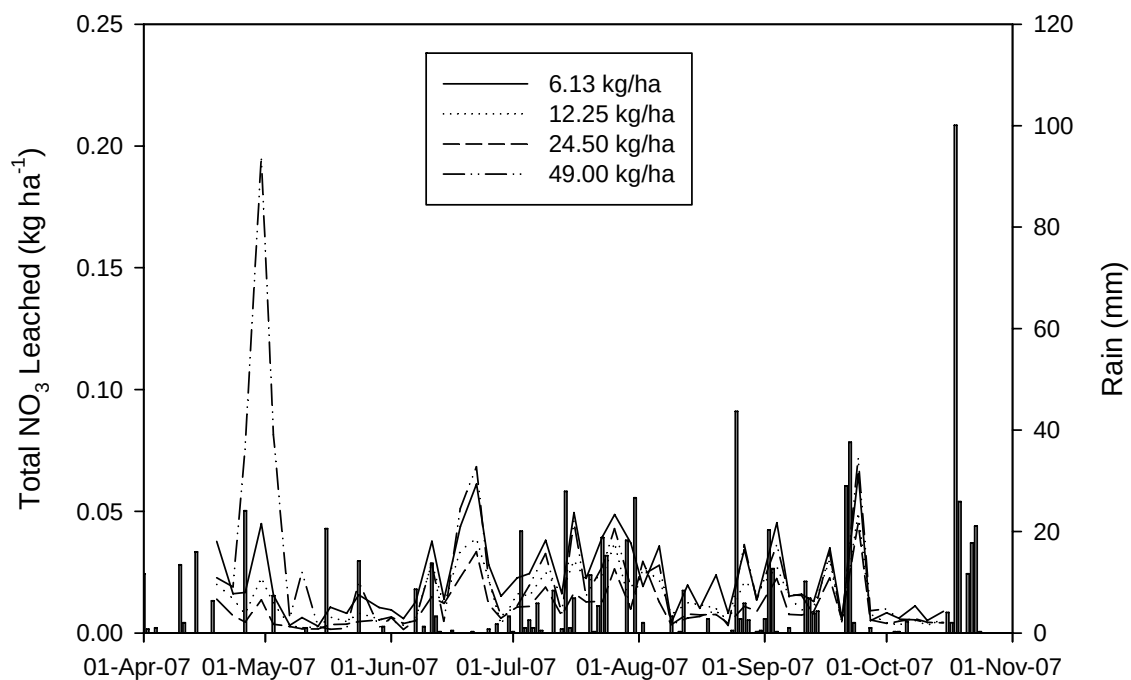


Figure 44: Total NO₃ leached from different nitrogen rates applied to established Centipedegrass in 2007 and the corresponding rainfall that occurred.

Table 181. Effect of irrigation and N-application rate on total N (MDL) on Centipede turf.

	Total N (kg/ha)							
	Pre	T1	T2	T3	T4	T5	T6	Total Post
Year								
2005.....	12.067 a	-	-	4.582 b	3.334a	0.276	0.113	8.822 a
2006.....	0.009 b	0.129	0.071	0.058 b	0.143b	0.159	0.092	0.651 b
2007.....	0.081 b	0.176	0.084	0.226 b	0.167b	0.129	0.127	0.910 b
<i>P</i> (F).....	***	NS	NS	**	*	NS	NS	*
Irrigation								
1.27 cm.....	4.490	0.111	0.067	1.902	1.303	0.197	0.104	3.766
2.54 cm.....	3.615	0.195	0.088	1.342	1.126	0.179	0.118	3.157
<i>P</i> (F).....	NS	NS	NS	NS	NS	NS	NS	NS
Rate (kg/ha)								
6.13.....	4.462	0.173	0.127 a	1.668	1.501	0.219	0.129	3.964
12.25.....	3.623	0.081	0.062 b	1.436	1.388	0.160	0.079	3.431
24.50.....	4.283	0.069	0.051 b	1.808	1.271	0.185	0.107	3.523
49.00.....	3.782	0.288	0.071 b	1.576	0.699	0.188	0.128	2.927
<i>P</i> (F).....	NS	NS	*	NS	NS	NS	NS	NS
<i>Year x Irr</i>	NS	NS	NS	NS	NS	NS	NS	NS
<i>Year x Rat</i>	NS	NS	NS	NS	NS	NS	NS	NS
<i>Irr. x Rate</i>	NS	NS	NS	NS	NS	NS	NS	NS
<i>Year x Irr.x Rate</i> ...	NS	NS	NS	NS	NS	NS	NS	NS

Data corrected for MDL if data ≤ 0.148 then $= 0.148$. Means followed by the same letter(s) in a column are not significantly different according to Duncan's Multiple Range Test ($P=0.05$).

***, **, * = $P < 0.001$, $P < 0.01$ and $P < 0.05$, respectively. NS = $P > 0.05$.

Table 182. Effect of irrigation and N-application rate on % nitrogen leached on Centipede turf.

	% nitrogen applied							
	Pre	T1	T2	T3	T4	T5	T6	Total Post
Year								
2005.....	95.45 a	-	-	34.73 a	29.20 a	2.13	0.82	71.95 a
2006.....	0.07 b	1.15	0.69	0.51 b	1.16 b	1.28	0.75	5.55 b
2007.....	0.52 b	1.03	0.77	1.91 b	1.45 b	1.10	1.02	7.27 b
<i>P</i> (F).....	***	NS	NS	**	*	NS	NS	*
Irrigation								
1.27 cm.....	35.88	0.92	0.59	13.67	12.70	1.56	0.85	31.86
2.54 cm.....	28.15	1.26	0.87	11.09	8.51	1.44	0.88	24.65
<i>P</i> (F).....	NS	NS	NS	NS	NS	NS	NS	NS
Rate (kg/ha)								
6.13.....	72.79 a	2.83 a	2.07 a	27.21 a	24.48 a	3.57 a	2.11 a	64.66 a
12.25.....	30.06 b	0.66 b	0.50 b	11.72 b	11.33 ab	1.31 b	0.64 b	28.01 b
24.50.....	17.48 b	0.28 b	0.21 b	7.38 b	5.19 b	0.76 b	0.44 b	14.38 b
49.00.....	7.72 b	0.59 b	0.15 b	3.22 b	1.43 b	0.38 b	0.26 b	5.97 b
<i>P</i> (F).....	****	****	****	****	*	****	****	***
<i>Year x Irr</i>	NS	NS	NS	NS	NS	NS	NS	NS
<i>Year x Rat</i>	****	NS	NS	****	*	NS	NS	**
<i>Irr. x Rate</i>	NS	NS	NS	NS	NS	NS	NS	NS
<i>Year x Irr.x Rate</i> ...	NS	NS	NS	NS	NS	NS	NS	NS

Data corrected for MDL if data ≤ 0.148 then =0.148. Means followed by the same letter(s) in a column are not significantly different according to Duncan's Multiple Range Test ($P=0.05$).

***, **, * = $P<0.001$, $P<0.01$ and $P<0.05$, respectively. NS = $P>0.05$.

IMPACT OF FERTILIZER APPLICATIONS TO SEMI-DORMANT AND DORMANT LAWN GRASSES ON ENVIRONMENTAL QUALITY

The Fall Fertility study was initiated during the fall of 2006 on newly established sod. Nitrogen was applied as soluble urea to centipedegrass and St. Augustinegrass. The rates evaluated were:

1. No treatment = zero N fertilizer
2. 6.0 kg ha⁻¹
3. 12.5 kg ha⁻¹
4. 24.0 kg ha⁻¹
5. 49.0 kg ha⁻¹

	2006-07	2007-08	2008-09
Pre-Treatment Period	05 Oct – 23 Oct	20 Aug – 30 Aug	19 Aug – 26 Aug
Application #1		31 Aug	28 Aug
Treatment Cycle #1	26 Oct – 04 Dec	31 Aug – 15 Oct	29 Aug – 07 Oct
Application #2		16 Oct	13 Oct
Treatment Cycle #2	07 Dec – 18 Jan	17 Oct – 29 Nov	14 Oct – 24 Nov
Application #3		30 Nov	01 Dec
Treatment Cycle #3	22 Jan – 04 Mar	01 Dec – 14 Jan	02 Dec – 14 Jan
Application #4		15 Jan	15 Jan
Treatment Cycle #4	07 Mar – 19 Apr	16 Jan – 25 Feb	15 Jan – 24 Feb
Application #5		29 Feb	02 Mar
Treatment Cycle #5		01 Mar – 15 Apr	03 Mar – 19 Apr
Treatment Cycle #6			21 Apr – 09 Jun

Shoot Growth

Shoot growth in 07-08 largely revealed that the highest rate of applied N 49.0 kg ha⁻¹ produced the greatest quantity of clippings. Minimal clippings were obtained from St. Augustinegrass (Table 183) through the winter months with a large collection on the first spring collection (7 May 2008). There were a number of significant turf type by N rate interactions so shoot growth data are separated by turf type in year 3 (2008-09). The 49.0 kg ha⁻¹ N application rate increased St. Augustinegrass shoot weight on 7 May 2008 and 20 May 2009 and 3 June 2009 (Table 185). The 24.0 kg ha⁻¹ N application rate also increased shoot growth over the untreated on 7 May 2008 (Table 185). In centipedegrass both 24.0 and 49.0 kg ha⁻¹ N applications increased shoot weight on 7 May 2008 and 15 June 2009 (Table 184). Shoot weight was only increased by 49.0 kg ha⁻¹ on 9 October 2008, 7 and 20 May 2009, and 3 June 2009 (Table 186).

Quality, Color, Density

2006-07

St. Augustinegrass: Turf quality and color were not affected by nitrogen rate during the first three fertilizer cycles. Ratings taken after the 5 Mar 2007 application show significant differences in quality and color (Tables 187 and 188). Higher rates of applied nitrogen yielded greater quality and color by promoting enhanced green-up. The threshold between acceptable quality was generally around 24.0 kg ha⁻¹ (Table 187). St.

Augustinegrass density was largely unaffected by nitrogen applications made to dormant or semi-dormant turf. As the turf was resuming growth in the spring, notable differences were observed. Density waned at the lower

rates of applied nitrogen. This was most evident in mid-May where rates below 24.0 kg ha⁻¹ had unacceptable turf density (Table 189).

Centipedegrass: Centipedegrass followed similar trends as St. Augustinegrass; however, it did not green-up until one month after the St. Augustinegrass. Nitrogen rates in excess of 12.0 kg ha⁻¹ promoted a more rapid spring green-up (Table 9). Acceptable turf quality was achieved with rates above 12.0 kg ha⁻¹ (Table 190). Centipedegrass density during the winter months was not affected by nitrogen rate (Table 192).

Combined Analysis: During the fall months, centipedegrass exhibited better turf quality than St. Augustinegrass (Table 193) which is likely attributed to turf color (Table 194). Centipedegrass loses color at first frost which is evident by the 17 and 36 days after the 23 October application where color drops from 8.0 to 2.0 (Table 194). St. Augustinegrass maintains better color during the winter months (Table 194). Across all nitrogen rates, centipedegrass had better turf quality during active growing conditions (Table 194). Turf density is was comparable between the two species and increasing nitrogen application rate produced greater turf density (Table 195)

2007-08

St. Augustinegrass: Through September, plots receiving any level of nutrition had acceptable turf quality (Table 196). From October 2007 through spring 2008, acceptable turf quality was evident only in turf receiving ≥ 24.0 kg ha⁻¹ (Table 196). N rates ≥ 24.0 kg ha⁻¹ retained color longer into the fall and promoted faster spring green-up (Table 197). Turf density was also best on plots receiving ≥ 24.0 kg ha⁻¹ (Table 198).

Centipedegrass: Centipedegrass followed similar trends as St. Augustinegrass (Table 199). Untreated centipedegrass had acceptable turf quality throughout 2007 indicating that residual nutrition (from sod production practices) was still sufficient (Table 199). Increasing levels of nitrogen improved turf quality throughout 2007. Late season turf color in the untreated control plots declined below acceptable levels however, even 6.0 kg ha⁻¹ produced acceptable turf color (Table 200). Turf density was acceptable at all levels of applied nitrogen (Table 201).

Combined Analysis: During the fall months, centipedegrass exhibited better turf quality than St. Augustinegrass (Table 202) which is likely attributed to turf color (Table 203). Turf density is was comparable between the two species and increasing nitrogen application rate produced greater turf density (Table 204).

2008-09

St. Augustinegrass: Nitrogen rates ≥ 24.0 kg ha⁻¹ significantly improved turf quality following the 28 August 2008 and 15 January 2009 applications, but differences were not detected following the March 2009 and April 2009 applications (Table 205). Nitrogen rates ≥ 24.0 kg ha⁻¹ improved turf color following the August 2008 application prior to the onset of dormancy and then continued to improve color once the turf greened up in March 2009 (Table 206). Turf density was also improved when N rates were ≥ 24.0 kg ha⁻¹ following August 2008 and January 2009 applications, but differences attributed to N rate were not detected following the March 2009 and April 2009 applications (Table 207). Higher rates of applied N yielded improved quality and color by enhancing spring green-up. The threshold between acceptable turf quality was generally around 24 kg ha⁻¹ (Table 205).

Centipedegrass: Centipedegrass followed similar trends as St. Augustinegrass (Table 208). Acceptable turf quality was achieved with N rates above 12.5 kg ha⁻¹ (Table 208). Nitrogen rates ≥ 12.5 kg ha⁻¹ promoted a more rapid spring green-up (Table 209) and centipedegrass density during the winter months was not affected by N rate (Table 210).

Combined Analysis – Turf Type: Centipedegrass turf exhibited higher quality, turf color and density compared to St. Augustinegrass turf during the fall months (Tables 211-213). Centipedegrass exhibited better turf quality

than St. Augustinegrass (Table 211) which is likely attributed to turf color (Table 212). Both St. Augustinegrass and centipedegrass lose color at first frost which is evident by the 32 days after the 15 January application where color drops from 6.4 to 1.0 and 7.5 to 1.0, respectively (Table 212). In general, increasing N application rate improved turf quality, color and density (Table 211-213).

Nitrate Leaching

2006-07

The initial sampling prior to the first run of the fall fertility study yielded significantly greater quantities of nitrate leaching than subsequent leaching cycles (Table 214). This phenomenon is likely due to the nitrogen that is applied during the production of the sod which is subsequently transported to the research site. Sod used in this study was in excellent condition and was not lacking in nutrition. Differences due to fertilizer rate were largely nonexistent except for Cycle T4 (07 Mar – 19 Apr) where St. Augustinegrass leached less than centipedegrass (Table 214). During this same cycle, fertilizer rate played a role in N leaching with the 49.0 kg ha⁻¹ rate leaching the most (0.928 kg ha⁻¹). On a percent of applied basis, values exceeded 100% due likely to nutrient import (Table 215).

2007-08

In 2007-08, leaching was minimal throughout the study. No differences existed between the two turf species during the Pre, T1, T2, and T3 cycles (Table 216). However, centipedegrass leached approximately four times more than St. Augustinegrass in T4 (0.913 vs. 0.234 kg ha⁻¹), T5 (0.504 vs. 0.126 kg ha⁻¹) and Total Post (2.364 vs. 0.902 kg ha⁻¹). Differences due to N rate were not existent during 2007-08 (Table 216). Expressed as a percent of applied, differences between the two species were never significant during 2007-08 (Table 217). However, difference due to N rate were present on each treatment cycle except for T5 (4 Mar – 15 Apr) (Table 217).

2008-09

In 2008-09 there were no differences between St. Augustinegrass and centipedegrass in the amount of NO₃-N leached or the percent of applied N (Tables 218 and 219). No significant differences in NO₃-N leaching between N application rates were detected until sampling periods T5 and T6 (March 2009 through June 2009) (Tables 218). During this time period N applied at 49 kg ha⁻¹ had the highest leaching (10.9 kg ha⁻¹); more than the other rates applied (Table 218). Leaching events consistently follow major rain events (Figure 45) and lead to the total NO₃-N leaching being highest with the 49 kg ha⁻¹ (Table 218). The percentage of N applied that was leached was highest at the 6.0 kg ha⁻¹ rate during the Pre, T1 and T2 sampling periods (Table 219). During the T5 and T6 periods and total accumulated % nitrogen applied was highest at the 49 kg ha⁻¹ which corresponds to the total NO₃-N leaching (Tables 218 and 219).

Combined Analysis – Years: Leaching was highest during 2006 and is likely attributed to nutrient import from the sod production farm (Table 220). Over the three years, centipedegrass leached more NO₃-N than St. Augustinegrass during the T3 and T4 time periods (Table 220; Figure 46). Differences in N application rate occurred only at the end of each winter season where the 49 kg N ha⁻¹ rate had the highest level of NO₃-N leaching (Table 220; Figure 47). The percent of applied nitrogen was highest in 2006 (Table 221) and the low rate (6.0 kg ha⁻¹) resulted in the highest % N lost, except during the T5 period where both 6.0 and 49 kg ha⁻¹ N rates had the highest % nitrogen leached (Table 221).

Table 183. Effect of turf type and N-application rate on St. Augustinegrass shoot growth in 2007-08.

Rate	Mass (g)						
	5 Sep 07	12 Sep 07	19 Sep 07	26 Sep 07	4 Oct 07	11 Oct 07	7 May 08
0.0 kg ha ⁻¹	0.360b	0.142b	0.265b	0.403b	0.516	0.352b	6.726c
6.0 kg ha ⁻¹	0.350b	0.235b	0.218b	0.302b	0.385	0.276b	6.949c
12.5 kg ha ⁻¹	0.696b	0.332b	0.424b	0.329b	0.473	0.262b	7.554c
24.0 kg ha ⁻¹	0.906b	0.607b	0.567b	0.562b	0.533	0.441ab	24.751b
49.0 kg ha ⁻¹	3.005a	2.655a	1.359a	1.433a	0.893	0.701a	55.918a
<i>LSD</i>	<i>0.851</i>	<i>0.688</i>	<i>0.505</i>	<i>0.452</i>	<i>ns</i>	<i>0.278</i>	<i>13.831</i>

Means followed by the same letter(s) in a column are not significantly different according to Fisher's Protected LSD ($P=0.05$).

Table 184. Effect of turf type and N-application rate on Centipedegrass shoot growth in 2007-08.

Rate	Mass (g)						
	5 Sep 07	12 Sep 07	19 Sep 07	26 Sep 07	4 Oct 07	11 Oct 07	7 May 08
0.0 kg ha ⁻¹	15.769	13.709c	10.892bc	8.963c	10.101b	7.292bc	11.042c
6.0 kg ha ⁻¹	27.434	11.564c	9.742c	8.301c	8.823b	6.500c	9.807c
12.5 kg ha ⁻¹	19.688	14.525bc	11.351bc	10.069c	10.621b	7.765bc	15.590c
24.0 kg ha ⁻¹	19.203	18.878b	14.981b	13.648b	11.624b	8.876b	29.863b
49.0 kg ha ⁻¹	23.910	29.995a	29.031a	18.762a	20.915a	13.948a	81.333a
<i>LSD</i>	<i>ns</i>	<i>5.156</i>	<i>4.758</i>	<i>2.772</i>	<i>3.588</i>	<i>2.316</i>	<i>9.851</i>

Means followed by the same letter(s) in a column are not significantly different according to Fisher's Protected LSD ($P=0.05$).

Table 185. Effect of turf type and N-application rate on St. Augustinegrass shoot growth in year 3 (2008-09).

N Rate	Mass (g)							
	7 May 08	24 Sep 08	9 Oct 08	7 May 09	10 May 09	3 Jun 09	15 Jun 09	24 Jun 09
0.0 kg ha ⁻¹	6.726c	1.588	0.558	0.963	0.057b	0.148b	0.276	2.037
6.0 kg ha ⁻¹	6.949c	1.089	0.421	0.776	0.036b	0.162b	0.304	1.508
12.5 kg ha ⁻¹	7.554c	1.376	0.401	0.775	0.056b	0.119b	0.255	2.675
24.0 kg ha ⁻¹	24.751b	1.052	0.591	0.848	0.038b	0.143b	0.390	1.558
49.0 kg ha ⁻¹	55.918a	1.399	1.059	2.132	0.161a	0.376a	0.589	3.129
<i>P(F)</i>	****	NS	NS	NS	*	**	NS	NS

****, **, * = $P>0.0001$, $P>0.01$, and $P>0.05$, respectively. NS = $P>0.05$. Means followed by the same letter(s) in a column are not significantly different according to Fisher's Protected LSD ($P=0.05$).

Table 186. Effect of turf type and N-application rate on centipedegrass shoot growth in year 3 (2008-09).

N Rate	Mass (g)							
	7 May 08	24 Sep 08	9 Oct 08	7 May 09	20 May 09	3 Jun 09	15 Jun 09	24 Jun 09
0.0 kg ha ⁻¹	11.042 c	9.199	7.288 b	3.654 bc	0.642 b	0.878 b	2.463 c	16.999
6.0 kg ha ⁻¹	9.807 c	7.367	6.805 b	2.814 bc	0.553 b	0.737 b	2.923 bc	18.958
12.5 kg ha ⁻¹	15.590 c	6.625	6.667 b	2.500 c	0.531 b	0.580 b	3.615 a-c	18.486
24 kg ha ⁻¹	29.863 b	10.490	7.940 b	3.760 b	1.275 b	0.746 b	4.704 a	20.934
49 kg ha ⁻¹	81.333 a	18.390	11.008 a	5.648 a	2.381 a	1.395 a	4.233 ab	18.864
P(F)	****	NS	*	**	**	**	*	NS

****, **, * = $P > 0.0001$, $P > 0.01$, and $P > 0.05$, respectively. NS = $P > 0.05$. Means followed by the same letter(s) in a column are not significantly different according to Fisher's Protected LSD ($P = 0.05$).

Table 187. N fertilization effects on St. Augustine turf quality in 2006-07.

N rate	Nitrogen application date													
	23 October			6 December			18 Jan	5 March		21 April				
	8 DAA	17 DAA	36 DAA	6 DAA	20 DAA	37 DAA	13 DAA	2 DAA	23 DAA	11 DAA	25 DAA	32 DAA	46 DAA	54 DAA
0.0 kg ha ⁻¹	5.5	5.1	5.8	4.3	3.8	4.1	3.5	5.0 c	4.6 c	4.9 c	6.4 c	5.4 d	6.6 b	6.1 d
6.0 kg ha ⁻¹	6.3	5.9	6.1	4.5	4.1	4.6	4.1	5.4 bc	4.3 bc	5.4 bc	6.8 bc	5.8 c	6.5 b	6.6 bc
12.5 kg ha ⁻¹	6.4	5.8	6.3	4.8	4.1	4.0	4.5	5.5 b	4.9 a-c	6.3 ab	6.6 bc	5.9 c	6.6 b	6.4 cd
24 kg ha ⁻¹	6.3	5.6	6.4	4.9	4.4	4.1	4.8	6.1 a	5.5 ab	6.5 ab	7.0 ab	6.4 b	7.0 b	6.9 b
49 kg ha ⁻¹	6.8	6.4	6.8	5.1	4.9	5.3	5.4	6.3 a	5.9 a	7.4 a	7.5 a	7.4 a	8.0 a	7.5 a
LSD	ns	ns	ns	ns	ns	ns	ns	0.5	1.1	1.2	0.5	0.3	0.6	0.4

Quality visually rated on scale of 1 to 9 where 9= best.

Means in each column followed by the same letter(s) are not significantly different according to Fisher's Protected LSD ($P=0.05$).

Table 188. N fertilization effects on St. Augustine turf color in 2006-07.

N rate	Nitrogen application date													
	23 October			6 December			18 Jan	5 March		21 April				
	8 DAA	17 DAA	36 DAA	6 DAA	20 DAA	37 DAA	13 DAA	2 DAA	23 DAA	11 DAA	25 DAA	32 DAA	46 DAA	54 DAA
0.0 kg ha ⁻¹	5.6	5.1	5.8	4.3	3.3	5.1	3.8	5.3 d	3.5 b	5.4 b	6.0 c	5.0 c	6.3 b	5.5 c
6.0 kg ha ⁻¹	6.3	5.8	6.1	4.5	3.8	4.9	4.3	5.6 cd	3.6 b	5.8 b	6.4 c	5.3 c	6.5 b	5.9 bc
12.5 kg ha ⁻¹	6.6	5.8	6.3	4.8	4.1	3.3	4.3	6.0 c	5.0 ab	6.3 b	6.4 c	5.5 bc	6.5 b	5.6 c
24 kg ha ⁻¹	6.0	5.8	6.4	4.9	4.5	5.0	5.0	6.6 b	6.0 a	6.3 b	7.1 b	6.0 b	6.8 b	6.4 b
49 kg ha ⁻¹	6.6	6.5	6.8	5.1	5.3	4.3	5.5	7.3 a	6.5 a	7.6 a	7.6 a	7.0 a	8.0 a	7.4 a
LSD	ns	ns	ns	ns	ns	ns	ns	0.6	1.6	0.9	0.5	0.6	0.8	0.5

Color visually rated on a scale of 1 to 9 where 9=best.

Means in each column followed by the same letter(s) are not significantly different according to Fisher's Protected LSD ($P=0.05$).

Table 189. N fertilization effects on St. Augustine turf density in 2006-07.

N rate	Nitrogen application date													
	23 October			6 December			18 Jan	5 March		21 April				
	8 DAA	17 DAA	36 DAA	6 DAA	20 DAA	37 DAA	13 DAA	2 DAA	23 DAA	11 DAA	25 DAA	32 DAA	46 DAA	54 DAA
0.0 kg ha ⁻¹	8.0	8.5	8.5	8.5	8.0	8.0	8.0	7.5 ab	7.1	6.3 b	6.8 b	5.8 d	6.9 bc	6.8 b
6.0 kg ha ⁻¹	8.0	8.5	8.5	8.5	8.0	8.0	8.0	7.3 b	6.9	6.5 b	7.0 b	6.0 cd	6.8 c	7.0 ab
12.5 kg ha ⁻¹	8.0	8.5	8.5	8.5	7.9	7.9	7.9	7.3 b	7.0	6.9 b	6.8 b	6.3 c	7.0 bc	7.0 ab
24 kg ha ⁻¹	8.0	8.5	8.5	8.5	7.9	7.9	7.9	7.8 a	7.4	6.9 b	7.4 ab	6.8 b	7.3 b	7.4 a
49 kg ha ⁻¹	8.0	8.5	8.5	8.5	7.9	7.9	7.9	7.9 a	7.6	7.8 a	7.8 a	7.8 a	8.0 a	7.5 a
LSD	ns	ns	ns	ns	ns	ns	ns	0.5	ns	0.6	0.6	0.5	0.5	0.5

Density visually rated on a scale of 1 to 9 where 9=best.

Means in each column followed by the same letter(s) are not significantly different according to Fisher's Protected LSD ($P=0.05$).

Table 190. N fertilization effects on Centipede turf quality in 2006-07.

N rate	Nitrogen application date													
	23 October			6 December			18 Jan	5 March		21 April				
	8 DAA	17 DAA	36 DAA	6 DAA	20 DAA	37 DAA	13 DAA	2 DAA	23 DAA	11 DAA	25 DAA	32 DAA	46 DAA	54 DAA
0.0 kg ha ⁻¹	8.0	8.0	2.0	1.5	1.5	1.5	1.5	1.5	3.5	5.9 b	6.9 b	6.0 c	6.6 c	6.9 b
6.0 kg ha ⁻¹	8.0	8.0	2.0	1.5	1.5	1.5	1.5	1.5	4.3	5.8 b	6.9 b	6.0 c	6.5 c	6.9 b
12.5 kg ha ⁻¹	8.0	8.0	2.0	1.5	1.5	1.5	1.5	1.5	4.4	6.5 ab	7.0 b	6.4 c	6.5 c	6.9 b
24 kg ha ⁻¹	8.0	8.0	2.0	1.5	1.5	1.5	1.5	1.5	3.4	7.1 a	7.5 a	6.9 b	7.3 b	7.5 a
49 kg ha ⁻¹	8.0	8.0	2.0	1.5	1.5	1.5	1.5	1.5	3.9	7.3 a	7.8 a	7.6 a	7.9 a	7.8 a
LSD	ns	ns	ns	ns	ns	ns	ns	ns	ns	1.1	0.3	0.4	0.5	0.3

Quality visually rated on scale of 1 to 9 where 9= best.

Means in each column followed by the same letter(s) are not significantly different according to Fisher's Protected LSD ($P=0.05$).

Table 191. N fertilization effects on Centipede turf color in 2006-07.

N rate	Nitrogen application date													
	23 October			6 December			18 Jan	5 March		21 April				
	8 DAA	17 DAA	36 DAA	6 DAA	20 DAA	37 DAA	13 DAA	2 DAA	23 DAA	11 DAA	25 DAA	32 DAA	46 DAA	54 DAA
0.0 kg ha ⁻¹	8.0	8.0	2.0	1.5	1.5	1.5	1.5	1.5	4.5	6.5 bc	7.1 bc	5.8 c	6.4 c	6.9 bc
6.0 kg ha ⁻¹	8.0	8.0	2.0	1.5	1.5	1.5	1.5	1.5	4.5	6.0 c	6.9 c	5.8 c	6.0 c	6.8 c
12.5 kg ha ⁻¹	8.0	8.0	2.0	1.5	1.5	1.5	1.5	1.5	4.6	7.0 ab	7.3 bc	6.4 b	6.4 c	6.9 bc
24 kg ha ⁻¹	8.0	8.0	2.0	1.5	1.5	1.5	1.5	1.5	4.6	7.3 ab	7.5 ab	6.8 b	7.3 b	7.4 ab
49 kg ha ⁻¹	7.9	8.0	2.0	1.5	1.5	1.5	1.5	1.5	4.3	7.9 a	7.9 a	8.0 a	8.3 a	7.8 a
LSD	ns	ns	ns	ns	ns	ns	ns	ns	ns	1.0	0.5	0.5	0.6	0.5

Color visually rated on a scale of 1 to 9 where 9=best.

Means in each column followed by the same letter(s) are not significantly different according to Fisher's Protected LSD ($P=0.05$).

Table 192. N fertilization effects on Centipede turf density in 2006-07.

N rate	Nitrogen application date													
	23 October			6 December			18 Jan	5 March		21 April				
	8 DAA	17 DAA	36 DAA	6 DAA	20 DAA	37 DAA	13 DAA	2 DAA	23 DAA	11 DAA	25 DAA	32 DAA	46 DAA	54 DAA
0.0 kg ha ⁻¹	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	7.0	6.0	6.9 b	6.3 b	6.9 b	7.1 c
6.0 kg ha ⁻¹	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	6.3	6.4	6.9 b	6.3 b	6.8 b	7.3 bc
12.5 kg ha ⁻¹	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	6.3	6.4	6.9 b	6.5 b	6.6 b	7.0 c
24 kg ha ⁻¹	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	6.3	6.8	7.6 a	7.1 a	7.3 ab	7.5 ab
49 kg ha ⁻¹	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	6.0	6.9	7.6 a	7.4 a	7.8 a	7.8 a
LSD	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	0.3	0.4	0.6	0.3

Density visually rated on a scale of 1 to 9 where 9=best.

Means in each column followed by the same letter(s) are not significantly different according to Fisher's Protected LSD ($P=0.05$).

Table 193. N fertilization effects on turf quality in 2006-07.

	Nitrogen application date													
	23 October			6 December			18 Jan	5 March		21 April				
	8 DAA	17 DAA	36 DAA	6 DAA	20 DAA	37 DAA	13 DAA	2 DAA	23 DAA	11 DAA	25 DAA	32 DAA	46 DAA	54 DAA
Turf														
St. Augustine	6.2 b	5.8 b	6.3 a	4.7 a	4.3 a	4.4 a	4.5 a	5.7	5.0	6.1	6.9	6.2	7.0	6.7
Centipede	8.0 a	8.0 a	2.0 b	1.5 b	1.5 b	1.5 b	1.5 b	1.5	3.9	6.5	7.2	6.6	7.0	7.2
LSD	0.5	0.4	0.5	0.4	0.3	0.5	0.4	-	-	ns	ns	ns	ns	ns
N rate														
0.0 kg ha ⁻¹	6.8	6.6	3.9	2.9	2.6	2.8	2.5	3.3	4.1	5.4 c	6.6 c	5.7 d	6.6 c	6.5 d
6.0 kg ha ⁻¹	7.1	6.9	4.1	3.0	2.8	3.1	2.8	3.4	4.3	5.6 c	6.8 c	5.9 d	6.5 c	6.8 c
12.5 kg ha ⁻¹	7.2	6.9	4.1	3.1	2.8	2.8	3.0	3.5	4.6	6.4 b	6.8 c	6.1 c	6.6 c	6.6 cd
24 kg ha ⁻¹	7.1	6.8	4.2	3.2	2.9	2.8	3.1	3.8	4.4	6.8 ab	7.3 b	6.6 b	7.1 b	7.2 b
49 kg ha ⁻¹	7.4	7.2	4.4	3.3	3.2	3.4	3.4	3.9	4.9	7.3 a	7.6 a	7.5 a	7.9 a	7.6 a
LSD	ns	ns	ns	ns	ns	ns	ns	-	-	0.8	0.3	0.2	0.4	0.2

Quality visually rated on scale of 1 to 9 where 9= best.

Means in each column followed by the same letter(s) are not significantly different according to Fisher's Protected LSD ($P=0.05$).

Table 194. N fertilization effects on turf color in 2006-07.

	Nitrogen application date													
	23 October			6 December			18 Jan	5 March		21 April				
	8 DAA	17 DAA	36 DAA	6 DAA	20 DAA	37 DAA	13 DAA	2 DAA	23 DAA	11 DAA	25 DAA	32 DAA	46 DAA	54 DAA
Turf														
St. Augustine	6.2 b	5.8 b	6.3 a	4.7 a	4.2 a	4.5 a	4.6 a	6.2	4.9	6.3	6.7 b	5.8 b	6.8	6.2 b
Centipede	8.0 a	8.0 a	2.0 b	1.5 b	1.5 b	1.5 b	1.5 b	1.5	4.5	6.9	7.3 a	6.5 a	6.9	7.1 a
LSD	0.5	0.4	0.5	0.4	0.5	0.6	0.4	-	-	ns	0.2	0.2	ns	0.2
N rate														
0.0 kg ha ⁻¹	6.8	6.6	3.9	2.9	2.4	3.3	2.6	3.4	4.0	5.9 c	6.6 c	5.4 d	6.3 c	6.2 c
6.0 kg ha ⁻¹	7.1	6.9	4.1	3.0	2.6	3.2	2.9	3.6	4.1	5.9 c	6.6 c	5.5 d	6.3 c	6.3 c
12.5 kg ha ⁻¹	7.3	6.9	4.1	3.1	2.8	2.4	2.9	3.8	4.8	6.6 b	6.8 c	5.9 c	6.4 c	6.3 c
24 kg ha ⁻¹	7.0	6.9	4.2	3.2	3.0	3.3	3.3	4.1	5.3	6.8 b	7.3 b	6.4 b	7.0 b	6.9 b
49 kg ha ⁻¹	7.3	7.3	4.4	3.3	3.4	2.9	3.5	4.4	5.4	7.8 a	7.8 a	7.5 a	8.1 a	7.6 a
LSD	ns	ns	ns	ns	ns	ns	ns	-	-	0.6	0.3	0.4	0.5	0.3

Color visually rated on a scale of 1 to 9 where 9=best.

Means in each column followed by the same letter(s) are not significantly different according to Fisher's Protected LSD ($P=0.05$).

Table 195. N fertilization effects on turf density in 2006-07.

	Nitrogen application date													
	23 October			6 December			18 Jan	5 March		21 April				
	8 DAA	17 DAA	36 DAA	6 DAA	20 DAA	37 DAA	13 DAA	2 DAA	23 DAA	11 DAA	25 DAA	32 DAA	46 DAA	54 DAA
Turf														
St. Augustine	8.0 b	8.5	8.5	8.5	7.9 b	7.9 b	7.9 b	7.5	7.2 a	6.9	7.1	6.5	7.2	7.1
Centipede	8.5 a	8.5	8.5	8.5	8.5 a	8.5 a	8.5 a	8.5	6.4 b	6.5	7.2	6.7	7.1	7.3
LSD	0	ns	ns	ns	0.1	0.1	0.1	-	0.3	ns	ns	ns	ns	ns
N rate														
0.0 kg ha ⁻¹	8.3	8.5	8.5	8.5	8.3	8.3	8.3	8.0	7.1	6.1 c	6.8 b	6.0 d	6.9 c	6.9 b
6.0 kg ha ⁻¹	8.3	8.5	8.5	8.5	8.3	8.3	8.3	7.9	6.6	6.4 bc	6.9 b	6.1 cd	6.8 c	7.1 b
12.5 kg ha ⁻¹	8.3	8.5	8.5	8.5	8.2	8.2	8.2	7.9	6.6	6.6 b	6.8 b	6.4 c	6.8 c	7.0 b
24 kg ha ⁻¹	8.3	8.5	8.5	8.5	8.2	8.2	8.2	8.1	6.8	6.8 b	7.5 a	6.9 b	7.3 b	7.4 a
49 kg ha ⁻¹	8.3	8.5	8.5	8.5	8.2	8.2	8.2	8.2	6.8	7.3 a	7.7 a	7.6 a	7.9 a	7.6 a
LSD	ns	ns	ns	ns	ns	ns	ns	-	ns	0.5	0.3	0.3	0.4	0.3

Density visually rated on a scale of 1 to 9 where 9=best.

Means in each column followed by the same letter(s) are not significantly different according to Fisher's Protected LSD ($P=0.05$).

Table 196. N fertilization effects on St. Augustine turf quality in 2007-08.

N rate	Nitrogen application date									
	31 August					30 November		29 February		
	7 DAA	14 DAA	24 DAA	35 DAA	45 DAA	2 DAA	45 DAA	14 DAA	38 DAA	
0.0 kg ha ⁻¹	6.3 c	6.3 c	6.4 d	5.5 d	5.6 b	7.0	6.0 c	6.0 c	4.0 d	
6.0 kg ha ⁻¹	6.8 c	6.8 c	7.0 c	6.3 c	5.8 b	6.8	6.3 c	6.3 c	5.3 c	
12.5 kg ha ⁻¹	6.9 bc	6.9 bc	7.3 c	6.4 c	6.0 b	6.3	6.3 c	6.3 c	5.8 c	
24 kg ha ⁻¹	7.5 b	7.5 b	8.0 b	7.0 b	7.0 a	7.0	7.0 b	7.0 b	7.0 b	
49 kg ha ⁻¹	8.3 a	8.3 a	8.5 a	7.5 a	7.5 a	7.9	8.0 a	8.0 a	8.0 a	
LSD	0.6	0.6	0.4	0.4	0.7	ns	0.4	0.4	0.5	

Nitrogen treatments applied 20 August 2007, 31 August 2007, 16 October 2007, 30 November 2007, 15 January 2008, and 29 February 2008.

Quality visually rated on a scale of 1 to 9 where 9= best.

Means in each column followed by the same letter(s) are not significantly different according to Fisher's Protected LSD ($P=0.05$).

Table 197. N fertilization effects on St. Augustine turf color in 2007-08.

N rate	Nitrogen application date								
	31 August					30 November		29 February	
	7 DAA	14 DAA	24 DAA	35 DAA	45 DAA	2 DAA	45 DAA	14 DAA	38 DAA
0.0 kg ha ⁻¹	5.1 c	5.1 c	6.3 c	5.3 c	5.1 b	6.1	1.5	1.5 b	5.0 d
6.0 kg ha ⁻¹	6.3 b	6.3 b	6.9 bc	6.3 b	5.3 b	6.0	1.5	1.5 b	5.3 cd
12.5 kg ha ⁻¹	6.4 b	6.4 b	7.1 b	6.1 b	5.5 b	5.8	1.5	1.8 b	5.8 c
24 kg ha ⁻¹	7.5 a	7.5 a	8.0 a	7.0 a	6.5 a	6.5	1.8	2.0 ab	7.0 b
49 kg ha ⁻¹	8.3 a	8.3 a	8.5 a	7.3 a	7.0 a	7.4	1.8	2.5 a	8.0 a
LSD	0.9	0.9	0.6	0.5	0.9	ns	ns	0.6	0.5

Nitrogen treatments applied 20 August 2007, 31 August 2007, 16 October 2007, 30 November 2007, 15 January 2008, and 29 February 2008.

Color visually rated on a scale of 1 to 9 where 9= best.

Means in each column followed by the same letter(s) are not significantly different according to Fisher's Protected LSD ($P=0.05$).

Table 198. N fertilization effects on St. Augustine turf density in 2007-08.

N rate	Nitrogen application date								
	31 August					30 November		29 February	
	7 DAA	14 DAA	24 DAA	35 DAA	45 DAA	2 DAA	45 DAA	14 DAA	38 DAA
0.0 kg ha ⁻¹	6.8 c	6.8 c	6.5 d	5.8 c	6.5 c	6.9	6.0 b	6.0 b	5.3 c
6.0 kg ha ⁻¹	7.0 bc	7.0 bc	7.0 c	6.0 c	6.5 c	6.6	6.5 b	6.5 b	5.8 c
12.5 kg ha ⁻¹	7.4 bc	7.4 bc	7.1 c	6.1 c	6.6 c	6.0	6.5 b	6.5 b	5.8 c
24 kg ha ⁻¹	7.6 ab	7.6 ab	8.0 b	7.3 b	7.3 b	6.8	7.8 a	7.8 a	7.0 b
49 kg ha ⁻¹	8.3 a	8.3 a	8.5 a	8.0 a	8.0 a	7.8	8.3 a	8.3 a	8.0 a
LSD	0.7	0.7	0.5	0.5	0.3	ns	0.8	0.8	0.6

Nitrogen treatments applied 20 August 2007, 31 August 2007, 16 October 2007, 30 November 2007, 15 January 2008, and 29 February 2008.

Density visually rated on a scale of 1 to 9 where 9= best.

Means in each column followed by the same letter(s) are not significantly different according to Fisher's Protected LSD ($P=0.05$).

Table 199. N fertilization effects on Centipede turf quality in 2007-08.

N rate	Nitrogen application date								
	31 August					30 November		29 February	
	7 DAA	14 DAA	24 DAA	35 DAA	45 DAA	2 DAA	45 DAA	14 DAA	38 DAA
0.0 kg ha ⁻¹	7.8	7.8	6.9 c	6.8 c	7.1 c	6.5	6.3	6.0 b	6.5
6.0 kg ha ⁻¹	7.4	7.4	7.1 c	6.4 c	7.3 bc	7.8	6.5	6.0 b	6.6
12.5 kg ha ⁻¹	7.8	7.8	7.8 b	7.3 b	7.8 ab	7.3	6.8	6.0 b	7.3
24 kg ha ⁻¹	7.9	7.6	8.4 a	7.6 b	7.5 bc	7.8	7.0	6.8 a	7.3
49 kg ha ⁻¹	8.1	8.1	8.5 a	8.1 a	8.3 a	7.1	7.0	6.8 a	7.9
LSD	ns	ns	0.3	0.5	0.5	ns	ns	0.5	ns

Nitrogen treatments applied 20 August 2007, 31 August 2007, 16 October 2007, 30 November 2007, 15 January 2008, and 29 February 2008.

Quality visually rated on a scale of 1 to 9 where 9= best.

Means in each column followed by the same letter(s) are not significantly different according to Fisher's Protected LSD ($P=0.05$).

Table 200. N fertilization effects on Centipede turf color in 2007-08.

N rate	Nitrogen application date								
	31 August					30 November		29 February	
	7 DAA	14 DAA	24 DAA	35 DAA	45 DAA	2 DAA	45 DAA	14 DAA	38 DAA
0.0 kg ha ⁻¹	7.8	7.8	6.8 c	6.8 c	6.6 c	6.3	1.0	1.0	7.3
6.0 kg ha ⁻¹	7.3	7.3	7.0 c	6.4 c	6.9 c	7.8	1.0	1.0	7.4
12.5 kg ha ⁻¹	7.5	7.5	8.0 b	7.3 b	7.4 b	7.0	1.0	1.0	7.8
24 kg ha ⁻¹	7.9	7.6	8.4 ab	7.6 b	7.0 bc	7.5	1.0	1.0	8.0
49 kg ha ⁻¹	8.1	8.1	8.5 a	8.1 a	8.0 a	6.6	1.0	1.0	8.1
LSD	ns	ns	0.4	0.5	0.4	ns	ns	ns	ns

Nitrogen treatments applied 20 August 2007, 31 August 2007, 16 October 2007, 30 November 2007, 15 January 2008, and 29 February 2008.

Color visually rated on a scale of 1 to 9 where 9= best.

Means in each column followed by the same letter(s) are not significantly different according to Fisher's Protected LSD ($P=0.05$).

Table 201. N fertilization effects on Centipede turf density in 2007-08.

N rate	Nitrogen application date								
	31 August					30 November		29 February	
	7 DAA	14 DAA	24 DAA	35 DAA	45 DAA	2 DAA	45 DAA	14 DAA	38 DAA
0.0 kg ha ⁻¹	7.6	7.6	7.0 c	6.8 c	7.4 b	7.0	6.5 b	6.5 b	7.3
6.0 kg ha ⁻¹	7.1	7.4	7.1 c	6.4 c	7.4 b	8.1	6.5 b	6.5 b	7.3
12.5 kg ha ⁻¹	7.6	7.9	7.5 b	7.3 b	7.9 ab	7.8	6.8 b	6.5 b	7.3
24 kg ha ⁻¹	7.6	7.6	8.4 a	7.6 b	7.8 b	8.1	7.0 ab	7.5 a	7.3
49 kg ha ⁻¹	8.1	8.1	8.5 a	8.1 a	8.5 a	7.5	7.8 a	7.8 a	7.9
<i>LSD</i>	<i>ns</i>	<i>ns</i>	0.3	0.5	0.7	<i>ns</i>	0.9	0.8	<i>ns</i>

Nitrogen treatments applied 20 August 2007, 31 August 2007, 16 October 2007, 30 November 2007, 15 January 2008, and 29 February 2008.

Density visually rated on a scale of 1 to 9 where 9= best.

Means in each column followed by the same letter(s) are not significantly different according to Fisher's Protected LSD ($P=0.05$).

Table 202. N fertilization effects on turf quality in 2007-08.

	Nitrogen application date								
	31 August					30 November		29 February	
	7 DAA	14 DAA	24 DAA	35 DAA	45 DAA	2 DAA	45 DAA	14 DAA	38 DAA
Turf									
St. Augustine...	7.1	7.1	7.4 b	6.5	6.4	7.0	6.7	6.7	6.0
Centipede	7.8	7.7	7.7 a	7.2	7.6	7.3	6.7	6.3	7.1
LSD	-	-	0.2	-	-	ns	-	-	-
N rate									
0.0 kg ha ⁻¹	7.0	7.0	6.6 e	6.1	6.4	6.8	6.1	6.0	5.3
6.0 kg ha ⁻¹	7.1	7.1	7.1 d	6.3	6.5	7.3	6.4	6.1	5.9
12.5 kg ha ⁻¹	7.3	7.3	7.5 c	6.8	6.9	6.8	6.5	6.1	6.5
24 kg ha ⁻¹	7.7	7.6	8.2 b	7.3	7.3	7.4	7.0	6.9	7.1
49 kg ha ⁻¹	8.2	8.2	8.5 a	7.8	7.9	7.5	7.5	7.4	7.9
LSD	-	-	0.2	-	-	ns	-	-	-

Nitrogen treatments applied 20 August 2007, 31 August 2007, 16 October 2007, 30 November 2007, 15 January 2008, and 29 February 2008.

Quality visually rated on a scale of 1 to 9 where 9= best. Means in each column followed by the same letter(s) are not significantly different according to Fisher's Protected LSD ($P=0.05$). “-”=significant turf by rate interaction.

Table 203. N fertilization effects on turf color in 2007-08.

	Nitrogen application date								
	31 August					30 November		29 February	
	7 DAA	14 DAA	24 DAA	35 DAA	45 DAA	2 DAA	45 DAA	14 DAA	38 DAA
Turf									
St. Augustine...	6.7	6.7	7.4 b	6.4	5.9	6.4	1.6	1.9	6.2
Centipede	7.7	7.7	7.7 a	7.2	7.2	7.0	1.0	1.2	7.7
LSD	-	-	0.2	-	ns	ns	ns	ns	-
N rate									
0.0 kg ha ⁻¹	6.4	6.4	6.5 d	6.0	5.9 d	6.2	1.3	1.3 c	6.1
6.0 kg ha ⁻¹	6.8	6.8	6.9 c	6.3	6.1 cd	6.9	1.3	1.3 c	6.3
12.5 kg ha ⁻¹	6.9	6.9	7.6 b	6.7	6.4 bc	6.4	1.3	1.4 bc	6.8
24 kg ha ⁻¹	7.7	7.6	8.2 a	7.3	6.8 b	7.0	1.4	1.8 ab	7.5
49 kg ha ⁻¹	8.2	8.2	8.5 a	7.7	7.5 a	7.0	1.4	2.0 a	8.1
LSD	-	-	0.4	-	0.5	ns	ns	0.4	-

Nitrogen treatments applied 20 August 2007, 31 August 2007, 16 October 2007, 30 November 2007, 15 January 2008, and 29 February 2008.

Color visually rated on a scale of 1 to 9 where 9= best. Means in each column followed by the same letter(s) are not significantly different according to Fisher's Protected LSD ($P=0.05$). "-"=significant turf by rate interaction.

Table 204. N fertilization effects on turf density in 2007-08.

	Nitrogen application date								
	31 August				45 DAA	30 Novemb		29 Februar	
	7 DAA	14 DAA	24 DAA	35 DAA		2 DAA	45 DAA	14 DAA	38 DAA
Turf									
St.	7.4	7.4	7.4	6.6	7.0 b	6.8	7.0	7.0	6.4
Augustine ...									
Centipede ...	7.6	7.7	7.7	7.2	7.8 a	7.7	6.9	7.0	7.4
LSD	ns	ns	ns	-	0.2	-	ns	ns	-
N rate									
0.0 kg ha ⁻¹	7.2 bc	7.2 b	6.8 d	6.3	6.9 c	6.9	6.3 c	6.3 b	6.3
6.0 kg ha ⁻¹	7.1 c	7.2 b	7.1 c	6.2	6.9 c	7.4	6.5 c	6.5 b	6.5
12.5 kg ha ⁻¹	7.5 bc	7.6 b	7.3 c	6.7	7.3 bc	6.9	6.6 c	6.5 b	6.5
24 kg ha ⁻¹	7.6 b	7.6 b	8.2 b	7.4	7.5 b	7.4	7.4 b	7.6 a	7.1
49 kg ha ⁻¹	8.2 a	8.2 a	8.5 a	8.1	8.3 a	7.6	8.0 a	8.0 a	7.9
LSD	0.5	0.6	0.3	-	0.4	-	0.5	0.5	-

Nitrogen treatments applied 20 August 2007, 31 August 2007, 16 October 2007, 30 November 2007, 15 January 2008, and 29 February 2008.

Density visually rated on a scale of 1 to 9 where 9= best. Means in each column followed by the same letter(s) are not significantly different according to Fisher's Protected LSD ($P=0.05$). "-"=significant turf by rate interaction.

Table 205. N fertilization effects on St. Augustine turf quality in 2008-09.

N rate	Nitrogen application date						
	28 August 2008		15 January 2009		2 March	17 April 2009	
	20 DAA	43 DAA	32 DAA		<u>2009</u> 46 DAA	27 DAA	63 DAA 69 DAA
0.0 kg ha ⁻¹	5.0 d	5.5 c	5.5 b		4.0	5.1	3.8 4.0 c
6.0 kg ha ⁻¹	5.9 c	6.1 bc	5.5 b		4.0	5.6	4.3 4.5 bc
12.5 kg ha ⁻¹	6.5 b	6.4 b	5.8 b		4.9	5.9	4.9 5.3 ab
24 kg ha ⁻¹	7.3 a	7.1 a	7.0 a		6.0	6.0	5.5 5.8 a
49 kg ha ⁻¹	7.8 a	7.8 a	6.5 a		3.4	5.5	4.9 4.8 a-c
LSD	0.6	0.7	0.6		ns	ns	ns 1.1

Nitrogen treatments applied 27 August 2008, 28 August 2008, 13 October 2008, 1 December 2008, 15 January 2009, 2 March 2009 and 17 April 2009.

Quality visually rated on a scale of 1 to 9 where 9= best. Means in each column followed by the same letter(s) are not significantly different according to Fisher's Protected LSD ($P=0.05$).

Table 206. N fertilization effects on St. Augustine turf color in 2008-09.

N rate	Nitrogen application date							
	28 August 2008		15 January 2009		2 March 2009	17 April 2009		
	20 DAA	43 DAA		32 DAA	46 DAA	27 DAA	63 DAA	69 DAA
0.0 kg ha ⁻¹	5.3 d	5.6 d	1.0		5.0 b	6.1	4.5 c	4.8 c
6.0 kg ha ⁻¹	6.1 c	6.0	1.0		5.0 b	5.6	4.9	4.8 c
12.5 kg ha ⁻¹		cd					bc	
	6.8	6.4	1.0		5.4	5.9	5.1	5.5 b
	bc	bc			ab		bc	
	24 kg ha ⁻¹	7.3	6.6 b	1.0	6.5 a	6.3	5.6 b	5.0
49 kg ha ⁻¹	ab							bc
	8.0 a	7.5 a	1.0		6.5 a	7.0	7.1 a	6.5 a
LSD	0.8	0.6		ns	1.3	ns	1.0	0.6

Nitrogen treatments applied 27 August 2008, 28 August 2008, 13 October 2008, 1 December 2008, 15 January 2009, 2 March 2009 and 17 April 2009.

Color visually rated on a scale of 1 to 9 where 9= best. Means in each column followed by the same letter(s) are not significantly different according to Fisher's Protected LSD ($P=0.05$).

Table 207. N fertilization effects on St. Augustine turf density in 2008-09.

N rate	Nitrogen application date						
	28 August 2008			15 January 2009			
	20 DAA	43 DAA	32 DAA	2 March 2009	27 DAA	63 DAA	69 DAA
0.0 kg ha ⁻¹	5.0 e	6.5 d	5.3 b	4.8	5.5	3.3	3.5 c
6.0 kg ha ⁻¹	5.5 d	6.8	5.8 b	5.0	5.5	4.3	4.5
		cd					bc
12.5 kg ha ⁻¹	6.5 c	6.9 c	5.5 b	5.5	5.8	4.8	5.3
							ab
24 kg ha ⁻¹	7.3 b	7.6 b	8.0 a	6.3	6.4	5.6	6.3 a
49 kg ha ⁻¹	7.9 a	8.1 a	8.3 a	5.0	5.4	4.9	5.0
							ab
LSD	0.5	0.3	1.0	ns	ns	ns	1.3

Nitrogen treatments applied 27 August 2008, 28 August 2008, 13 October 2008, 1 December 2008, 15 January 2009, 2 March 2009 and 17 April 2009.

Density visually rated on a scale of 1 to 9 where 9= best. Means in each column followed by the same letter(s) are not significantly different according to Fisher's Protected LSD ($P=0.05$).

Table 208. N fertilization effects on centipede turf quality in 2008-09.

N rate	Nitrogen application date							
	28 August 2008		15 January 2009		2 March 2009	17 April 2009		
	20 DAA	43 DAA		32 DAA	46 DAA	27 DAA	63 DAA	69 DAA
0.0 kg ha ⁻¹	7.9	7.3 bc	5.5 cd		5.6 b	5.9 c	5.5	5.0 b
6.0 kg ha ⁻¹	6.8	7.1 c	5.0 d		5.5 b	6.4 c	5.8	5.0 b
12.5 kg ha ⁻¹	7.1	7.3 bc	5.8 bc		6.6 ab	6.6 bc	6.4	6.0 ab
24 kg ha ⁻¹	6.9	7.8 b	6.3 ab		7.3 a	7.6 a	6.8	6.3 ab
49 kg ha ⁻¹	8.3	8.5 a	6.5 a		6.0 b	7.5 ab	6.8	6.8 a
LSD	ns	0.6		0.7	1.1	0.9	ns	1.3

Nitrogen treatments applied 27 August 2008, 28 August 2008, 13 October 2008, 1 December 2008, 15 January 2009, 2 March 2009 and 17 April 2009.

Quality visually rated on a scale of 1 to 9 where 9= best. Means in each column followed by the same letter(s) are not significantly different according to Fisher's Protected LSD ($P=0.05$).

Table 209. N fertilization effects on centipede turf color in 2008-09.

N rate	Nitrogen application date						
	28 August 2008	15 January 2009					
	20 DAA	43 DAA	32 DAA	2 March 2009	27 DAA	63 DAA	69 DAA
0.0 kg ha ⁻¹	7.9	7.1 bc	1.0	6.3 c	6.1 c	6.0 bc	5.5 b
6.0 kg ha ⁻¹	6.6	7.0 c	1.0	6.3 c	6.3 c	5.6 c	5.0 b
12.5 kg ha ⁻¹	7.3	7.3 bc	1.0	6.8 bc	6.8 bc	6.3 bc	6.0 b
24 kg ha ⁻¹	7.0	7.8 ab	1.0	7.4 ab	7.6 ab	6.8 ab	5.5 b
49 kg ha ⁻¹	8.3	8.4 a	1.0	8.0 a	8.3 a	7.5 a	7.5 a
LSD	ns	0.7	ns	0.7	1.0	0.9	1.2

Nitrogen treatments applied 27 August 2008, 28 August 2008, 13 October 2008, 1 December 2008, 15 January 2009, 2 March 2009 and 17 April 2009.

Color visually rated on a scale of 1 to 9 where 9= best. Means in each column followed by the same letter(s) are not significantly different according to Fisher's Protected LSD ($P=0.05$).

Table 210. N fertilization effects on centipede turf density in 2008-09.

N rate	Nitrogen application date						
	28 August 2008			15 January 2009			
	20 DAA	43 DAA	32 DAA	2 March 2009	27 DAA	63 DAA	69 DAA
0.0 kg ha ⁻¹	8.0	7.4 bc	6.0	5.8	5.8 c	4.8 b	4.8
6.0 kg ha ⁻¹	6.8	7.1 c	5.3	5.8	6.4 bc	5.6 ab	5.0
12.5 kg ha ⁻¹	6.8	7.4 bc	5.8	6.8	6.6 a- c	6.4 a	5.8
24 kg ha ⁻¹	6.6	8.0 b	6.5	7.0	7.5 a	6.9 a	6.3
49 kg ha ⁻¹	8.4	8.9 a	7.3	6.5	7.1 ab	6.4 a	6.3
LSD	ns	0.9	ns	ns	1.0	1.3	ns

Nitrogen treatments applied 27 August 2008, 28 August 2008, 13 October 2008, 1 December 2008, 15 January 2009, 2 March 2009 and 17 April 2009.

Density visually rated on a scale of 1 to 9 where 9= best. Means in each column followed by the same letter(s) are not significantly different according to Fisher's Protected LSD ($P=0.05$).

Table 211. N fertilization effects on turf quality in 2008-09.

	Nitrogen application date							
	28 August 2008		15 January 2009		2 March 2009	17 April 2009		
	20 DAA	43 DAA	32 DAA		46 DAA	27 DAA	63 DAA	69 DAA
Turf								
St. Augustine	6.5	6.6 b	6.1		4.4 b	5.6 b	4.7 b	4.9 b
Centipede	7.4	7.6 a	5.8		6.2 a	6.8 a	6.2 a	5.8 a
LSD	-	0.7	ns		0.9	0.8	1.0	0.6
N rate								
0.0 kg ha ⁻¹	6.4	6.4 c	5.5 bc		4.8 b	5.5 c	4.6 c	4.5 b
6.0 kg ha ⁻¹	6.3	6.6 c	5.3 c		4.8 b	6.0 bc	5.0 bc	4.8 b
12.5 kg ha ⁻¹	6.8	6.8 c	5.8 b		5.8 ab	6.3 c	5.6 ab	5.6 a
24 kg ha ⁻¹	7.1	7.4 b	6.6 a		6.6 a	6.8 a	6.1 a	6.0 a
49 kg ha ⁻¹	8.0	8.1 a	6.5 a		4.6 b	6.5 ab	5.8 ab	5.8 a
LSD	-	0.5	0.4		1.1	0.8	0.9	0.8

Nitrogen treatments applied 27 August 2008, 28 August 2008, 13 October 2008, 1 December 2008, 15 January 2009, 2 March 2009 and 17 April 2009.

Quality visually rated on a scale of 1 to 9 where 9= best. Means in each column followed by the same letter(s) are not significantly different according to Fisher's Protected LSD ($P=0.05$). “-”=significant turf by rate interaction.

Table 212. N fertilization effects on turf color in 2008-09.

	Nitrogen application date							
	28 August 2008		15 January 2009		2 March 2009	17 April 2009		
	20 DAA	43 DAA	32 DAA		46 DAA	27 DAA	63 DAA	69 DAA
Turf								
St. Augustine	6.7	6.4 b	1.0		5.7 b	6.2 b	5.5	5.3
Centipede	7.4	7.5 a	1.0		6.9 a	7.0 a	6.4	5.9
LSD	-	0.5	ns		0.9	0.6	ns	ns
N rate								
0.0 kg ha ⁻¹	6.6	6.4 c	1.0		5.6 b	6.1 bc	5.3 c	5.1 bc
6.0 kg ha ⁻¹	6.4	6.5 c	1.0		5.6 b	5.9 c	5.3 c	4.9 c
12.5 kg ha ⁻¹	7.0	6.8 bc	1.0		6.1 b	6.3 bc	5.7 bc	5.8 b
24 kg ha ⁻¹	7.1	7.2 b	1.0		6.9 a	6.9 ab	6.2 b	5.3 bc
49 kg ha ⁻¹	8.1	7.9 a	1.0		7.3 a	7.6 a	7.3 a	7.0 a
LSD	-	0.4	ns		0.7	1.0	0.6	0.7

Nitrogen treatments applied 27 August 2008, 28 August 2008, 13 October 2008, 1 December 2008, 15 January 2009, 2 March 2009 and 17 April 2009.

Color visually rated on a scale of 1 to 9 where 9= best. Means in each column followed by the same letter(s) are not significantly different according to Fisher's Protected LSD ($P=0.05$). “-”=significant turf by rate interaction.

Table 213. N fertilization effects on turf density in 2008-09.

	Nitrogen application date							
	28 August 2008		15 January 2009		2 March 2009		17 April 2009	
	20 DAA	43 DAA		32 DAA	46 DAA	27 DAA	63 DAA	69 DAA
Turf								
St. Augustine	6.4	7.2 b	6.6		5.3 b	5.7 b	4.6 b	4.9
Centipede	7.3	7.8 a	6.2		6.4 a	6.7 a	6.0 a	5.6
LSD	-	0.4		ns	0.9	0.7	1.1	ns
N rate								
0.0 kg ha ⁻¹	6.5	6.9 c	5.6 b		5.3 c	5.6 b	4.0 c	4.1 c
6.0 kg ha ⁻¹	6.1	6.9 c	5.5 b		5.4 c	5.9 b	4.9	4.8
12.5 kg ha ⁻¹	6.6	7.1 c	5.6 b		6.1	6.2 b	5.6	5.5
24 kg ha ⁻¹	6.9	7.8 b	7.3 a		6.6 a	6.9 a	6.3 a	6.3 a
49 kg ha ⁻¹	8.1	8.5 a	7.8 a		5.8	6.3	5.6	5.6
LSD	-	0.4		0.8	0.7	0.7	1.0	0.9

Nitrogen treatments applied 27 August 2008, 28 August 2008, 13 October 2008, 1 December 2008, 15 January 2009, 2 March 2009 and 17 April 2009.

Density visually rated on a scale of 1 to 9 where 9= best. Means in each column followed by the same letter(s) are not significantly different according to Fisher's Protected LSD ($P=0.05$). "-"=significant turf by rate interaction.

Table 214. Effect of turf type and N-application rate on total nitrogen leached in 2006-07.

	Total N (kg ha ⁻¹)					
	Pre	T1	T2	T3	T4	Total Post
Turf type						
St. Augustine.....	29.847	12.970	5.718	1.237	0.189 b	49.960
Centipede	23.322	13.913	7.607	2.305	1.061 a	48.209
<i>P(F)</i>	NS	NS	NS	NS	***	NS
Rate						
0.0 kg ha ⁻¹	25.885	11.295	5.751	1.796	0.686 ab	45.411
6.0 kg ha ⁻¹	32.760	13.903	7.993	1.495	0.424 b	56.576
12.5 kg ha ⁻¹	22.838	11.260	5.203	1.647	0.679 ab	41.627
24 kg ha ⁻¹	24.224	15.478	6.763	1.381	0.407 b	48.253
49 kg ha ⁻¹	27.216	15.272	7.602	2.536	0.928 a	53.554
<i>P(F)</i>	NS	NS	NS	NS	*	NS
<i>Turf x Rate</i>	NS	NS	NS	NS	NS	NS

Nitrogen treatments applied on 23 Oct 06, 6 Dec 06, 18 Jan 07, 5 Mar 07.

Pre=5 Oct 06 – 23 Oct 06, T1=26 Oct 06 – 4 Dec 06, T2=7 Dec 06 – 18 Jan 07, T3= 22 Jan 07 – 4 Mar 07, T4=7 Mar 07 – 19 Apr 07, Total post =accumulated N post 23 Oct 06 treatment.

Data corrected for MDL if data ≤0.148 then =0.148. No significant interactions between application date and rate, therefore only means for main effects of application date and rate are presented. Means followed by the same letter(s) in a column are not significantly different according to Duncan's Multiple Range Test ($P=0.05$). ***, * = $P<0.001$ and $P<0.05$, respectively. NS = $P>0.05$.

Table 215. Effect of turf type and N-application rate on total nitrogen leached in 2006-07.

	% nitrogen applied					
	Pre	T1	T2	T3	T4	Total Post
Turf type						
St. Augustine.....	281.79	109.69	46.47	7.99	1.37 b	165.51
Centipede	160.80	99.04	62.80	16.52	6.68 a	185.05
<i>P(F)</i>	NS	NS	NS	NS	**	NS
Rate						
0.0 kg ha ⁻¹	-	-	-	-	-	-
6.0 kg ha ⁻¹	546.00 a	231.71 a	133.22 a	24.92 a	7.07 a	396.93 a
12.5 kg ha ⁻¹	182.70 b	90.08 b	41.62 b	13.17 b	5.44 a	150.31 b
24 kg ha ⁻¹	100.93 b	64.49 b	28.18 b	5.75 b	1.69 b	100.12 b
49 kg ha ⁻¹	55.54 b	31.17 b	15.52 b	5.18 b	1.89 b	53.75 b
<i>P(F)</i>	*	****	***	***	**	****
<i>Turf x Rate</i>	NS	NS	NS	NS	NS	NS

Nitrogen treatments applied on 23 Oct 06, 6 Dec 06, 18 Jan 07, 5 Mar 07. Pre=5 Oct 06 – 23 Oct 06, T1=26 Oct 06 – 4 Dec 06, T2=7 Dec 06 – 18 Jan 07, T3= 22 Jan 07 – 4 Mar 07, T4=7 Mar 07 – 19 Apr 07, Total post =accumulated N post 23 Oct 06 treatment. Data corrected for MDL if data ≤0.148 then =0.148. No significant interactions between application date and rate, therefore only means for main effects of application date and rate are presented. Means followed by the same letter(s) in a column are not significantly different according to Duncan's Multiple Range Test ($P=0.05$). ****, ***, ** and * = $P<0.0001$, $P<0.001$, $P<0.01$ and $P<0.05$, respectively. NS = $P>0.05$.

Table 216. Effect of turf type and N-application rate on total nitrogen leached in 2007-08.

	Total N (kg ha ⁻¹)						Total Post
	Pre	T1	T2	T3	T4	T5	
Turf type							
St. Augustine.....	0.040	0.118	0.178	0.205	0.234b	0.126b	0.902b
Centipede	0.049	0.190	0.257	0.297	0.913 a	0.504a	2.364 a
<i>P(F)</i>	NS	NS	NS	NS	*	*	*
Rate							
0.0 kg ha ⁻¹	0.051	0.129	0.188	0.257	0.516	0.272	1.771
6.0 kg ha ⁻¹	0.045	0.158	0.243	0.234	0.338	0.163	1.180
12.5 kg ha ⁻¹	0.051	0.168	0.234	0.267	0.458	0.362	1.540
24 kg ha ⁻¹	0.027	0.170	0.186	0.236	0.509	0.161	1.290
49 kg ha ⁻¹	0.050	0.138	0.228	0.261	1.046	0.615	2.383
<i>P(F)</i>	NS	NS	NS	NS	NS	NS	NS
<i>Turf x Rate</i>	NS	NS	NS	NS	*	NS	NS

Nitrogen treatments applied on 31 Aug 07, 16 Oct 07, 30 Nov 07, 15 Jan 08, 29 Feb 08.

Pre=20 Aug 07 – 30 Aug 07, T1=4 Sep 07 – 15 Oct 07, T2=19 Oct 07 – 29 Nov 07, T3=3 Dec 07 – 14 Jan 08, T4=17 Jan 08 – 25 Feb 08, T5 = 4 Mar 08 – 15 Apr 08, Total post =accumulated N post 31 Aug 07 treatment.

Data corrected for MDL if data ≤ 0.148 then =0.148. No significant interactions between application date and rate, therefore only means for main effects of application date and rate are presented. Means followed by the same letter(s) in a column are not significantly different according to Duncan's Multiple Range Test ($P=0.05$). * = $P<0.05$, respectively. NS = $P>0.05$.

Table 217. Effect of turf type and N-application rate on total nitrogen leached in 2007-08.

	% nitrogen applied						Total Post
	Pre	T1	T2	T3	T4	T5	
Turf type							
St. Augustine.....	0.33	0.95	1.37	1.67	1.85	0.99	6.83
Centipede	0.35	1.54	2.21	2.11	4.92	2.78	13.56
<i>P(F)</i>	NS	NS	NS	NS	NS	NS	NS
Rate							
0.0 kg ha ⁻¹	-	-	-	-	-	-	-
6.0 kg ha ⁻¹	0.74 a	2.63 a	4.05 a	3.90 a	5.64 a	2.72	18.93 a
12.5 kg ha ⁻¹	0.41 ab	1.34 b	1.87 b	2.14 b	3.66 ab	2.90	11.91 ab
24 kg ha ⁻¹	0.11 b	0.71 b	0.77 b	0.98 c	2.12 b	0.67	5.26 b
49 kg ha ⁻¹	0.09 b	0.28 b	0.47 b	0.53 c	2.13 b	1.26	4.67 b
<i>P(F)</i>	**	**	***	****	*	NS	**
<i>Turf x Rate</i>	NS	NS	NS	NS	NS	NS	NS

Nitrogen treatments applied on 31 Aug 07, 16 Oct 07, 30 Nov 07, 15 Jan 08, 29 Feb 08. Pre=20 Aug 07 – 30 Aug 07, T1=4 Sep 07 – 15 Oct 07, T2=19 Oct 07 – 29 Nov 07, T3=3 Dec 07 – 14 Jan 08, T4=17 Jan 08 – 25 Feb 08, T5 = 4 Mar 08 – 15 Apr 08, Total post =accumulated N post 31 Aug 07 treatment. Data corrected for MDL if data ≤ 0.148 then =0.148. No significant interactions between application date and rate, therefore only means for main effects of application date and rate are presented. Means followed by the same letter(s) in a column are not significantly different according to Duncan's Multiple Range Test ($P=0.05$). ****, ***, ** and * = $P<0.0001$, $P<0.001$, $P<0.01$ and $P<0.05$, respectively. NS = $P>0.05$.

Table 218. Effect of turf type and N-application rate on total NO₃-N leached in 2008-09.

	Total N (kg ha ⁻¹)							
	Pre	T1	T2	T3	T4	T5	T6	Total Post
Turf type								
St.								
Augustinegrass	0.087	0.094	0.155	0.058	0.346	2.600	1.479	5.577
Centipedegrass	0.112	0.077	0.171	0.065	0.391	2.829	1.039	5.202
<i>P(F)</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>
N Rate								
0.0 kg ha ⁻¹						0.616		
	0.115	0.101	0.190	0.039	0.229	b	0.213 b	1.881 b
6.0 kg ha ⁻¹						0.443		
	0.094	0.080	0.111	0.036	0.206	b	0.268 b	1.487 b
12.5 kg ha ⁻¹						0.737		
	0.108	0.062	0.139	0.035	0.252	b	0.500 b	2.132 b
24 kg ha ⁻¹						0.880		
	0.080	0.093	0.133	0.055	0.359	b	0.312 b	2.293 b
49 kg ha ⁻¹						10.895		
	0.101	0.093	0.241	0.145	0.796	a	5.004 a	19.152 a
<i>P(F)</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>	****	****	****
<i>Turf x N Rate</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>

Nitrogen treatments applied on 28 Aug 09, 13 Oct 08, 1 Dec 08, 15 Jan 09, 2 Mar 09.

Pre=19 Aug 08 – 26 Aug 08, T1=2 Sep 08 – 7 Oct 08, T2=14 Oct 08 – 24 Nov 08, T3=2 Dec 08 – 20 Jan 09, T4=27 Jan 09 – 24 Feb 09, T5 = 3 Mar 09 – 4 Apr 09, T6 = 21 Apr 09 – 9 Jun 09,

Total post = accumulated N post 28 Aug 08 treatment. Data corrected for MDL if data ≤ 0.148 then = 0.148. No significant interactions between application date and rate, therefore only means for main effects of application date and rate are presented. Means followed by the same letter(s) in a column are not significantly different according to Duncan's Multiple Range Test (*P*=0.05).

**** = *P*<0.0001, NS = *P*>0.05.

Table 219. Effect of turf type and N-application rate on % of applied nitrogen in 2008-09.

	% of Applied N							Total Post
	Pre	T1	T2	T3	T4	T5	T6	
Turf type								
St.								
Augustinegrass	0.66	0.63	0.95	0.36	2.09	9.73	6.02	22.87
Centipedegrass	0.82	0.57	1.06	0.36	2.19	9.86	3.97	20.59
<i>P(F)</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>
N Rate								
0.0 kg ha ⁻¹	-	-	-	-	-	-	-	-
6.0 kg ha ⁻¹	1.57 a	1.33 a	1.85 a	0.60	3.43	7.39 b	4.47 b	23.22 ab
12.5 kg ha ⁻¹	0.86 ab	0.50 b	1.11 ab	0.28	2.02	5.90 b	4.00 b	16.20 b
24 kg ha ⁻¹	0.33 b	0.39 b	0.56 b	0.23	1.50	3.67 b	1.30 b	8.62 b
49 kg ha ⁻¹	0.21 b	0.19 b	0.49 b	0.30	1.63	2.23 a	10.21 a	38.88 a
<i>P(F)</i>	**	*	**	<i>NS</i>	<i>NS</i>	**	*	*
<i>Turf x N Rate</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>

Nitrogen treatments applied on 28 Aug 09, 13 Oct 08, 1 Dec 08, 15 Jan 09, 2 Mar 09. Pre=19 Aug 08 – 26 Aug 08, T1=2 Sep 08 – 7 Oct 08, T2=14 Oct 08 – 24 Nov 08, T3=2 Dec 08 – 20 Jan 09, T4=27 Jan 09 – 24 Feb 09, T5 = 3 Mar 09 – 4 Apr 09, T6 = 21 Apr 09 – 9 Jun 09, Total post =accumulated N post 28 Aug 08 treatment. Data corrected for MDL if data ≤ 0.148 then =0.148. No significant interactions between application date and rate, therefore only means for main effects of application date and rate are presented. Means followed by the same letter(s) in a column are not significantly different according to Duncan's Multiple Range Test ($P=0.05$). ** and * = $P<0.01$ and $P<0.05$, respectively. $NS = P>0.05$.

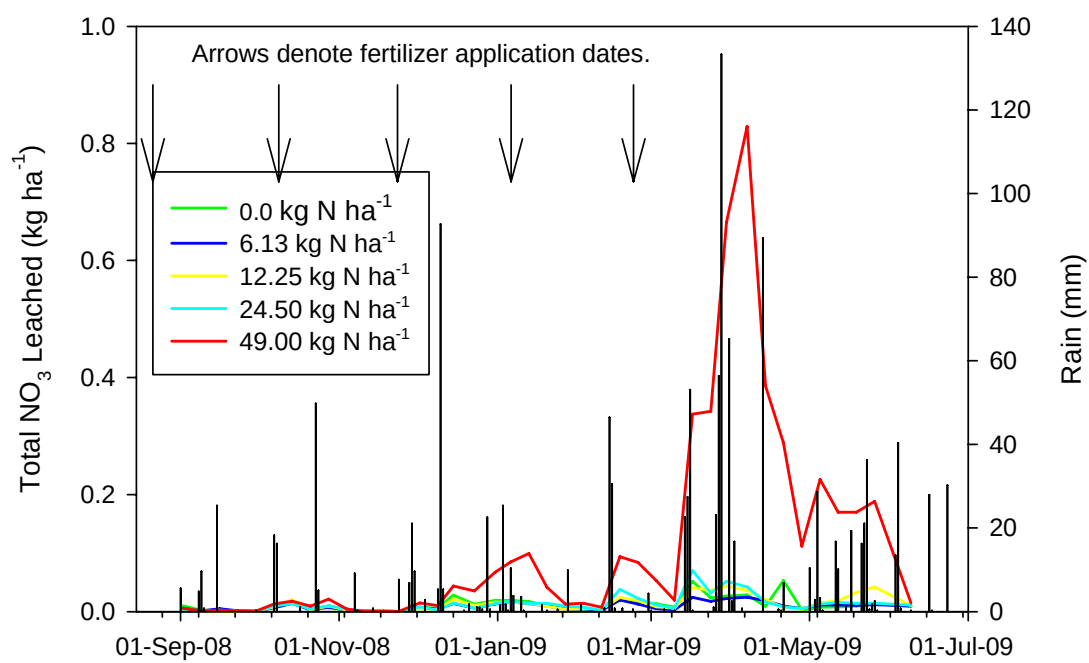


Figure 68: Fall fertility 2008 total NO₃ leached from different nitrogen rates and the corresponding rainfall that occurred.

Table 220. Effect of year, turf type and N-application rate on total nitrogen leached.

	Total N (kg ha ⁻¹)						
	Pre	T1	T2	T3	T4	T5	Total Post
Year							
2006-07	26.584 a	.	13.442 a	6.663 a	1.771 a	0.625 b	22.500 a
2007-08	0.045 b	0.153 a	0.217 b	0.251 b	0.573 b	0.315 b	1.579 b
2008-09	0.100 b	0.086 b	0.163 b	0.062 b	0.369 b	2.714 a	5.261 b
<i>P(F)</i>	****	*	****	****	****	***	****
Turf type							
St.							
Augustinegrass	9.991	0.106	4.434	1.994 b	0.606 b	0.972	8.822
Centipedegrass	7.960	0.132	4.857	2.657 a	1.203 a	1.464	10.738
<i>P(F)</i>	NS	NS	NS	*	*	NS	NS
N Rate							
0.0 kg ha ⁻¹	8.683	0.114	4.052	2.016	0.847 b	0.525 b	7.671 b
6.0 kg ha ⁻¹	10.966	0.119	4.752	2.754	0.680 b	0.344 b	8.782 b
12.5 kg ha ⁻¹	7.666	0.115	3.878	1.835	0.786 b	0.593 b	7.434 b
24 kg ha ⁻¹	8.110	0.132	5.266	2.352	0.750 b	0.483 b	9.120 b
49 kg ha ⁻¹	9.517	0.115	5.247	2.669	1.459 a	4.146 a	15.893 a
<i>P(F)</i>	NS	NS	NS	NS	**	****	***
<i>Year x Turf</i>	NS	*	NS	*	NS	NS	NS
<i>Year x N Rate</i>	NS	NS	NS	NS	NS	****	*
<i>Turf x N Rate</i>	NS	NS	NS	NS	NS	NS	NS
<i>Year x Turf x N Rate</i>	NS	NS	NS	NS	NS	NS	NS

Data corrected for MDL if data ≤ 0.148 then =0.148. No significant interactions between application date and rate, therefore only means for main effects of application date and rate are presented. Means followed by the same letter(s) in a column are not significantly different according to Duncan's Multiple Range Test ($P=0.05$). NS = $P>0.05$. ****, ***, **, * = $P>0.0001$, $P>0.001$, $P>0.01$, and $P>0.05$, respectively. NS = $P>0.05$. Means followed by the same letter(s) in a column are not significantly different according to Fisher's Protected LSD ($P=0.05$).

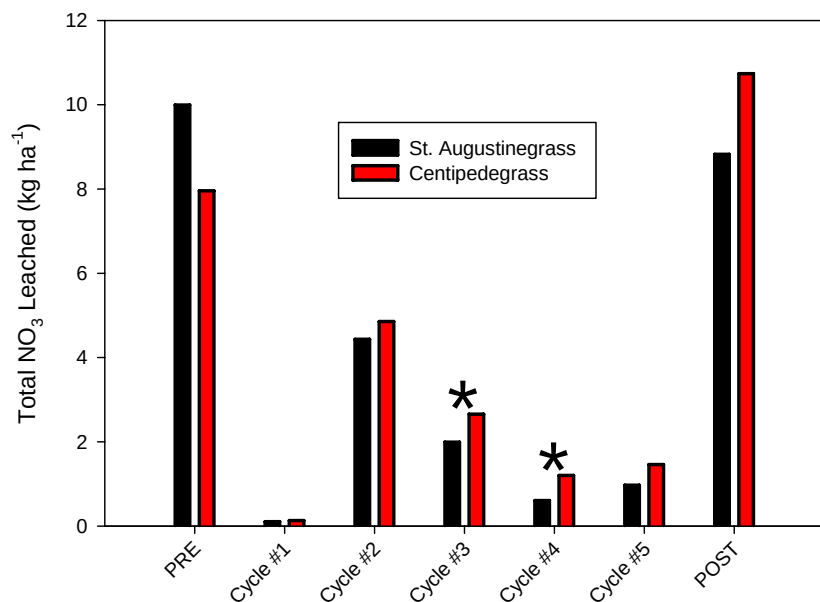


Figure 46. Comparison of NO₃-N leaching losses from five nitrogen rates applied to either St. Augustinegrass or centipedegrass over three winter seasons (2006 – 2009). Cycles are six weeks in duration with Cycle #1 starting around 01 September each year. The “*” indicates significance (P>0.05) according to Duncan’s Multiple Range Test (P=0.05).

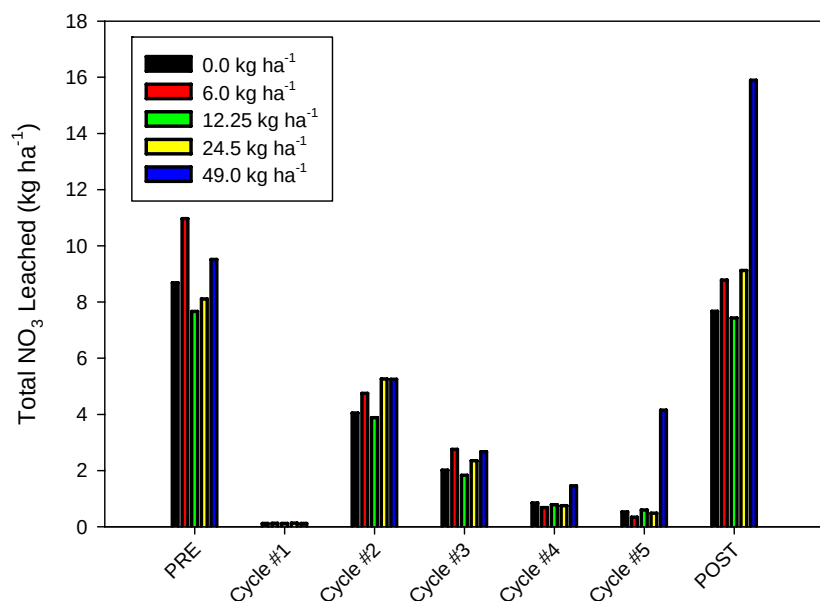


Figure 47. Comparison of leaching losses from five nitrogen rates applied to St. Augustinegrass and centipedegrass over three winter seasons (2006 – 2009). Cycles are six weeks in duration with Cycle #1 starting around 01 September each year.

Table 221. Effect of year, turf type and N application rate on % of applied nitrogen.

	% of Applied N						
	Pre	T1	T2	T3	T4	T5	Total Post
Year							
2006-07	221.30 a	-	104.36 a	54.64 a	12.26 a	4.02 c	175.28 a
2007-08	0.34 b	1.24 a	1.79 b	1.89 b	3.39 b	1.89 c	10.19 b
2008-09		0.60 b	1.00 b	0.35 b	2.14 b	9.80 a	21.73 b
<i>P(F)</i>	***	*	****	****	**	****	****
Turf type							
St.							
Augustinegrass	94.26	0.79	37.34	16.16	3.98 b	4.03	65.07
Centipedegrass	53.99	1.05	34.10	21.75	7.88 a	6.44	73.06
<i>P(F)</i>	NS	NS	NS	NS	**	NS	NS
N Rate							
0.0 kg ha ⁻¹	-	-	-	-	-	-	-
6.0 kg ha ⁻¹						5.73	
12.5 kg ha ⁻¹	182.77 a	1.98 a	79.21 a	45.91 a	11.33 a	ab	146.36 a
						4.74	
24 kg ha ⁻¹	61.33 b	0.92 b	31.02 b	14.68 b	6.28 b	bc	59.47 b
49 kg ha ⁻¹	33.79 b	0.55 b	21.94 b	9.80 b	3.12 c	2.01 c	38.00 b
	18.61 b	0.24 b	10.71 b	5.45 b	2.98 c	8.46 a	32.43 b
<i>P(F)</i>	**	****	****	****	****	**	****
<i>Year x Turf</i>	NS	NS	NS	NS	*	NS	NS
<i>Year x N Rate</i>	***	NS	****	****	****	****	***
<i>Turf x N Rate</i>	NS	NS	NS	NS	NS	NS	NS
<i>Year x Turf x N</i>	NS	NS	NS	NS	NS	NS	NS
Rate							

Data corrected for MDL if data ≤ 0.148 then =0.148. No significant interactions between application date and rate, therefore only means for main effects of application date and rate are presented. Means followed by the same letter(s) in a column are not significantly different according to Duncan's Multiple Range Test ($P=0.05$). ****, ***, **, * = $P>0.0001$, $P>0.001$, $P>0.01$, and $P>0.05$, respectively. NS = $P>0.05$.

INFLUENCE OF NITROGEN SOURCE AND TIMING ON NO₃-N LEACHING WHEN APPLIED TO CENTIPEDEGRASS AND ST. AUGUSTINEGRASS

The N Source and Timing study was initiated during the summer of 2008 after establishment of new sod was completed. Deterioration and subsequent contamination by bermudagrass and torpedograss warranted stripping of existing turf, multiple non-selective herbicide applications, and resodding with St. Augustinegrass and centipedegrass before the initiation of the nitrogen source and timing study. Prior to sod installation, the lysimeters and irrigation heads were retrofitted for better functionality. Nitrogen sources included in this study were:

6. No treatment = zero N fertilizer
7. Low Control (Ammonium Nitrate 34-0-0) @ 49 kg N ha⁻¹/60 days (1/60)
8. Quick Release/High Control (Urea 46-0-0) @ 49 kg N ha⁻¹/60 days (1/60)
9. 30% Slow Release (John Deere Landscapes 16-0-8) @ 49 kg N ha⁻¹/60 days (1/60)
10. 50% Slow Release (Harrells 19-0-19) @ 49 kg N ha⁻¹/60 days (1/60)
11. Polymer Coated product (Polyon 41-0-0) @ 49 kg N ha⁻¹/60 days (1/60)
12. Polymer Coated product (Polyon 41-0-0) @ 98 kg N ha⁻¹/120 days (2/120)
13. Organic Product (Milorganite 6-2-0) @ 49 kg N ha⁻¹/60 days (1/60)

These N sources were applied to both St. Augustinegrass and centipedegrass every 60d, however, treatment #7 was applied every 120 days on both species.

	2008	2009	2010	2011
Pre-Treatment Period	05 Aug – 12 Aug	06 Apr – 14 Apr	01 Apr – 14 Apr	30 Mar – 11 Apr
Application #1	19 Aug	15 Apr	15 Apr	12 Apr
Treatment Cycle #1	19 Aug – 14 Oct	15 Apr – 11 Jun	15 Apr – 10 Jun	12 Apr – 08 Jun
Application #2		12 Jun	11 Jun	09 Jun
Treatment Cycle #2	15 Oct – 15 Dec	12 Jun – 12 Aug	12 Jun – 08 Aug	10 Jun – 15 Aug
Application #3		13 Aug	09 Aug	
Treatment Cycle #3		13 Aug – 08 Oct	09 Aug – 07 Oct	
Application #4		09 Oct	08 Oct	
Treatment Cycle #4		09 Oct – 07 Dec	08 Oct – 07 Dec	
Post Treatment Period	07 Feb – 30 Mar	08 Dec – Mar 30	07 Dec – 29 Mar	16 Aug – 30 Aug

Color, Quality, Density

2008 – Initial visual ratings of both untreated centipedegrass and St. Augustinegrass exceeded the minimum acceptable values 9d after fertilizer application indicating that the newly established sod likely came with sufficient nutrient import (Table 222). N sources containing soluble N (Ammonium nitrate, urea, 30% SRN, and 50% SRN) all increased color, quality, and density within 9d of application and noticeable differences were observed throughout the duration of 2008. The PCU material (both rates) did not improve the color, quality, or density in 2008. The biosolid (BSD) increased turf color and quality over that of the untreated control. No differences were observed between species.

2009 – Throughout 2009, centipedegrass exhibited better turf quality, color, and density than St. Augustinegrass (Tables 223-225). On the initial rating date in 2009 (17 Apr), no differences in turf quality and density due to fertilizer source were observed (Tables 223 and 225). Fertilizer treatments did influence spring color where all fertilizer except the biosolid had better color than the untreated control (Table 224).

As expected, soluble N sources yielded rapid improvements in green-up and turf quality following each application (Tables 223 and 224). The biosolid material generally provided the lowest quality compared to other N sources but the turf was still acceptable. The PCU @ 2.0 lbs treatment applied twice provided early season improvement but this was not observed season long. Early season differences in turf density were negligible but by the end of the season, the 50% SRN and PCU @ 2.0 lb treatments exhibited maximum density (Table 225). Among the fertilizer treatments, the biosolid had the least density of all the treatments.

2010 – The winter of 2009/2010 was colder than normal resulting in significant deterioration of the St. Augustinegrass. Due to a Species X Fertilizer Treatment interaction, fertilizer means are presented separately for each species (Tables 226 – 228).

St. Augustinegrass: Spring ratings showed that plots treated with soluble N sources and the PCU @ 2.0 lbs had quality comparable to the untreated control (Table 226). The 30% SRN, 50% SRN, PCU @ 1.0 lb, and biosolid treatments all had minimally acceptable turf quality. All other treatments were unacceptable. The deterioration from the Nov 2009 ratings was 42%, 33%, and 40% for the ammonium nitrate, urea, and PCU @ 2.0 lb treatments, respectively. The reduction in quality for the other fertilizer sources was comparable to the untreated control (~ 20%). Turf color differences due to fertilizer treatments were not substantially different from each other but were 2 to 3 rating points better than the untreated control. Turf density estimates were significant. The 50% SRN resulted in the greatest density throughout the season. The ammonium nitrate, urea, and the PCU @ 2.0 lbs had the least dense turf.

Centipedegrass: Fertilizer treatment differences in centipedegrass quality, color, and density were negligible.

2011 – St. Augustinegrass turf quality in 2011 was largely below acceptable quality. Only the 30% SRN, 50% SRN, and biosolid treatments had acceptable quality at the beginning of the season through 30 June (Table 229). By 14 July, one month following the second fertilizer application, all treatments except ammonium sulfate and urea had acceptable quality.

Acceptable color was maintained season-long with the 30% SRN and 50% SRN materials. Acceptable color was not achieved until 3 June (52 days after initial application (DAA) for the biosolid; 30 June (79 DAA) for PCU @ 2.0 lbs; and 29 July (108 DAA) for the remaining treatments (Table 260). The greatest St. Augustinegrass density was achieved by using the 30% SRN, 50% SRN, and PCU @ 1.0 lb products. The two soluble N sources generally produced unacceptable turf density (Table 231).

All fertilizer treatments resulted in acceptable centipedegrass quality (Table 259), color (Table 260), and density (Table 231).

Shoot Mass

2008 – Fertilizer sources had no effect on St. Augustinegrass shoot mass in 2008 (Table 232). Centipedegrass, however, was influenced by fertilizer source. All sources containing soluble N increased shoot mass 20 DAA. By 51 DAA, the ammonium nitrate, 30% SRN, and 50% SRN treatments were still influencing shoot growth. All other treatments were not different from the untreated control.

2009 – Differences in St. Augustinegrass shoot mass due to fertilizer treatments were observed on 10 of the 14 collection dates (Table 233). The 50% SRN treatment produced the greatest shoot mass on 9 of the 14 collection dates. The PCU @ 2.0 lbs had the second greatest impact. Centipedegrass shoot growth was most influence by the PCU @ 2.0 lbs treatment (8 of 14 collection dates) followed by ammonium nitrate (5 of 14 collection dates) (Table 234). In general, centipedegrass produced 8 – 10 times the quantity of shoots compared to St. Augustinegrass.

2010 – Similar to 2009, St. Augustinegrass shoot mass was most influenced (9 of 12 collection dates) by the 50% SRN treatment (Table 235). The 30% SRN generated the second greatest quantity of clippings (8 of 12 collection dates). Centipedegrass differed in its response to fertilizer treatments in 2010. The 30% SRN, 50% SRN, and both PCU treatments each produced the most clippings on 3 of 12 collection dates throughout the growing season.

2011 – The 50% SRN treatment produced the greatest quantity of St. Augustinegrass clippings on all rating dates in 2011 followed by the 30% SRN source (5 of 12 collection dates), and PCU @ 2.0 lbs (2 of 12 collection dates) (Table 237). PCU @ 1.0 lb and PCU @ 2.0 lbs produced the most shoot mass on 4 of 7 collection dates and 2 of 7 collection dates, respectively (Table 238).

Root Growth

Throughout the duration of the study, differences in rooting attributed to fertilizer source were not significant (Tables 239-242). In general, however, centipedegrass produced ~30% more roots than St. Augustinegrass on 3 of the 4 sampling dates.

Nitrate Leaching

2008 – New sod was laid on 21 Jul 2008 and leachate sample collection began 5 Aug 2008. A single application (49.0 kg ha⁻¹) of each N source was distributed on 19 Aug 2008. In the 120 days following fertilizer application, centipedegrass leached 53% less nitrogen than St. Augustinegrass (Table 243).

During the first 120 days following application, the 30% SRN material leached significantly more NO₃⁻-N than the other products (Table 243). All other fertilizer sources were not different from the untreated control. After subtracting the leached quantity detected in the untreated control from the fertilizer source treatments, only the 30% SRN material contributed more NO₃⁻-N leaching than the untreated control. The 30% SRN source leached 42% of the applied nitrogen.

Given the levels of NO₃⁻-N collected from the untreated plots over the 120 sampling period (12.5 kg N ha⁻¹), the NO₃⁻-N in the leachate is likely attributed to residual fertilizer (nutrient import) that accompanied the new sod and was leached due to the abundant irrigation applied during following sod installation. Leachate samples collected in the 8 days prior to fertilizer application, (16 days following sod installation), averaged 8.7 kg N ha⁻¹.

2009 – Leaching in 2009 was considerably less than in 2008. Throughout the four 60-day sampling periods, no differences due to turf species or fertilizer source were noted (Tables 244 and 245). Over the 49 week study period (21 Apr 2009 – 30 Mar 2010), centipedegrass leached 67% less N than St. Augustinegrass (1.86 vs. 5.65 kg N ha⁻¹). Similarly, after subtracting the leached quantity detected in the untreated control from the fertilizer source treatments, 49 week leaching totals ranged from 0.0 kg N ha⁻¹ (PCU @ 1.0 lb) to 3.8 kg N ha⁻¹ (ammonium nitrate and urea); however, leaching differences among treatments were not different from each other. These leaching amounts equate to 0.25 – 1.9% of applied nitrogen.

2010 – The winter of 2009/2010 was colder than normal resulting in significant deterioration of the St. Augustinegrass. Consequently, St. Augustinegrass leached more NO₃⁻-N than centipedegrass on all 60 day cycles, 120 day totals, post 60 day periods, and seasonal totals (Tables 246 and 247). The four 60-day treatment cycles averaged 4.87 kg N ha⁻¹ for St. Augustinegrass and 0.22 kg N ha⁻¹ for centipedegrass. The 49 week (20 Apr 2009 – 29 Mar 2010) seasonal leaching total was 23.16 kg N ha⁻¹ for St. Augustinegrass and 1.27 kg N ha⁻¹ for centipedegrass (Table 246).

Several of the 60-day cycles in 2010 showed a significant Species x Treatment interaction. In all cases, the centipedegrass x fertilizer source treatment interaction was not significant (Table 247). There were differences in leaching from St. Augustinegrass due to fertilizer source treatment. At the mid-point of the experiment (120 day total following the first two fertilizer applications (or single application of PCU @ 2 lbs), leaching from St. Augustinegrass ranged from 1.5 (PCU @ 1.0 lb) to 22.9 (urea) kg N ha⁻¹ (Table 247). Seasonal leaching totals from St. Augustinegrass ranged from 7.6 (PCU @ 1.0 lb) to 46.2 (urea) kg N ha⁻¹ (Table 247). On a percent of applied basis calculated over the 49 weeks study, urea leached the most (23.6%) followed by ammonium nitrate (20.3%); PCU @ 2.0 lbs (18.5%); 30% SRN (15.4%); 50% SRN (6.6%); biosolid (5.4%); and PCU @ 1.0 lb (3.9%) (Table 247).

2011 – Leaching from St. Augustinegrass continued to be greater than leaching from centipedegrass in 2011 (Table 248). However, there was a significant Species x Fertilizer Source interaction during the first 60 days of the 2011 season (Table 249). For the first time in the four year study, centipedegrass was influenced by fertilizer source but from a positive perspective. All plots treated with fertilizer leached *less* than the untreated control plots but the quantity of NO₃⁻-N that was leached was negligible (< 0.029% of applied). Following the second fertilizer cycle, leaching from St. Augustinegrass fertilized with PCU @ 2.0 lbs was 4.2 kg N ha⁻¹ (4.3% of applied) (Table 249). No differences between the other fertilizer sources were noted. Over the 120 day cumulative sampling period, PCU @ 2.0 lbs leached 5.6 kg N ha⁻¹ followed by the 30% SRN (2.85 kg N ha⁻¹); though this was not different from the untreated control (0.89 kg N ha⁻¹) (Table 249).

Table 222. Effect of nitrogen source on turf quality, color and density in 2008.

	Rating date (days after application)								
	Quality			Color			Density		
	28 Aug (9)	17 Sep (29)	10 Oct (52)	28 Aug (9)	17 Sep (29)	10 Oct (52)	28 Aug (9)	17 Sep (29)	10 Oct (52)
Species									
St. Augustinegrass	7.7	7.5	7.5	8.0	7.2	7.2	7.0	8.1	8.0
Centipedegrass	7.7	7.6	7.5	8.0	7.4	7.5	7.0	7.8	7.6
<i>LSD</i>	<i>ns</i>	<i>ns</i>	<i>ns</i>	<i>ns</i>	<i>ns</i>	<i>ns</i>	<i>ns</i>	<i>ns</i>	<i>ns</i>
Treatment (lbs N 1000 ft ⁻²)									
Untreated	7.3b	7.0d	7.1c	7.3c	6.6c	6.9c	7.0	7.8cd	7.1d
Am. Nitrate (34-0-0) @ 1 lb N	8.2a	8.3a	8.0a	8.8a	8.0a	8.0a	7.0	8.4a	8.2a
Urea (46-0-0) @ 1 lb N	8.2a	7.8bc	7.7ab	8.6a	7.6ab	7.6ab	7.0	8.1ab	8.1ab
30% SRN (16-0-8) @ 1 lb N	8.0a	8.1ab	7.6ab	8.5ab	7.8ab	7.6ab	7.0	8.3a	8.1a
50% SRN (19-0-0) @ 1 lb N	7.9a	7.7c	7.7ab	8.2b	7.6ab	7.6ab	7.0	7.8b- d	7.9a-c
PCU (41-0-0) @ 1 lb N	7.2b	7.1d	7.1c	7.3c	6.8c	6.8c	7.0	7.6d	7.5cd
PCU (41-0-0) @ 2 lbs N	7.3b	7.1d	7.3bc	7.6c	6.8c	7.2bc	7.0	7.6d	7.6b- d
BSD (6-2-0) @ 1 lb N	7.5b	7.6c	7.5b	7.5c	7.4b	7.3bc	7.0	7.9bc	7.9a-c
<i>LSD</i>	0.3	0.4	0.4	0.4	0.5	0.5	<i>ns</i>	0.3	0.6

Treatments applied 19 August 2008.

Quality, color and density visually rated on scale of 1 to 9 where 9=best.

No significant interactions between species and treatment, therefore only means for main effects of species and treatment are presented. Means followed by the same letter(s) in a column are not significantly different according to Fisher's Least Significant Test ($P=0.05$).

Table 223. Effect of nitrogen source applications on turf quality in 2009.

	Rating date											
	17 Apr	14 May	19 Jun	25 Jun	10 Jul	24 Jul	7 Aug	24 Aug	4 Sep	23 Sep	8 Oct	21 Oct
Species												
St. Augustinegrass	3.2 b	6.4 b	6.6 b	5.6 b	6.3 b	6.6 b	6.4 b	6.7	7.2 b	7.4 b	7.1 b	7.0
Centipedegrass	7.2 a	7.4 a	8.0 a	7.1 a	7.2 a	8.0 a	7.6 a	7.5	8.3 a	8.3 a	8.4 a	8.3
LSD	1.6	0.7	0.6	0.5	0.7	0.8	0.9	ns	0.6	0.6	0.5	-
Treatment (lbs N 1000 ft ²)												
Untreated	5.5	5.9 d	5.1 d	5.3 d	4.6 c	5.0 d	5.3 d	4.6 e	5.1 c	5.1 c	5.1 c	5.1
Am. Nitrate (34-0-0) @ 1 lb N	5.5	7.6 a	8.5 a	7.5 a	7.6 a	7.9 b	7.4 ab	8.3 a	8.3 a	8.0 ab	7.8 b	7.9
Urea (46-0-0) @ 1 lb N	5.2	7.5 a	8.3 ab	7.3 ab	7.5 a	7.9 ab	7.1 b	7.8 ab	8.1 a	7.9 b	8.3 ab	8.1
30% SRN (16-0-8) @ 1 lb N	5.0	7.3 ab	8.2 ab	6.6 a-c	7.6 a	7.6 ab	7.1 b	7.8 ab	8.3 a	8.4 ab	7.9 b	8.4
50% SRN (19-0-0) @ 1 lb N	4.6	7.3 ab	7.9 b	6.5 bc	7.3 a	7.9 ab	7.4 ab	7.5 bc	8.4 a	8.6 a	8.5 a	8.6
PCU (41-0-0) @ 1 lb N	5.0	6.1 d	6.3 c	5.9 cd	6.1 b	7.1 c	7.4 ab	7.0 cd	7.8 b	8.6 a	8.5 a	8.4
PCU (41-0-0) @ 2 lbs N	5.3	6.9 bc	7.8 b	6.0 cd	7.3 a	8.1 a	8.0 a	7.5 bc	8.3 a	8.5 ab	8.5 a	8.0
BSD (6-2-0) @ 1 lb N	5.3	6.6 c	6.2 c	5.8 cd	6.0 b	6.8 c	6.4 c	6.5 d	7.8 b	8.0 ab	7.8 b	6.8
LSD	ns	0.4	0.5	0.9	0.4	0.6	0.7	0.5	0.4	0.6	0.6	-

Treatments applied every 60 days (15 Apr, 12 June, 13 Aug, and 09 Oct) except PCU (41-0-0) @ 2 lbs N which was applied every 120 days (15 Apr and 13 Aug).

Quality visually rated on scale of 1 to 9 where 9=best.

No significant interactions between turf type and treatment for most dates, therefore only means for main effects of turf and treatment are presented.

Means followed by the same letter(s) in a column are not significantly different according to Fisher's Least Significant Test ($P=0.05$).

"-"= significant turf by treatment interaction and LSD not reported.

Table 224. Effect of nitrogen source applications on turf color in 2009.

	Rating date										
	17 Apr	14 May	19 Jun	25 Jun	10 Jul	24 Jul	7 Aug	24 Aug	4 Sep	23 Sep	8 Oct
Species											
St. Augustinegrass	5.8	6.6 b	6.6 b	5.6 b	6.1 b	6.5 b	6.2 b	6.7	7.1 b	7.3 b	7.1
Centipedegrass	6.3	7.5 a	7.9 a	6.9 a	7.2 a	8.0 a	7.4 a	7.5	7.8 a	8.1 a	8.4
LSD	ns	0.5	0.6	0.6	0.7	0.7	0.9	Ns	0.6	0.7	0.6
Treatment (lbs N 1000 ft ²)											
Untreated	5.5 c	5.9 d	4.9 d	4.4 d	4.3 d	4.8 d	4.9 e	4.4 e	4.8 c	5.3 b	5.5
Am. Nitrate (34-0-0) @ 1 lb N	6.0 b	7.7 a	8.6 a	7.4 a	7.6 a	7.6 b	7.1 bc	8.3 a	7.9 ab	7.8 a	7.8
Urea (46-0-0) @ 1 lb N	6.3 b	7.8 a	8.3 ab	7.4 a	7.5 ab	7.8 ab	6.8 cd	7.8 ab	7.8 ab	7.8 a	8.0
30% SRN (16-0-8) @ 1 lb N	6.0 b	7.5 ab	8.3 ab	6.9 ab	7.5 ab	7.8 ab	7.0 bc	7.6 b	8.0 ab	7.9 a	7.6
50% SRN (19-0-0) @ 1 lb N	6.0 b	7.5 ab	8.0 b	6.5 b	7.3 ab	8.0 ab	7.3 a-c	7.5 bc	8.1 a	8.0 a	8.1
PCU (41-0-0) @ 1 lb N	5.9 bc	6.1 d	6.0 c	5.3 c	5.8 c	6.9 c	7.5 ab	6.9 d	7.5 b	8.4 a	8.4
PCU (41-0-0) @ 2 lbs N	6.8 a	7.1bc	7.8 b	6.4 b	7.1 b	8.3 a	7.9 a	7.4 b-d	8.0 ab	8.4 a	8.3
BSD (6-2-0) @ 1 lb N	5.9 bc	6.7 c	6.1 c	5.8 c	6.0 c	6.8 c	6.3 d	7.0 cd	7.6 ab	8.3 a	8.1
LSD	0.5	0.5	0.5	0.5	0.4	0.6	0.7	0.6	0.6	0.7	0.6

Treatments applied every 60 days (15 Apr, 12 June, 13 Aug, and 09 Oct) except PCU (41-0-0) @ 2 lbs N which was applied every 120 days (15 Apr and 13 Aug). Color visually rated on scale of 1 to 9 where 9=best.

No significant interactions between species and treatment, therefore only means for main effects of turf and treatment are presented. Means followed by different letter(s) in a column are not significantly different according to Fisher's Least Significant Test ($P=0.05$).

"-"= significant turf by treatment interaction and LSD not reported.

Table 225. Effect of nitrogen source applications on turf density in 2009.

	Rating date										
	17 Apr	14 May	19 Jun	25 Jun	10 Jul	24 Jul	7 Aug	24 Aug	4 Sep	23 Sep	8 Oct
Species											
St. Augustinegrass	6.4 b	6.6 b	6.7 b	6.0 b	6.7 b	6.9 b	6.9	7.3	7.4 b	7.7	7.7
Centipedegrass	7.1 a	7.4 a	8.3 a	7.3 a	7.3 a	8.0 a	7.7	7.5	8.1 a	8.1	8.1
LSD	0.6	0.7	0.4	0.6	0.6	0.8	ns	ns	0.5	ns	ns
Treatment (lbs N 1000 ft ²)											
Untreated	6.6	6.3 e	5.9 c	5.3 c	5.4 c	5.9 d	5.8 d	5.3 f	5.6 c	5.6 b	5.6
Am. Nitrate (34-0-0) @ 1 lb N	6.8	7.6 a	8.4 a	7.8 a	7.8 a	8.1 a	7.8 ab	8.5 a	8.5 a	8.0 a	8.0
Urea (46-0-0) @ 1 lb N	6.9	7.5 a	8.3 a	7.9 a	7.6 a	8.1 a	7.5 b	8.4 ab	8.3 a	8.1 a	8.1
30% SRN (16-0-8) @ 1 lb N	6.6	7.4 ab	8.3 a	7.1 b	7.8 a	7.8 a	7.4 b	8.1 a-c	8.4 a	8.1 a	8.1
50% SRN (19-0-0) @ 1 lb N	6.8	7.3 ab	7.9 a	7.1 b	7.5 a	8.0 a	7.9 ab	7.9 bc	8.3 a	8.5 a	8.5
PCU (41-0-0) @ 1 lb N	6.6	6.4 de	6.6 b	5.6 c	6.4 b	7.1 b	7.5 b	7.1 d	7.5 b	8.3 a	8.3
PCU (41-0-0) @ 2 lbs N	7.1	7.0 bc	7.9 a	6.6 b	7.4 a	8.1 a	8.3 a	7.6 cd	8.1 a	8.6 a	8.6
BSD (6-2-0) @ 1 lb N	6.6	6.8 dc	6.8 b	5.8 c	6.5 b	6.6 c	6.5 c	6.3 e	7.4 b	8.0 a	7.9
LSD	ns	0.4	0.5	0.6	0.4	0.5	0.7	0.6	0.4	0.7	0.6

Treatments applied every 60 days (15 Apr, 12 June, 13 Aug, and 09 Oct) except PCU (41-0-0) @ 2 lbs N which was applied every 120 days (15 Apr and 12 June). Density visually rated on scale of 1 to 9 where 9=best.

No significant interactions between species and treatment, therefore only means for main effects of turf and treatment are presented. Means followed by different letters are not significantly different according to Fisher's Least Significant Test ($P=0.05$).

"-"= significant turf by treatment interaction and LSD not reported.

Table 226. Effect of nitrogen source applications on turf quality in 2010.

Species and Treatment (lbs N 1000 ft ²)	Rating Date											
	29 Apr	13 May	27 May	10 Jun	24 Jun	9 Jul	26 Jul	6 Aug	19 Aug	3 Sep	16 Sep	30 Sep
St. Augustinegrass												
Untreated	4.3 c	4.3 c	4.0 b	3.8 d	4.3 d	4.8 d	4.3 d	4.8 d	6.8	4.5 c	4.8 b	4.5 d
Am. Nitrate (34-0-0) @ 1 lb N	4.5 c	5.0 bc	4.8 ab	4.0 cd	5.8 c	5.0 cd	5.5 cd	6.0 cd	6.5	5.8 bc	6.8 a	6.3 c
Urea (46-0-0) @ 1 lb N	5.3 bc	5.5 b	4.8 ab	5.0 a-c	6.3 bc	5.0 cd	5.5 cd	6.5 bc	5.5	6.0 ab	6.8 a	6.8 bc
30% SRN (16-0-8) @ 1 lb N	6.5 a	6.5 a	6.0 a	5.3 ab	7.0 ab	6.0 a-c	7.3 ab	7.0 a-c	8.0	6.3 ab	7.3 a	7.8 ab
50% SRN (19-0-0) @ 1 lb N	6.5 a	6.5 a	6.0 a	5.8 a	7.8 a	6.5 a	7.8 a	8.3 a	7.5	7.3 a	7.5 a	8.0 a
PCU (41-0-0) @ 1 lb N	6.0 ab	5.5 b	5.8 a	5.3 ab	6.3 bc	6.3 ab	7.0 ab	7.5 ab	8.3	7.3 a	7.5 a	8.0 a
PCU (41-0-0) @ 2 lbs N	4.8 c	5.3 b	4.8 ab	4.5 ab	6.3 bc	5.3 b-d	6.3 bc	6.5 bc	7.0	5.8 bc	6.8 a	7.0 a-c
BSD (6-2-0) @ 1 lb N	6.0 ab	5.8 ab	5.5 a	5.0 a-c	6.8 b	6.0 a-c	6.3 bc	7.5 ab	7.5	7.0 ab	7.5 a	7.3 a-c
LSD	1.1	0.8	1.3	1.0	0.9	1.2	1.4	1.5	ns	1.5	1.2	1.2
Centipedegrass												
Untreated	5.0 c	5.0 d	5.3 d	5.0 b	5.3 d	5.5 b	5.3 d	5.3 c	6.0 b	5.3 d	5.3 c	5.3 d
Am. Nitrate (34-0-0) @ 1 lb N	7.5 a	8.0 a	8.3 b	8.5 a	9.0 a	9.0 a	8.8 a	8.5 ab	9.0 a	8.5 ab	8.5 ab	8.5 a-c
Urea (46-0-0) @ 1 lb N	7.5 a	7.8 a	9.0 a	8.5 a	9.0 a	8.8 a	8.0 b	8.3 b	7.8 a	8.5 ab	8.8 ab	8.8 ab
30% SRN (16-0-8) @ 1 lb N	7.0 ab	7.5 ab	8.3 b	8.5 a	8.8 ab	9.0 a	7.8 bc	8.0 b	8.0 a	7.3 c	8.3 b	8.0 c
50% SRN (19-0-0) @ 1 lb N	7.0 ab	7.8 a	8.3 b	8.8 a	9.0 a	9.0 a	7.8 bc	8.5 ab	8.0 a	7.8 bc	8.5 ab	8.5 a-c
PCU (41-0-0) @ 1 lb N	7.0 ab	7.0 bc	7.8 b	8.3 a	8.3 bc	9.0 a	8.8 a	9.0 a	8.8 a	8.5 ab	8.8 ab	9.0 a
PCU (41-0-0) @ 2 lbs N	6.8 b	7.0 bc	7.8 b	8.3 a	8.8 bc	9.0 a	8.8 a	9.0 a	9.0 a	8.8 a	9.0 a	8.8 ab
BSD (6-2-0) @ 1 lb N	6.5 b	6.8 c	7.0 c	8.0 a	8.0 c	8.8 a	7.3 c	8.0 b	8.0 a	8.3 ab	8.8 ab	8.3 bc
LSD	0.6	0.5	0.6	0.8	0.5	0.4	0.7	0.5	1.5	0.8	0.7	0.6
Split-plot analysis P(F)												
Species	.0019	.0004	.0001	.0001	.0001	.0001	.0030	.0003	.0109	.0008	.0033	.0106
Treatment	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0175	.0001	.0001	.0001
Species*Treatment	.0002	.0002	.0008	.0012	.0002	.0001	.0006	.0180	.1050	.0135	.1753	.0233

Treatments applied every 60 days (15 Apr, 11 June, 09 Aug, and 08 Oct) except PCU (41-0-0) @ 2 lbs N which was applied every 120 days (15 Apr and 09 Aug). Quality visually rated on scale of 1 to 9 where 9=best.

Significant interactions between species and treatment, therefore treatment means for each species are presented. Means followed by the same letter(s) in each column are not significantly different according to Fisher's Least Significant Test ($P=0.05$).

Table 227. Effect of nitrogen source applications on turf color in 2010.

Species and Treatment (lbs N 1000 ft ⁻²)	Rating Date											
	29 Apr	13 May	27 May	10 Jun	24 Jun	9 Jul	26 Jul	6 Aug	19 Aug	3 Sep	16 Sep	30 Sep
St. Augustinegrass												
Untreated	4.0 d	4.3 e	3.8 d	3.5 c	4.0 d	4.3 c	4.5 b	4.5 b	6.8	4.5 ab	4.8 b	4.8 b
Am. Nitrate (34-0-0) @ 1 lb N	5.0 c	5.3 d	4.5 cd	5.0 b	6.5 bc	5.8 ab	7.3 a	7.3 a	6.8	6.5 a	7.0 a	6.8 a
Urea (46-0-0) @ 1 lb N	5.5 bc	5.5 cd	5.0 bc	5.0 b	6.5 bc	5.8 ab	7.0 a	7.3 a	6.0	6.5 a	6.8 a	7.0 a
30% SRN (16-0-8) @ 1 lb N	7.0 a	6.8 a	6.0 ab	6.5 a	7.3 ab	6.3 ab	7.5 a	7.3 a	8.3	6.8 a	7.3 a	7.3 a
50% SRN (19-0-0) @ 1 lb N	7.0 a	6.5 ab	6.5 a	6.5 a	7.8 a	6.8 a	7.8 a	7.8 a	7.8	7.3 a	7.3 a	7.3 a
PCU (41-0-0) @ 1 lb N	5.8 b	6.0 bc	6.3 a	6.3 a	6.3 c	6.5 ab	7.3 a	7.5 a	7.8	7.3 a	7.5 a	7.5 a
PCU (41-0-0) @ 2 lbs N	5.0 c	5.5 cd	5.5 a-c	5.0 b	6.5 bc	5.5 b	7.3 a	7.3 a	7.3	7.0 a	7.3 a	7.3 a
BSD (6-2-0) @ 1 lb N	5.5 bc	5.3 d	5.5 a-c	5.8 a	6.8 bc	6.3 ab	7.0 a	7.5 a	7.5	7.3 a	7.3 a	7.3 a
LSD	0.7	0.7	1.2	1.0	0.8	1.1	0.9	0.8	ns	0.8	1.0	1.0
Centipedegrass												
Untreated	5.0 e	5.0 c	5.0 f	4.5 c	4.8 c	5.0 d	5.0 e	4.8 c	6.0 b	5.0 c	5.0 d	5.0 d
Am. Nitrate (34-0-0) @ 1 lb N	7.5 ab	8.0 a	8.5 ab	8.3 a	8.8 a	8.5 b	8.0 b	8.0 b	8.8 a	8.5 a	8.8 a	8.8 a
Urea (46-0-0) @ 1 lb N	7.8 a	8.0 a	9.0 a	8.3 a	8.8 a	8.5 b	8.0 b	8.0 b	7.5 ab	8.3 a	8.5 ab	8.5 ab
30% SRN (16-0-8) @ 1 lb N	7.5 ab	8.0 a	8.3 bc	8.0 ab	8.5 a	8.0 c	7.3 cd	7.8 b	7.3 ab	7.3 b	7.5 c	7.5 c
50% SRN (19-0-0) @ 1 lb N	7.3 b	7.8 a	8.3 bc	8.8 a	8.5 a	8.0 c	7.8 bc	8.3 ab	8.0 a	7.3 b	7.8 bc	7.8 bc
PCU (41-0-0) @ 1 lb N	6.5 c	6.5 b	7.8 cd	8.0 ab	7.5 a	8.3 bc	8.8 a	9.0 a	8.3 a	8.5 a	8.5 ab	8.5 ab
PCU (41-0-0) @ 2 lbs N	6.5 c	6.5 b	7.5 de	8.0 ab	8.3 a	9.0 a	8.8 a	9.0 a	8.8 a	8.8 a	8.8 a	8.8 a
BSD (6-2-0) @ 1 lb N	6.0 d	6.5 b	7.0 e	7.3 b	7.3 b	8.0 c	7.0 d	7.5 b	8.0 a	8.3 a	8.8 a	8.8 a
LSD	0.5	0.5	0.5	0.9	0.7	0.5	0.7	0.8	1.5	0.8	0.8	0.8
Split-plot analysis P(F)												
Species	.0021	.0001	.0001	.0001	.0050	.0001	.0338	.0087	.1379	.0018	.0100	.0338
Treatment	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0373	.0001	.0001	.0001
Species*Treatment	.0001	.0001	.0001	.0024	.0019	.0005	.0120	.0344	.1070	.0086	.0461	.0900

Treatments applied every 60 days (15 Apr, 11 June, 09 Aug, and 08 Oct) except PCU (41-0-0) @ 2 lbs N which was applied every 120 days (15 Apr and 09 Aug).

Color visually rated on scale of 1 to 9 where 9=best.

Significant interactions between species and treatment, therefore treatment means for each species are presented.

Means followed by the same letter(s) in each column and species are not significantly different according to Fisher's Least Significant Difference.

Table 228. Effect of nitrogen source applications on turf density in 2010.

Species and Treatment (lbs N 1000 ft ⁻²)	Rating Date											
	29 Apr	13 May	27 May	10 Jun	24 Jun	9 Jul	26 Jul	6 Aug	19 Aug	3 Sep	16 Sep	30 Sep
St. Augustinegrass												
Untreated	5.3 cd	4.5 c	4.3 d	4.5 c	4.5 d	4.3 e	4.5 e	4.8 e	7.5	5.3 c	5.3 c	5.0 e
Am. Nitrate (34-0-0) @ 1 lb N	5.0 d	5.3 bc	5.0 cd	5.3 bc	6.5 c	5.0 de	5.8 de	6.0 de	7.3	6.5 bc	7.0 b	8.5 d
Urea (46-0-0) @ 1 lb N	5.3 cd	5.8 ab	5.5 a-d	6.0 ab	6.8 bc	5.5 cd	6.5 cd	6.8 cd	5.8	7.0 a-c	7.5 ab	7.0 cd
30% SRN (16-0-8) @ 1 lb N	6.5 ab	6.5 a	6.8 a	6.3 ab	7.5 ab	6.5 a-c	7.8 a-c	7.5 bc	8.3	7.8 ab	8.0 ab	7.8 a-c
50% SRN (19-0-0) @ 1 lb N	7.0 a	6.5 a	6.5 ab	6.5 a	7.8 a	7.3 a	8.3 a	9.0 a	8.3	8.8 a	8.5 a	8.8 a
PCU (41-0-0) @ 1 lb N	6.8 ab	6.3 a	6.5 ab	6.0 ab	7.0 a-c	6.8 ab	8.0 ab	8.3 ab	8.5	8.5 a	8.5 a	8.5 ab
PCU (41-0-0) @ 2 lbs N	5.0 d	5.3 bc	5.3 b-d	5.8 ab	6.3 c	6.0 b-d	6.8 b-d	7.3 b-d	7.8	6.3 bc	7.5 ab	7.5 b-d
BSD (6-2-0) @ 1 lb N	6.0 bc	6.0 ab	6.0 a-c	5.8 ab	6.8 bc	6.0 b-d	7.0 a-d	8.3 ab	8.3	7.5 ab	8.0 ab	7.8 a-c
LSD	1.0	0.9	1.3	1.1	0.9	1.2	1.4	1.3	ns	1.8	1.4	1.2
Centipedegrass												
Untreated	5.0 e	5.0 d	5.5 d	5.3 c	5.3 c	5.5 d	5.8 b	6.0 b	6.5 b	5.8 c	5.8 c	5.5 c
Am. Nitrate (34-0-0) @ 1 lb N	7.5 ab	8.3 a	8.8 a	7.5 ab	9.0 a	9.0 a	9.0 a	9.0 a	9.0 a	9.0 a	9.0 a	8.5 ab
Urea (46-0-0) @ 1 lb N	8.0 a	7.8 ab	9.0 a	7.8 ab	9.0 a	9.0 a	9.0 a	9.0 a	8.0 a	8.8 ab	8.8 ab	9.0 a
30% SRN (16-0-8) @ 1 lb N	7.8 ab	8.5 a	8.8 a	8.5 a	9.0 a	8.9 ab	8.8 a	9.0 a	9.0 a	8.5 ab	8.5 ab	8.3 b
50% SRN (19-0-0) @ 1 lb N	7.3 bc	7.8 ab	8.8 a	8.8 a	9.0 a	8.3 bc	8.8 a	9.0 a	8.8 a	8.5 ab	8.8 ab	8.0 b
PCU (41-0-0) @ 1 lb N	6.8 cd	6.8 c	7.8 b	8.3 ab	9.0 a	8.3 bc	9.0 a	9.0 a	9.0 a	9.0 a	9.0 a	8.3 b
PCU (41-0-0) @ 2 lbs N	6.5 d	7.3 bc	7.8 b	8.5 a	9.0 a	8.8 ab	9.0 a	9.0 a	9.0 a	9.0 a	9.0 a	8.5 ab
BSD (6-2-0) @ 1 lb N	6.3 d	6.5 c	7.0 c	7.0 b	8.0 b	8.0 c	8.8 a	8.8 a	8.3 a	8.3 b	8.3 b	8.0 b
LSD	0.6	0.8	0.7	1.4	0.3	0.6	0.5	0.3	1.3	0.6	0.6	0.7
Split-plot analysis P(F)												
Species	.0163	.0055	.0001	.0015	.0001	.0001	.0018	.0003	.0184	.0001	.0027	.0088
Treatment	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0026	.0001	.0001	.0001
Species*Treatment	.0001	.0003	.0009	.3959	.0010	.0001	.0083	.0010	.0934	.0220	.1931	.0012

Treatments applied every 60 days (15 Apr, 11 June, 09 Aug, and 08 Oct) except PCU (41-0-0) @ 2 lbs N which was applied every 120 days (15 Apr and 11 June). Density visually rated on scale of 1 to 9 where 9=best.

Significant interactions between species and treatment, therefore treatment means for each species are presented.

Means followed by the same letter(s) in each column and species are not significantly different according to Fisher's Least Significant Test ($P=0.05$).

Table 229. Effect of nitrogen source applications on turf quality in 2011.

Species and Treatment (lbs N 1000 ft ⁻²)	Rating Date								
	2 May	19 May	3 Jun	16 Jun	30 Jun	14 Jul	29 Jul	12 Aug	25 Aug
St. Augustinegrass									
Untreated	3.0 c	4.0 d	4.0 e	3.8 d	3.8 c	3.5 d	3.5 c	3.5 c	4.0 d
Am. Nitrate (34-0-0) @ 1 lb N	4.3 b	4.3 cd	4.5 e	4.5 cd	5.0 b	5.3 bc	6.0 b	5.8 b	5.8 c
Urea (46-0-0) @ 1 lb N	4.8 b	4.8 bc	4.8 de	5.0 c	5.0 b	5.0 c	6.0 b	6.0 b	6.0 bc
30% SRN (16-0-8) @ 1 lb N	6.3 a	6.5 a	6.3 bc	7.3 a	7.3 a	7.3 a	7.8 a	7.3 a	7.3 a
50% SRN (19-0-0) @ 1 lb N	6.8 a	6.3 a	7.3 a	7.5 a	7.8 a	7.8 a	8.0 a	7.5 a	7.3 a
PCU (41-0-0) @ 1 lb N	5.0 b	5.3 b	5.5 cd	5.3 c	5.8 b	6.0 b	6.8 b	7.5 a	7.0 ab
PCU (41-0-0) @ 2 lbs N	4.3 b	4.8 bc	4.5 e	5.0 c	5.5 b	6.0 b	6.8 b	6.5 ab	6.5 a-c
BSD (6-2-0) @ 1 lb N	6.0 a	6.0 a	6.5 ab	6.3 b	7.0 a	7.0 a	6.8 b	6.0 b	6.3 a-c
LSD	0.8	0.7	0.9	0.9	1.0	0.9	0.9	1.0	1.0
Centipedegrass									
Untreated	5.0 b	5.3 b	5.0 b	4.3 c	4.3 b	4.3 d	5.0 d	4.8 d	5.0 d
Am. Nitrate (34-0-0) @ 1 lb N	7.0 a	6.8 a	7.5 a	7.0 ab	7.5 a	7.3 ab	7.5 a-c	7.5 a-c	7.0 c
Urea (46-0-0) @ 1 lb N	6.8 a	6.8 a	7.3 a	6.8 b	7.3 a	7.0 ab	7.3 bc	7.3 bc	7.0 c
30% SRN (16-0-8) @ 1 lb N	7.0 a	7.0 a	7.0 a	7.5 a	7.3 a	6.8 bc	7.3 bc	7.0 c	7.0 c
50% SRN (19-0-0) @ 1 lb N	6.8 a	6.8 a	7.5 a	6.8 b	6.8 a	6.0 c	7.0 c	7.0 c	7.5 bc
PCU (41-0-0) @ 1 lb N	6.8 a	7.3 a	7.8 a	6.8 b	7.0 a	7.3 ab	7.8 a-c	8.0 a	8.5 a
PCU (41-0-0) @ 2 lbs N	7.0 a	7.3 a	7.8 a	7.0 ab	7.5 a	7.8 a	8.3 a	7.8 ab	8.0 ab
BSD (6-2-0) @ 1 lb N	6.8 a	7.3 a	7.8 a	7.0 ab	7.5 a	7.8 a	8.0 ab	7.0 c	7.5 bc
LSD	0.7	0.7	0.8	0.7	1.0	0.8	0.8	0.7	0.7
Split-plot analysis P(F)									
Species	.0001	.0004	.0001	.0025	.0019	.0079	.0315	.0091	.0502
Treatment	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001
Species*Treatment	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0038	.0543

Treatments applied every 60 days (12 Apr and 11 June) except PCU (41-0-0) @ 2 lbs N which was applied once on 15 Apr).

Quality visually rated on scale of 1 to 9 where 9=best.

Significant interactions between species and treatment, therefore treatment means for each species are presented. Means followed by the same letter(s) in each column and species are not significantly different according to Fisher's Least Significant Test ($P=0.05$).

Table 230. Effect of nitrogen source applications on turf color in 2011.

Species and Treatment (lbs N 1000 ft ⁻²)	Rating Date								
	2 May	19 May	3 Jun	16 Jun	30 Jun	14 Jul	29 Jul	12 Aug	25 Aug
St. Augustinegrass									
Untreated	3.3 d	4.0 d	4.0 d	3.3 f	4.0 d	4.0 e	3.8 c	4.3 c	4.3 c
Am. Nitrate (34-0-0) @ 1 lb N	4.8 c	4.3 cd	4.5 cd	4.5 e	5.0 c	5.0 d	6.3 b	6.3 b	5.8 b
Urea (46-0-0) @ 1 lb N	4.5 c	4.8 bc	4.5 cd	4.8 de	5.0 c	5.0 d	6.3 b	6.3 b	5.8 b
30% SRN (16-0-8) @ 1 lb N	6.3 a	6.0 a	6.0 b	7.0 a	7.3 a	7.3 a	7.5 a	7.0 ab	6.8 a
50% SRN (19-0-0) @ 1 lb N	6.0 ab	6.3 a	6.8 a	6.8 ab	7.8 a	7.5 a	7.3 a	6.5 b	6.8 a
PCU (41-0-0) @ 1 lb N	5.0 c	5.3 b	5.0 c	5.5 cd	5.3 bc	5.8 cd	6.3 b	7.5 a	7.0 a
PCU (41-0-0) @ 2 lbs N	5.0 c	4.8 bc	5.0 c	5.3 c-e	6.0 b	6.3 bc	6.8 ab	6.5 a	6.5 ab
BSD (6-2-0) @ 1 lb N	5.3 bc	5.3 b	6.3 ab	6.0 bc	7.0 a	6.8 ab	7.0 ab	6.3 b	6.5 ab
LSD	0.8	0.7	0.7	0.8	1.0	1.0	1.0	1.0	0.9
Centipedegrass									
Untreated	5.0 c	5.0 b	5.0 b	4.8 b	4.5 b	4.3 e	4.3 d	5.0 d	4.8 c
Am. Nitrate (34-0-0) @ 1 lb N	7.0 a	7.0 a	6.5 a	6.8 a	7.5 a	7.3 ab	7.5 ab	7.5 ab	7.3 ab
Urea (46-0-0) @ 1 lb N	6.8 ab	6.8 a	6.8 a	6.8 a	7.3 a	7.0 bc	7.0 bc	7.5 ab	6.8 b
30% SRN (16-0-8) @ 1 lb N	7.3 a	7.0 a	7.0 a	7.5 a	7.3 a	6.5 c	6.5 c	7.0 bc	6.8 b
50% SRN (19-0-0) @ 1 lb N	6.5 ab	7.0 a	7.3 a	7.0 a	6.8 a	5.8 d	6.8 c	6.8 c	6.8 b
PCU (41-0-0) @ 1 lb N	6.0 b	6.8 a	7.0 a	6.8 a	7.0 a	7.0 bc	7.8 a	8.0 a	8.0 a
PCU (41-0-0) @ 2 lbs N	6.5 ab	7.5 a	7.3 a	7.0 a	7.5 a	7.8 a	7.8 a	7.3 bc	8.0 a
BSD (6-2-0) @ 1 lb N	6.5 ab	7.0 a	7.0 a	6.8 a	7.5 a	7.8 a	8.0 a	7.0 bc	7.5 ab
LSD	0.9	1.0	0.9	0.9	0.8	0.7	0.6	0.6	0.9
Split-plot analysis P(F)									
Species	.0001	.0001	.0002	.0045	.0015	.0140	.0591	.0225	.0871
Treatment	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001
Species*Treatment	.0436	.0057	.0029	.0078	.0001	.0001	.0004	.2848	.0879

Treatments applied every 60 days (12 Apr and 11 June) except PCU (41-0-0) @ 2 lbs N which was applied once on 15 Apr).

Color visually rated on scale of 1 to 9 where 9=best.

Significant interactions between species and treatment, therefore treatment means for each species are presented. Means followed by the same letter(s) in each column and species are not significantly different according to Fisher's Least Significant Test ($P=0.05$).

Table 231. Effect of nitrogen source applications on turf density in 2011.

Species and Treatment (lbs N 1000 ft ⁻²)	Rating Date								
	2 May	19 May	3 Jun	16 Jun	30 Jun	14 Jul	29 Jul	12 Aug	25 Aug
St. Augustinegrass									
Untreated	4.3 e	4.0 d	4.0 c	4.3 e	3.8 e	4.0 e	4.0 e	4.0 d	4.0 d
Am. Nitrate (34-0-0) @ 1 lb N	5.3 d	4.8 cd	5.0 b	5.3 de	5.3 d	6.0 d	6.8 d	5.8 c	6.0 c
Urea (46-0-0) @ 1 lb N	5.5 cd	5.5 bc	5.0 b	5.5 cd	5.3 d	6.0 d	6.5 d	6.3 c	6.5 c
30% SRN (16-0-8) @ 1 lb N	6.5 b	6.8 a	7.3 a	7.5 ab	7.5 ab	8.0 ab	8.5 ab	8.0 ab	8.3 a
50% SRN (19-0-0) @ 1 lb N	7.5 a	7.3 a	8.0 a	8.0 a	8.3 a	8.8 a	8.8 a	8.8 a	8.5 a
PCU (41-0-0) @ 1 lb N	6.3 bc	6.8 a	5.8 b	5.8 cd	6.3 c	7.3 bc	7.8 bc	8.0 ab	8.0 ab
PCU (41-0-0) @ 2 lbs N	5.5 cd	5.0 cd	5.3 b	5.3 de	5.8 cd	6.8 cd	7.3 cd	7.0 bc	7.0 bc
BSD (6-2-0) @ 1 lb N	6.3 bc	6.5 ab	7.5 a	6.5 bc	7.3 b	7.3 bc	7.8 bc	6.8 bc	6.8 c
LSD	1.0	1.1	0.9	1.1	0.9	0.9	1.0	1.3	1.2
Centipedegrass									
Untreated	5.3 b	5.5 c	5.5 b	5.3 b	5.0 b	4.5 b	4.8 c	4.3 c	4.8 c
Am. Nitrate (34-0-0) @ 1 lb N	7.3 a	7.5 ab	8.0 a	7.3 a	7.8 a	7.8 a	8.3 ab	8.0 ab	7.8 b
Urea (46-0-0) @ 1 lb N	6.8 a	7.5 ab	7.8 a	7.3 a	7.5 a	7.3 a	7.8 b	7.5 ab	7.8 b
30% SRN (16-0-8) @ 1 lb N	7.3 a	7.5 ab	8.0 a	8.0 a	7.8 a	8.0 a	8.0 ab	7.5 ab	8.0 b
50% SRN (19-0-0) @ 1 lb N	7.0 a	8.0 a	8.0 a	7.3 a	7.8 a	7.8 a	8.0 ab	7.5 ab	8.3 ab
PCU (41-0-0) @ 1 lb N	7.0 a	7.3 b	8.5 a	7.0 a	7.8 a	7.8 a	8.8 a	8.5 a	8.8 a
PCU (41-0-0) @ 2 lbs N	7.0 a	7.8 ab	8.3 a	7.5 a	7.5 a	7.8 a	8.8 a	8.3 a	8.3 ab
BSD (6-2-0) @ 1 lb N	7.0 a	7.3 b	8.0 a	7.3 a	7.8 a	8.0 a	7.8 b	7.0 b	7.8 b
LSD	0.5	0.7	0.8	1.1	0.7	0.8	0.8	1.1	0.7
Split-plot analysis P(F)									
Species	.0004	.0002	.0002	.0113	.0001	.0678	.1057	.1536	.0146
Treatment	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001
Species*Treatment	.0040	.0019	.0001	.0043	.0001	.0023	.0008	.0036	.0358

Treatments applied every 60 days (12 Apr and 11 June) except PCU (41-0-0) @ 2 lbs N which was applied once on 15 Apr).

Density visually rated on scale of 1 to 9 where 9=best.

Significant interactions between species and treatment, therefore treatment means for each species are presented. Means followed by the same letter(s) in each column and species are not significantly different according to Fisher's Least Significant Test ($P=0.05$).

Table 232. Effect of nitrogen source applications on shoot mass in 2008.

Treatment (lbs N 1,000 ft ⁻²)	Shoot mass (g)			
	St. Augustinegrass		Centipedegrass	
	8 Sep	9 Oct	8 Sep	9 Oct
Untreated	4.18	1.54	18.98 d	9.59 c
Am. Nitrate (34-0-0) @ 1 lb N	3.66	2.81	29.81 a	17.55 a
Urea (46-0-0) @ 1 lb N	4.44	3.25	26.52 a-c	12.81 bc
30% SRN (16-0-8) @ 1 lb N	3.81	2.81	30.77 a	14.42 ab
50% SRN (19-0-0) @ 1 lb N	2.67	2.54	29.30 ab	14.05 ab
PCU (41-0-0) @ 1 lb N	1.81	0.76	19.66 cd	9.65 c
PCU (41-0-0) @ 2 lbs N	2.10	1.81	22.53 b-d	13.32 a-c
BSD (6-2-0) @ 1 lb N	2.85	1.52	19.93 cd	12.86 bc
<i>Pr>F</i>	<i>ns</i>	<i>ns</i>	7.16	4.39

Treatments applied 19 August 2008.

Significant interactions between species and treatment, therefore means for treatment are presented for each species. Means followed by the same letter(s) in a column are not significantly different according to Fisher's Least Significant Difference ($P=0.05$).

Table 233. Effect of nitrogen source applications on St. Augustinegrass shoot mass in 2009.

Treatment (lbs N 1,000 ft ⁻²)	Shoot mass (g)													
	St. Augustinegrass													
	7 May	20 May	3 Jun	15 Jun	24 Jun	8 Jul	23 Jul	5 Aug	19 Aug	2 Sep	23 Sep	8 Oct	21 Oct	29 Oct
	Aug Aug													
Untreated	0.76	0.05	0.26	1.33 c	1.96 c	1.78 d	0.63 d	0.20 b	0.11 e	0.19 e	0.00 b	0.78 e	0.34 e	1.42
AN (34-0-0) @ 1 lb N	0.55	0.05	0.32	2.41 bc	5.02 a	4.85 b	3.42 a-c	1.90 b	2.81 bc	3.98 ab	0.15 b	4.50 bc	2.32 cd	0.81
Urea (46-0-0) @ 1 lb N	0.48	0.13	0.26	2.11 bc	4.15 ab	3.95 bc	3.10 b-d	2.23 b	2.61 bc	2.04 cd	0.00 b	3.35 b-d	1.98 cd	0.39
30% SRN (16-0-8) @ 1 lb N	0.59	0.13	0.23	2.47 bc	3.78 ab	5.62 b	2.90 b-d	2.39 b	2.28 b-d	3.66 a-c	0.27 b	5.10 b	3.34 bc	0.49
50% SRN (19-0-0) @ 1 lb N	0.40	0.16	0.48	3.75 ab	5.34 a	7.99 a	5.75 a	5.27 a	4.80 a	5.22 a	1.26 a	9.37 a	5.57 a	0.53
PCU (41-0-0) @ 1 lb N	0.60	0.10	0.35	2.38 bc	3.08 bc	2.80 cd	1.60 b-d	1.39 b	1.23 c-e	1.09 de	0.00 b	2.72 c-e	2.41 c	0.37
PCU (41-0-0) @ 2 lbs N	0.52	0.15	0.59	5.50 a	4.69 ab	4.39 bc	4.11 ab	5.01 a	3.26 ab	2.93 bc	0.24 b	7.41 a	4.71 ab	0.56
BSD (6-2-0) @ 1 lb N	0.44	0.07	0.29	2.08 bc	1.95 c	2.45 cd	1.09 cd	0.83 b	0.70 de	1.01 de	0.00 b	1.96 de	0.74 de	0.44
<i>LSD</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>	1.91	1.82	1.94	2.55	2.31	1.85	1.69	0.57	2.08	1.63	<i>NS</i>

Treatments applied every 60 days (15 Apr, 12 June, 13 Aug, and 09 Oct) except PCU (41-0-0) @ 2 lbs N which was applied every 120 days (15 Apr and 13 Aug).

Significant interactions between species and treatment, therefore means for treatment are presented for each species. Means followed by the same letter(s) in a column are not significantly different according to Fisher's Least Significant Difference ($P=0.05$).

Table 234. Effect of nitrogen source applications on centipedegrass shoot mass in 2009.

Treatment (lbs N 1,000 ft ²)	Shoot mass (g)													
	Centipedegrass													
	7 May	20 May	3 Jun	15 Jun	24 Jun	8 Jul	23 Jul	5 Aug	19 Aug	2 Sep	23 Sep	8 Oct	21 Oct	29 Oct
Untreated	3.80 d	1.00 d	0.89	5.56	13.46 d	19.60	11.80 d	6.41	3.95 f	3.68 e	2.38 e	5.94 e	2.19 c	4.04
Am. Nitrate (34-0-0) @ 1 lb N	18.23 a	6.69 a	6.55	43.46	84.07 a	60.73	36.80	16.13	18.37	24.26 e	8.19 c	23.40 t	7.40 t	3.43
Urea (46-0-0) @ 1 lb N	13.51 b	4.90 ab	1.55	17.98	75.67	61.04	37.67	13.84	15.11 c	21.51 e	6.98 c	18.73 c	6.81 t	1.43
30% SRN (16-0-8) @ 1 lb N	13.58 b	5.33 ab	1.66	16.87	57.19 b	62.13	38.80	13.81	15.25	21.16 t	8.40 t	20.30 t	6.26 t	2.37
50% SRN (19-0-0) @ 1 lb N	8.75 c	3.48 bc	1.34	15.56	58.09 b	61.21	48.50	17.29	16.68	20.51 t	11.22 e	25.73 t	9.48 t	2.83
PCU (41-0-0) @ 1 lb N	5.27 cd	1.58 d	1.25	9.87	29.29	32.10	24.31	15.59	11.45 d	12.51 c	12.85 e	28.03 t	9.05 t	2.43
PCU (41-0-0) @ 2 lbs N	7.01 cd	3.66 bc	7.43	28.37	53.69	65.90	53.02	22.83	18.66 a	16.84 c	14.12 e	40.20 t	16.13 a	2.80
BSD (6-2-0) @ 1 lb N	4.80 d	2.19 dc	5.05	16.06	31.08	30.24	19.35	10.23	7.73 e	10.90 c	5.40 c	10.87 c	3.25 c	2.14
LSD	3.79	1.86	NS	NS	24.60	11.13	15.60	2.96	3.22	3.04	4.56	8.67	3.49	NS

Treatments applied every 60 days (15 Apr, 12 June, 13 Aug, and 09 Oct) except PCU (41-0-0) @ 2 lbs N which was applied every 120 days (15 Apr and 13 Aug).

Significant interactions between species and treatment, therefore means for treatment are presented for each species.

Means followed by the same letter(s) in a column are not significantly different according to Fisher's Least Significant Difference ($P=0.05$).

Table 235. Effect of nitrogen source applications on St. Augustinegrass shoot mass in 2010.

Treatment (lbs N 1,000 ft ²)	Shoot mass (g)									
	St. Augustinegrass									
	20 May	3 Jun	17 Jun	1 Jul	15 Jul	29 Jul	12 Aug	26 Aug	9 Sep	23 Sep
Untreated	0.03b	0.11b	0.36c	0.96c	1.72d	0.60c	0.16c	0.89d	0.37c	0.19
AN (34-0-0) @ 1 lb N	0.01b	0.22b	1.99bc	2.35bc	4.18bc	3.22bc	1.96b	10.04bc	2.20b	0.40
Urea (46-0-0) @ 1 lb N	0.01b	0.19b	1.20bc	1.98bc	3.41cd	3.69bc	1.96b	7.86c	1.80bc	0.44
30% SRN (16-0-8) @ 1 lb N	0.23a	0.43b	2.58b	4.69ab	5.59b	7.80a	3.70a	14.31ab	2.98b	0.47
50% SRN (19-0-0) @ 1 lb N	0.35a	1.12a	7.28a	7.45a	8.09a	8.97a	4.07a	18.80a	5.07a	0.80
PCU (41-0-0) @ 1 lb N	0.03b	0.46b	2.54b	3.38bc	4.68bc	8.00a	3.60a	10.43bc	2.41b	0.72
PCU (41-0-0) @ 2 lbs N	0.00b	0.20b	2.07bc	4.26b	3.60bd	5.03ab	3.51a	10.43bc	2.84b	1.00
BSD (6-2-0) @ 1 lb N	0.00b	0.18b	1.44bc	4.17b	3.44cd	2.87bc	1.18bc	9.16bc	2.30b	0.37
LSD	0.15	0.42	2.05	2.89	2.00	4.17	1.31	6.00	1.77	NS

Treatments applied every 60 days (15 Apr, 11 June, 09 Aug, and 08 Oct) except PCU (41-0-0) @ 2 lbs N which was applied every 120 days (15 Apr and 09 Aug).

Significant interactions between species and treatment, therefore means for treatment are presented for each species.

Means followed by the same letter(s) in a column are not significantly different according to Fisher's Least Significant Difference ($P=0.05$).

Table 236. Effect of nitrogen source applications on centipedegrass shoot mass in 2010.

Treatment (lbs N 1,000 ft ⁻²)	Shoot mass (g)									
	Centipedegrass									
	20 May	3 Jun	17 Jun	1 Jul	15 Jul	29 Jul	12 Aug	26 Aug	9 Sep	23 Sep
Untreated	1.43 e	0.35 d	5.42 e	10.33 e	17.66 d	11.88 d	2.41 c	6.06 d	5.38 d	4.17 c
Am. Nitrate (34-0-0) @ 1 lb N	18.52 a	7.09 bc	45.56 a	36.72 cd	35.92 c	24.27 bc	9.57 b	40.97 ab	22.73 bc	12.78 b
Urea (46-0-0) @ 1 lb N	16.37 ab	6.33 bc	40.42 ab	42.07 bc	36.20 c	23.62 bc	10.71 b	37.41 b	24.31 ab	13.72 b
30% SRN (16-0-8) @ 1 lb N	20.54 a	7.66 ab	41.31 a	51.81 a	38.56 bc	26.62 b	9.20 b	39.45 ab	19.36 c	11.28 b
50% SRN (19-0-0) @ 1 lb N	18.10 a	9.58 a	45.79 a	44.82 b	40.25 a-c	27.65 b	11.24 b	45.35 a	26.32 ab	14.78 b
PCU (41-0-0) @ 1 lb N	9.48 cd	5.17 c	34.79 bc	33.71 d	44.63 ab	40.00 a	16.55 a	29.90 c	27.72 a	20.65 a
PCU (41-0-0) @ 2 lbs N	11.86 bc	6.69 bc	34.21 c	35.80 d	45.55 a	39.63 a	19.09 a	36.41 b	27.94 a	19.23 a
BSD (6-2-0) @ 1 lb N	5.77 de	2.26 d	25.23 d	33.11 d	37.36 c	19.91 c	7.82 b	29.92 c	22.31 bc	13.43 b
LSD	4.61	1.93	5.90	5.38	6.59	5.58	3.42	5.62	4.80	3.54

Treatments applied every 60 days (15 Apr, 11 June, 09 Aug, and 08 Oct) except PCU (41-0-0) @ 2 lbs N which was applied every 120 days (15 Apr and 09 Aug).

Significant interactions between species and treatment, therefore means for treatment are presented for each species.

Means followed by the same letter(s) in a column are not significantly different according to Fisher's Least Significant Difference.

Table 237. Effect of nitrogen source applications on St. Augustinegrass shoot mass in 2011.

Treatment (lbs N 1,000 ft ⁻²)	Shoot mass (g)						
	St. Augustinegrass						
	26 May	9 Jun	23 Jun	7 Jul	21 Jul	4 Aug	18 Aug
Untreated	0.38 bc	0.27 c	0.49 d	1.29 c	1.00 d	1.14 d	0.62 d
Am. Nitrate (34-0-0) @ 1 lb N	0.29 c	0.41 c	1.48 d	5.95 c	8.28 bc	12.74 bc	7.20 bc
Urea (46-0-0) @ 1 lb N	0.25 c	0.27 c	1.24 d	3.89 c	4.43 cd	6.57 cd	4.03 cd
30% SRN (16-0-8) @ 1 lb N	0.61 ab	1.11 b	8.84 b	12.71 b	10.63 b	11.14 bc	6.61 c
50% SRN (19-0-0) @ 1 lb N	0.71 a	2.43 a	20.34 a	24.36 a	20.31 a	28.16 a	12.27 a
PCU (41-0-0) @ 1 lb N	0.28 c	0.58 c	2.09 cd	5.44 c	8.28 bc	14.72 bc	11.58 ab
PCU (41-0-0) @ 2 lbs N	0.41 bc	0.58 c	2.62 cd	5.85 c	9.32 bc	19.55 ab	12.24 a
BSD (6-2-0) @ 1 lb N	0.38 bc	0.92 b	4.37 c	6.43 c	5.66 b-d	8.45 cd	5.89 c
LSD	0.26	0.33	2.37	5.26	5.19	8.90	4.40

Treatments applied every 60 days (12 Apr and 11 June) except PCU (41-0-0) @ 2 lbs N which was applied once on 15 Apr). Significant interactions between species and treatment, therefore means for treatment are presented for each species. Means followed by the same letter(s) in a column are not significantly different according to Fisher's Least Significant Difference ($P=0.05$).

Table 238. Effect of nitrogen source applications on centipedegrass shoot mass in 2011.

Treatment (lbs N 1,000 ft ⁻²)	Shoot mass (g)						
	Centipedegrass						
	26 May	9 Jun	23 Jun	7 Jul	21 Jul	4 Aug	18Aug
Untreated	2.56 a- c	5.22 e	14.63 c	17.77 d	15.84 c	15.45 d	10.84 e
Am. Nitrate (34-0-0) @ 1 lb N	1.94 bc	5.36 e	27.64 b	52.16 bc	36.85 b	50.59 bc	40.83 bc
Urea (46-0-0) @ 1 lb N	1.99 bc	8.04 cd	32.79 ab	54.85 bc	36.49 b	55.78 b	43.70 ab
30% SRN (16-0-8) @ 1 lb N	2.05 bc	6.32 de	36.79 a	73.66 a	45.05 a	53.47 b	35.58 c
50% SRN (19-0-0) @ 1 lb N	1.85 c	6.89 de	30.30 ab	62.93 ab	45.98 a	55.83 b	36.04 c
PCU (41-0-0) @ 1 lb N	2.95 a	12.65 a	37.53 a	55.34 bc	48.24 a	61.08 ab	44.02 ab
PCU (41-0-0) @ 2 lbs N	2.75 ab	10.79 ab	37.47 a	58.80 bc	46.21 a	70.60 a	48.69 a
BSD (6-2-0) @ 1 lb N	2.93 a	9.48 bc	31.86 ab	47.97 c	35.96 b	40.36 c	27.33 d
LSD	0.87	2.00	7.36	14.07	7.62	10.77	7.61

Treatments applied every 60 days (12 Apr and 11 June) except PCU (41-0-0) @ 2 lbs N which was applied once on 15 Apr). Significant interactions between species and treatment, therefore means for treatment are presented for each species. Means followed by the same letter(s) in a column are not significantly different according to Fisher's Least Significant Difference ($P=0.05$).

Table 239. Effect of nitrogen source applications on turfgrass rooting in 2009.

	14 Apr 2009			15 Aug 2009		
	Root	Ash	% ash	Root	Ash	% ash
Turf						
St. Augustinegrass	0.360	0.096	20.67	0.142	0.036	19.69 a
Centipedegrass	0.332	0.058	16.15	0.152	0.017	10.54 b
LSD	ns	ns	ns	ns	ns	
Treatment (lbs N 1,000 ft ⁻²)						
Untreated	0.271	0.046	12.52	0.172	0.060	21.45
Am. Nitrate (34-0-0) @ 1 lb N	0.356	0.089	20.81	0.129	0.017	14.23
Urea (46-0-0) @ 1 lb N	0.316	0.054	14.95	0.166	0.022	12.37
30% SRN (16-0-8) @ 1 lb N	0.405	0.103	18.49	0.138	0.022	11.95
50% SRN (19-0-0) @ 1 lb N	0.324	0.061	17.76	0.136	0.028	18.93
PCU (41-0-0) @ 1 lb N	0.412	0.104	19.83	0.159	0.031	17.54
PCU (41-0-0) @ 2 lbs N	0.342	0.065	18.48	0.146	0.015	10.27
BSD (6-2-0) @ 1 lb N	0.342	0.093	23.44	0.127	0.017	12.83
LSD	ns	ns	ns	ns	ns	ns

Treatments applied every 60 days (15 Apr, 12 June, 13 Aug, and 09 Oct) except PCU (41-0-0) @ 2 lbs N which was applied every 120 days (15 Apr and 13 Aug).

No significant interactions between species and treatment, therefore only means for main effects of turf and treatment are presented. Means followed by the same letter(s) in a column are not significantly different according to Fisher's Least Significant Test ($P=0.05$), except for second rating of Ash and % Ash in 2009 were separated by Duncan's Multiple Range Test due to unbalanced data. ns= not significant.

Table 240. Effect of nitrogen source applications on turfgrass rooting in 2010.

	15 Apr 2010			9 Aug 2010		
	Root	Ash	% ash	Root	Ash	% ash
Turf						
St. Augustinegrass	0.248	0.029	10.43	0.319	0.064	16.25
Centipedegrass	0.363	0.053	12.87	0.411	0.087	16.59
<i>LSD</i>	<i>ns</i>	<i>ns</i>	<i>ns</i>	-	<i>ns</i>	-
Treatment (lbs N 1,000 ft ⁻²)						
Untreated	0.244	0.030	12.28	0.330	0.054	15.06
Am. Nitrate (34-0-0) @ 1 lb N	0.256	0.021	8.45	0.302	0.060	15.16
Urea (46-0-0) @ 1 lb N	0.291	0.024	8.24	0.351	0.045	12.21
30% SRN (16-0-8) @ 1 lb N	0.317	0.047	12.52	0.420	0.108	22.06
50% SRN (19-0-0) @ 1 lb N	0.300	0.045	12.99	0.352	0.073	14.78
PCU (41-0-0) @ 1 lb N	0.389	0.068	14.19	0.383	0.075	17.48
PCU (41-0-0) @ 2 lbs N	0.376	0.064	13.08	0.442	0.136	19.21
BSD (6-2-0) @ 1 lb N	0.273	0.033	11.45	0.341	0.055	15.40
<i>LSD</i>	<i>ns</i>	<i>ns</i>	<i>ns</i>	-	<i>ns</i>	-

Treatments applied every 60 days (15 Apr, 11 June, 09 Aug, and 08 Oct) except PCU (41-0-0) @ 2 lbs N which was applied every 120 days (15 Apr and 09 Aug).

No significant interactions between species and treatment, except for 9 Aug root and % ash, therefore only means for main effects of turf and treatment are presented. Means followed by the same letter(s) in a column are not significantly different according to Fisher's Least Significant Test ($P=0.05$). ns= not significant. "-"=significant interaction between turf and treatment.

Table 241. Effect of nitrogen source applications on turfgrass rooting in 2011

	12 Apr 2011		
	Root	Ash	% ash
Turf			
St. Augustinegrass	0.261	0.028	8.84
Centipedegrass	0.338	0.063	15.91
<i>LSD</i>	<i>ns</i>	<i>ns</i>	-
Treatment (lbs N 1,000 ft ⁻²)			
Untreated	0.221	0.023	8.25
Am. Nitrate (34-0-0) @ 1 lb N	0.262	0.036	11.07
Urea (46-0-0) @ 1 lb N	0.337	0.070	15.62
30% SRN (16-0-8) @ 1 lb N	0.327	0.043	11.76
50% SRN (19-0-0) @ 1 lb N	0.323	0.047	12.46
PCU (41-0-0) @ 1 lb N	0.348	0.076	19.80
PCU (41-0-0) @ 2 lbs N	0.289	0.040	11.22
BSD (6-2-0) @ 1 lb N	0.291	0.030	8.83
<i>LSD</i>	<i>ns</i>	<i>ns</i>	-

Treatments applied every 60 days (12 Apr and 11 June) except PCU (41-0-0) @ 2 lbs N which was applied once on 15 Apr).

No significant interactions between species and treatment, therefore only means for main effects of turf and treatment are presented. Means followed by the same letter(s) in a column are not significantly different according to Fisher's Least Significant Test ($P=0.05$). ns= not significant.

Table 242. Effect of nitrogen source applications on turfgrass rooting in 2011.

Treatment (lbs N 1,000 ft ⁻²)	12 Apr 2011 % ash	
	St. Augustinegrass	Centipedegrass
Untreated	5.29 a	11.21
Am. Nitrate (34-0-0) @ 1 lb N	5.39 a	16.74
Urea (46-0-0) @ 1 lb N	4.11 a	27.14
30% SRN (16-0-8) @ 1 lb N	10.98 a	12.53
50% SRN (19-0-0) @ 1 lb N	3.30 a	21.67
PCU (41-0-0) @ 1 lb N	24.92 b	14.68
PCU (41-0-0) @ 2 lbs N	8.98 a	13.46
BSD (6-2-0) @ 1 lb N	7.73 a	9.93
LSD	12.23	ns

Treatments applied every 60 days (12 Apr and 11 June) except PCU (41-0-0) @ 2 lbs N which was applied once on 15 Apr).

Means followed by the same letter(s) in a column are not significantly different according to Fisher's Least Significant Test ($P=0.05$). ns= not significant.

Table 243 . Effect of various nitrogen sources on total NO₃-N leached in 2008.

	Total N (kg ha ⁻²)					
	Pre*	Application 19 Aug 08			Post	Total
		60 day T1	60 day T2	120 day Total		
Turf						
St. Augustinegrass	8.820	14.053	7.627	21.681 a	1.164	22.844 a
Centipedegrass	8.573	7.673	2.448	10.120 b	0.456	10.576 b
<i>Pr>F</i>	0.9399	0.1081	0.0578	0.0148	0.1902	0.0111
Treatment (lbs N 1,000 ft ⁻²)						
Untreated	7.096	8.082 bc	4.396 b	12.478 bc	0.919	13.396 bc
Am. Nitrate (34-0-0) @ 1 lb N	9.776	14.293 ab	7.266 b	21.559 b	1.327	22.885 ab
Urea (46-0-0) @ 1 lb N	7.197	6.673 c	2.073 b	8.747 c	0.634	9.380 c
30% SRN (16-0-8) @ 1 lb N	10.559	18.516 a	14.396 a	32.912 a	0.492	33.354 a
50% SRN (19-0-0) @ 1 lb N	9.032	11.091 bc	6.146 b	17.236 bc	0.858	18.095 bc
PCU (41-0-0) @ 1 lb N	9.142	10.028 bc	0.774 b	10.801 c	0.219	11.020 c
PCU (41-0-0) @ 2 lbs N	9.363	12.554 a-c	3.372 b	15.926 bc	0.994	16.921 bc
BSD (6-2-0) @ 1 lb N	7.408	5.668 c	1.877 b	7.545 c	1.084	8.629 c
<i>Pr>F</i>	0.8371	0.0150	0.0037	0.0003	0.8535	0.0004
<i>Turf x Treatment Pr>F</i>	0.5415	0.2458	0.8053	0.4691	0.5446	0.3522

Treatments applied 19 August 2008.

* Pre = 5 Aug – 12 Aug, T1 = 19 Aug-14 Aug, T2 = 21 Oct-15 Dec, Post = 7 Feb – 30 Mar, and Total = 19 Aug-30 Mar.

Data corrected for MDL if data ≤ 0.148 then = 0.148. Means for main effects of turf and treatment are presented. Means followed by the same letter(s) in a column and group are not

significantly different according to Fisher's Protected LSD ($P=0.05$).

Table 244. Effect of various nitrogen sources on total $\text{NO}_3\text{-N}$ leached in 2009.

Table 2-7. Effect of various nitrogen sources on total $\text{NO}_3\text{-N}$ reached in 2007.									
Total N (kg ha^{-1})									

Treatments applied every 60 days (15 Apr, 12 June, 13 Aug, and 09 Oct) except PCU (41-0-0) @ 2 lbs N which was applied every 120 days (15 Apr and 13 Aug).

* Pre = 6 Apr – 14 Apr, T1 = 21 Apr-9 Jun, T2= 15 Jun- 11 Aug, T3=18 Aug-6 Oct, T4=13 Oct – 7 Dec, Post =15 Dec-30 Mar, and Total= 21 Apr-30 Mar.

Data corrected for MDL if data ≤ 0.148 then = 0.148. Means for main effects of species and treatment are presented. Means followed by the same letter(s) in a column and group are not significantly different according to Fisher's Protected LSD ($P=0.05$), except for Pre and T1 Duncan's Multiple Range Test ($P=0.05$) was used on unbalanced data.

Table 245. Effect of various nitrogen sources on total NO₃-N leached in 2009 when there was a significant species by treatment interaction.

Total N (kg ha ⁻¹)		
Application		
15 Apr 09		
60 day T2		
Treatment (lbs N 1,000 ft ⁻²)	St. Aug	Cent
Untreated	0.233	0.118
Am. Nitrate (34-0-0) @ 1 lb N	0.193	0.293
Urea (46-0-0) @ 1 lb N	0.194	0.290
30% SRN (16-0-8) @ 1 lb N	0.245	0.234
50% SRN (19-0-0) @ 1 lb N	0.247	0.165
PCU (41-0-0) @ 1 lb N	0.115	0.239
PCU (41-0-0) @ 2 lbs N	0.240	0.269
BSD (6-2-0) @ 1 lb N	0.241	0.137
<i>Pr>F</i>	<i>0.0906</i>	<i>0.1394</i>

Treatments applied every 60 days (15 Apr, 12 June, 13 Aug, and 09 Oct) except PCU (41-0-0) @ 2 lbs N which was applied every 120 days (15 Apr and 13 Aug).

Data corrected for MDL if data ≤0.148 then = 0.148. Means for main effects of species and treatment are presented. Means followed by the same letter(s) in a column and group are not significantly different according to Fisher's Protected LSD (*P*=0.05).

Table 246. Nitrogen Source Study in 2010.

	Pre*	Total N (kg ha ⁻²)						Post	Total
		Application 15 Apr 10			Application 9 Aug 10				
		60 day T1	60 day T2	120 day Total	60 day T3	60 day T4	120 day Total		
Species									
St. Augustinegrass	0.269	6.641	3.767 a	10.408	4.213 a	4.848 a	9.060 a	3.692	23.161
Centipedegrass	0.012	0.276	0.219 b	0.495	0.165 b	0.205 b	0.370 b	0.407	1.271
<i>Pr>F</i>	0.0199	0.027	0.0285	0.0265	0.0103	0.0006	0.0025	0.005	0.0096
		5						7	
Treatment (lbs N 1,000 ft ⁻²)									
Untreated	0.028	0.360	0.189	0.548	0.162	0.193	0.355	0.354	1.258
Am. Nitrate (34-0-0) @ 1 lb	0.311	5.947	4.361	10.308	3.883	3.478	7.361	2.958	20.627
N									
Urea (46-0-0) @ 1 lb N	0.234	7.300	4.452	11.752	4.085	5.089	9.175	2.946	23.873
30% SRN (16-0-8) @ 1 lb N	0.253	5.219	2.459	7.678	2.489	3.306	5.795	2.240	15.713
50% SRN (19-0-0) @ 1 lb N	0.127	2.269	1.309	3.578	1.507	1.166	2.673	0.920	7.171
PCU (41-0-0) @ 1 lb N	0.034	0.671	0.301	0.972	0.868	1.253	2.121	1.338	4.431
PCU (41-0-0) @ 2 lbs N	0.024	4.961	2.388	7.349	3.507	4.204	7.711	3.739	18.798
BSD (6-2-0) @ 1 lb N	0.051	0.944	0.483	1.428	1.012	1.521	2.532	1.899	5.859
<i>.Pr>F</i>	0.0206	0.030	0.1190	0.0302	0.5352	0.3498	0.3440	0.029	0.0383
		3						1	
<i>Species x Treatment Pr>F</i>	0.0217	0.035	0.1408	0.0365	0.5444	0.3610	0.3541	0.030	0.0439
		3						1	

Treatments applied every 60 days (15 Apr, 11 June, 09 Aug, and 08 Oct) except PCU (41-0-0) @ 2 lbs N which was applied every 120 days (15 Apr and 09 Aug).

* Pre = 6 Apr – 13 Apr, T1 = 20 Apr-8 Jun, T2= 14 Jun- 3 Aug, T3=10 Aug-5 Oct, T4 =12 Oct – 7 Dec, Post =14 Dec-29 Mar, and Total= 20 Apr-29 Mar.

Data corrected for MDL if data ≤ 0.148 then = 0.148. Means for main effects of species and treatment are presented. Means followed by the same letter(s) in a column and group are not significantly different according to Fisher's Protected LSD ($P=0.05$).

Table 247. Nitrogen Source Study in 2010 by species when there was a significant interaction.

Treatment (lbs N 1,000 ft ⁻²)	Total N (kg ha ⁻²)									
	Application 15 Apr 10									
	Pre		60 day T1		120 day Total		Post		Total	
	<u>St.</u> <u>Aug</u>	<u>Cent</u>	<u>St.</u> <u>Aug</u>	<u>Cent</u>	<u>St.</u> <u>Aug</u>	<u>Cent</u>	<u>St.</u> <u>Aug</u>	<u>Cent</u>	<u>St.</u> <u>Aug</u>	<u>Cent</u>
Untreated	0.044 b	0.012	0.517	0.202	0.755	0.342	0.420 c	0.28 8	1.584	0.931
Am. Nitrate (34-0-0) @ 1 lb N	0.609 a	0.015	11.60 0	0.294	20.04 9	0.566	5.505 ab	0.41 1	39.87 7	1.376
Urea (46-0-0) @ 1 lb N	0.455 ab	0.012	14.25 9	0.341	22.88 1	0.623	5.432 ab	0.46 1	46.23 8	1.507
30% SRN (16-0-8) @ 1 lb N	0.495 ab	0.010	10.10 8	0.330	14.76 8	0.588	4.096 a-c	0.38 5	30.09 6	1.330
50% SRN (19-0-0) @ 1 lb N	0.244 ab	0.010	4.256	0.282	6.657	0.498	1.284 bc	0.55 6	12.92 2	1.420
PCU (41-0-0) @ 1 lb N	0.058 b	0.011	1.087	0.255	1.491	0.453	2.282 bc	0.39 5	7.638	1.223
PCU (41-0-0) @ 2 lbs N	0.047 b	0.012	9.633	0.289	14.19 3	0.505	7.094 a	0.38 4	36.34 7	1.250
BSD (6-2-0) @ 1 lb N	0.090 b	0.012	1.673	0.216	2.472	0.383	3.422 a-c	0.37 5	10.58 3	1.134
<i>Pr>F</i>	0.0483	0.486	0.051 7	0.355 8	0.052 4	0.240 3	0.0474	0.68 70	0.061 9	0.516 7

Treatments applied every 60 days (15 Apr, 11 June, 09 Aug, and 08 Oct) except PCU (41-0-0) @ 2 lbs N which was applied every 120 days (15 Apr and 09 Aug).

* Pre = 6 Apr – 13 Apr, T1 = 20 Apr-8 Jun, T2= 14 Jun- 3 Aug, T3=10 Aug-5 Oct, T4 =12 Oct – 7 Dec, Post =14 Dec-29 Mar, and Total= 20 Apr-29 Mar.

Data corrected for MDL if data ≤ 0.148 then = 0.148. Means for main effects of species and treatment are presented. Means followed by the same letter(s) in a column and group are not significantly different according to Fisher's Protected LSD ($P=0.05$), except where data was unbalanced (Pre St. Augustinegrass) where means separated using Duncan's Multiple Range Test ($P=0.05$).

Table 248. Nitrogen Source Study in 2011.

	Total N (kg ha ⁻²)					
	Pre*	Application 12 Apr 11			Post	Total
		60 day T1	60 day T2	120 day Total		
Species						
St. Augustinegrass	0.372	0.546 a	1.585	2.132	0.014	2.145
Centipedegrass	0.010	0.008 b	0.405	0.413	0.014	0.428
<i>Pr>F</i>	0.0019	0.0371	0.0855	0.0656	0.8589	0.661
Treatment (lbs N 1,000 ft ⁻²)						
Untreated	0.061	0.065	0.613	0.679	0.021	0.700
Am. Nitrate (34-0-0) @ 1 lb	0.103	0.175	0.588	0.764	0.015	0.779
N						
Urea (46-0-0) @ 1 lb N	0.286	0.478	1.129	1.608	0.018	1.625
30% SRN (16-0-8) @ 1 lb N	0.181	0.224	1.099	1.323	0.015	1.338
50% SRN (19-0-0) @ 1 lb N	0.062	0.024	0.573	0.597	0.012	0.609
PCU (41-0-0) @ 1 lb N	0.170	0.331	1.122	1.453	0.012	1.465
PCU (41-0-0) @ 2 lbs N	0.517	0.707	2.262	2.969	0.009	2.979
BSD (6-2-0) @ 1 lb N	0.167	0.213	0.574	0.787	0.012	0.799
<i>Pr>F</i>	0.0564	0.0609	0.0179	0.0210	0.1606	0.0218
<i>Species x Treatment Pr>F</i>	0.0497	0.0558	0.0052	0.0083	0.0096	0.0084

Treatments applied every 60 days (12 Apr and 11 June) except PCU (41-0-0) @ 2 lbs N which was applied once on 15 Apr).

* Pre = 5 Apr – 11 Apr, T1 = 19 Apr-7 Jun, Post = 16 Aug-30 Aug, and Total = 19 Apr-30 Aug. Data corrected for MDL if data ≤ 0.148 then = 0.148. Means for main effects of species and treatment are presented. Means followed by the same letter(s) in a column and group are not significantly different according to Fisher's Protected LSD ($P=0.05$).

Table 249. Nitrogen Source Study in 2011 by species when there was a significant interaction.

Treatment (lbs N 1,000 ft ⁻²)	Total N (kg ha ⁻²)											
	Application 12 Apr 11											
	Pre*		60 day T1		60 day T2		120 day Total		Post		Total	
	St. Aug	Cent	St. Aug	Cent	St. Aug	Cent	St. Aug	Cent	St. Aug	Cent	St. Aug	Cent
Untreated	0.103	0.018	0.117	0.014	0.890	0.336	1.008	0.350	0.029 a	0.01	1.037 t	0.362
Am. Nitrate (34-0-0) @ 1 lb N	0.200	0.007	0.342	0.009	0.810	0.366	1.153	0.375	0.011 c	0.01	1.163 t	0.394
Urea (46-0-0) @ 1 lb N	0.560	0.011	0.951	0.006	1.900	0.359	2.851	0.365	0.074	0.01	2.875	0.376
30% SRN (16-0-8) @ 1 lb N	0.356	0.006	0.441	0.007	1.862	0.336	2.302	0.343	0.012	0.01	2.314 t	0.361
50% SRN (19-0-0) @ 1 lb N	0.109	0.015	0.040	0.008	0.397	0.749	0.436	0.757	0.008 c	0.01	0.444 t	0.774
PCU (41-0-0) @ 1 lb N	0.334	0.006	0.656	0.006	1.866	0.378	2.521	0.384	0.010 c	0.01	2.531 t	0.399
PCU (41-0-0) @ 2 lbs N	1.201	0.004	1.410	0.003	4.197	0.328	5.607	0.331	0.009 c	0.01	5.616 ε	0.341
BSD (6-2-0) @ 1 lb N	0.321	0.013	0.415	0.011	0.760	0.389	1.174	0.399	0.010 c	0.01	1.184 t	0.413
<i>Pr>F</i>	0.116	0.005	0.082	0.005	0.017	0.437	0.024	0.441	0.0148	0.55	0.024	0.4530
	4	1	0	6	9	4	2	6		27	6	

Treatments applied every 60 days (12 Apr and 11 June) except PCU (41-0-0) @ 2 lbs N which was applied once on 15 Apr). * Pre = 5 Apr – 11 Apr, T1 = 19 Apr-7 Jun, Post = 16 Aug-30 Aug, and Total = 19 Apr-30 Aug.

Data corrected for MDL if data ≤ 0.148 then = 0.148. Means for main effects of species and treatment are presented.

Means followed by the same letter(s) in a column and group are not significantly different according to Fisher's Protected LSD ($P=0.05$).

Table 250. Effect of year, species and N-application rate on total nitrogen leached.

	Total N (kg ha ⁻¹)							Post	Total
	1 st N application				2 nd N application				
	60 day T1	60 day T2	120 day total	60 day T3	60 day T4	120 day total			
Year									
2008	8.697 t	10.863	5.037	15.900	-	-	-	0.810	16.710
2009	0.187 t	0.255	0.216	0.467	0.338	0.922	1.260	2.025	3.752
2010	0.136 t	3.459	1.993	5.452	2.189	2.526	4.715	2.049	12.216
2011	0.188 t	0.277	0.995	1.272	-	-	-	0.014	1.287
<i>P(F)</i>	***	***	***	****	*	*	**	**	***
Species									
St. Augustinegrass	2.498	5.421	3.298	8.677	2.283	3.156	5.436	2.054	13.449
Centipedegrass	2.179	2.046	0.822	2.868	0.244	0.295	0.539	0.395	3.533
<i>P(F)</i>	NS	****	**	***	*	***	**	***	***
Treatment (lbs N 1,000 ft ⁻²)									
Untreated	1.842	2.179	1.343	3.522	0.215	0.254	0.469	0.482	4.239
Am. Nitrate (34-0-0)									
@ 1 lb N	2.622	5.202	3.115	8.316	2.116	2.349	4.465	1.868	12.417
Urea (46-0-0) @ 1 lb N	1.962	3.680	1.974	5.654	2.240	3.454	5.694	1.552	10.053
30% SRN (16-0-8) @ 1 lb N	2.783	6.058	4.548	10.606	1.463	2.284	3.747	1.325	13.805
50% SRN (19-0-0) @ 1 lb N	2.351	3.409	2.058	5.468	0.930	1.178	2.108	1.029	7.551
PCU (41-0-0) @ 1 lb N	2.359	2.801	0.594	3.394	0.558	0.770	1.328	0.571	4.629
PCU (41-0-0) @ 2 lbs N	2.795	4.619	2.069	6.689	1.913	2.587	4.500	1.954	10.892
BSD (6-2-0) @ 1 lb N	2.007	1.808	0.781	2.532	0.673	0.917	1.591	1.015	4.343
<i>P(F)</i>	NS	***	***	****	NS	NS	NS	***	****
<i>Year x Species</i>	NS	**	NS	**	*	**	**	**	**
<i>Year x Treatment</i>	NS	**	****	****	NS	NS	NS	NS	***
<i>Species x Treatment</i>	NS	*	NS	*	NS	NS	NS	**	**
<i>Year x Species x Treatment</i>	NS	NS	NS	NS	NS	NS	NS	NS	NS

Data corrected for MDL if data ≤ 0.148 then =0.148. No significant interactions between application date and rate, therefore only means for main effects of application date and rate are presented. Means followed by the same letter(s) in a column are not significantly different according to Duncan's Multiple Range Test ($P=0.05$). NS = $P>0.05$. ****, ***, **, * = $P>0.0001$, $P>0.001$, $P>0.01$, and $P>0.05$, respectively. NS = $P>0.05$. Means followed by the same letter(s) in a column are not significantly different according to Duncan's Multiple Range Test ($P=0.05$).

Table 251. Effect of year, species and N-application rate on % of applied nitrogen.

	% of applied N						Post	Total
	1 st N application			2 nd N application				
	60 day T1	60 day T2	120 day total	60 day T3	60 day T4	120 day total		
Year								
2008	17.32	4.55	14.21	-	-	-	0.69	14.90
2009	0.42	0.17	0.39	0.06	0.16	0.20	0.34	0.62
2010	7.11	2.24	6.16	0.51	0.44	0.85	0.35	2.22
2011	0.52	0.96	1.29	-	-	-	0.01	1.30
<i>P(F)</i>	****	***	****	*	**	**	*	****
Species								
St. Augustinegrass	10.43	3.53	9.37	0.53	0.56	0.97	0.59	7.82
Centipedegrass	2.25	0.43	1.66	0.05	0.04	0.08	0.11	1.70
<i>P(F)</i>	****	**	****	*	***	**	**	****
Treatment (lbs N 1,000 ft ⁻²)								
Untreated	-	-	-	-	-	-	-	-
Am. Nitrate (34-0-0) @								
1 lb N	9.54	2.66	7.64	0.72	0.60	1.14	0.70	6.89
Urea (46-0-0) @ 1 lb N	7.11	1.94	5.50	0.51	0.59	0.97	0.38	3.84
30% SRN (16-0-8) @ 1								
lb N	10.08	3.94	8.98	0.25	0.29	0.48	0.25	7.71
50% SRN (19-0-0) @ 1								
lb N	5.62	1.96	4.77	0.13	0.12	0.22	0.29	4.29
PCU (41-0-0) @ 1 lb N	4.22	0.53	2.64	0.06	0.07	0.11	0.09	2.53
PCU (41-0-0) @ 2 lbs								
N	4.71	2.11	6.83	0.28	0.38	0.66	0.50	5.94
BSD (6-2-0) @ 1 lb N	3.10	0.70	2.22	0.06	0.06	0.10	0.22	2.11
<i>P(F)</i>	***	**	****	NS	NS	NS	*	****
<i>Year x Species</i>	***	*	**	*	**	**	NS	****
<i>Year x Treatment</i>	***	***	****	NS	NS	NS	NS	****
<i>Species x Treatment</i>	**	NS	**	NS	NS	NS	*	**
<i>Year x Species x Treatment</i>	NS	NS	NS	NS	NS	NS	NS	NS

Data corrected for MDL if data ≤ 0.148 then =0.148. Where there was a significant interaction between year, species and/or treatment mean separation not shown. Means followed by the same letter(s) in a column are not significantly different according to Duncan's Multiple Range Test ($P=0.05$). NS = $P>0.05$. ****, ***, **, * = $P>0.0001$, $P>0.001$, $P>0.01$, and $P>0.05$, respectively. NS = $P>0.05$.

INFLUENCE OF SLOW RELEASE NITROGEN SOURCE ON NO₃⁻-N LEACHING WHEN APPLIED TO CENTIPEDEGRASS

The Slow Release N Source study was initiated during the summer of 2008 following the second run of the centipedegrass sod establishment study. The centipedegrass sod in this study was originally installed on 21 August 2007. Leachate sample collection began 5 Aug 2008. A single application (98.0 kg ha⁻¹) of each N source was distributed on 19 Aug 2008 and 12 Apr 2011. In 2009 and 2010, each nitrogen source was applied at 98.0 kg ha⁻¹ twice with 120d between subsequent applications. Nitrogen sources included in this study were:

1. PCU + SCU (39-0-0)
2. XCU (43-0-0)
3. Methylene Urea (40-0-0)
4. PCU – 120 day (43-0-0)
5. Florikan (15-2-15)
6. Corn Gluten Meal (9-0-0)

	2008	2009	2010	2011
Pre-Treatment Period	05 Aug – 12 Aug	06 Apr – 14 Apr	06 Apr – 14 Apr	05 Apr – 11 Apr
Application #1	19 Aug	15 Apr	15 Apr	12 Apr
Treatment Cycle #1	19 Aug – 14 Oct	15 Apr – 11 Aug	15 Apr – 08 Aug	12 Apr – 07 Jun
Application #2		12 Aug	09 Aug	
Treatment Cycle #2		12 Aug – 07 Dec	09 Aug – 07 Dec	08 Jun – 09 Aug
Post Treatment Period	07 Feb – 30 Mar	08 Dec – Mar 30	08 Dec – 29 Mar	10 Aug – 30 Aug

Color, Quality, Density

2008 – The initial rating 9 days after application (DAA) revealed no differences in turf quality (Table 252) or turf density (Table 254) but surges in color were observed (Table 253). The PCU + SCU, Florikan, and methylene urea products quickly improved turf color indicating they had released some nitrogen. The PCU – 120 Day and Corn Gluten Meal treatments did not quickly improve turf color. By 29 and 52 DAA, the PCU – 120 Day material produced acceptable color but lagged behind all other SRN sources.

At 52 DAA, all SRN sources provided acceptable turf quality while Florikan produced the highest level followed by PCU + SCU, XCU, and Corn Gluten Meal (Table 1). The methylene urea treatment provided a moderated level of turf quality compared to other sources. No differences in turf density were observed in 2008 (Table 254).

2009 – In 2009, the only difference in turf quality was observed 29 DAA where PCU – 120 Day yielded quality slightly below the other SRN sources except Corn Gluten Meal (Table 255). The best treatments were XCU, PCU + SCU, and methylene urea. Turf color differences between SRN sources were significant only on two rating dates – 14 May (29 DAA) and 4 September (21 days after second application) (Table 5). As with turf quality, PCU – 120 Day and Corn Gluten Meal each yielded lower turf color compared to the other SRN sources when assessed in the spring. In September, PCU + SCU and methylene urea provided the best turf color. No differences in turf density were observed in 2009 (Table 257).

2010 – Differences in turf quality were observed on 4 or 14 rating dates; three of which were early in the growing season (Table 258). Consistent with previous years, the PCU – 120 Day product was slow to promote improved turf quality (Table 258), turf color (Table 259), and turf density (Table 260). The reduction in turf quality on the 3 September rating date is very interesting and was observed in late August by the field staff. Turf quality in plots treated with Corn Gluten Meal was substantially reduced by an infestation of sod webworms attracted to only



Figure 48. Centipedegrass infested with sod webworms. The damage was only present in plots treated with corn gluten meal. Note three affected areas adjacent to the wood post on the right of the image.

those plots treated with this SRN source (Figure 48). There is no indication in the literature as to why these insects would be attracted to this organic fertilizer source.

Differences in turf color also followed similar trends to previous years where the PCU – 120 Day SRN source did not provide the early spring color (Table 8) and turf density (Table 9).

2011 – The consequence of providing a cumulative rate of 196 kg N 1,000⁻² per year on centipedegrass was fully realized in 2011. The rate of

nitrogen exceeds the annual N rate by 200 to 400% depending on the level of maintenance given. No differences in turf quality (Table 261) and turf density (Table 263) were observed in 2011; however, all ratings were significantly below an acceptable level. Centipedegrass quality deteriorated over the winter 2010/2011 and never fully recovered. A slight increase in turf color was observed following the spring application of SRN sources with Florikan providing a slight increase in color (Table 262).

Shoot Mass

2008 – Initial shoot mass collections in 2008 showed no statistical differences among treatments (Table 264). Numerically, PCU – 120 Day and Corn Gluten Meal yielded fewer clippings – consisted with the delayed response observed with the turf visual ratings.

2009 – In 2009, differences were observed on 5 of the 14 shoot collection dates. Following the spring application, Florikan, XCU, and PCU + SCU produce a flush of growth which is reflected in the increased quantity of clippings (Table 265). PCU – 120 Day produced the least quantity of clippings for the first 61 days following application following by an increase in clipping production (Table 265).

2010 – Similar to 2009, differences were observed on 5 of the 12 shoot collection dates. Florikan produced to greatest amount of clippings and PCU – 120 Day produced the least amount (Tables 267 and 268).

2011 – Clipping yields in 2011 were less than in similar collection periods in previous years. This is due to the deterioration of the turf following repeat applications of high levels of nitrogen. On all ratings 5 of the 6 collection dates, Corn Gluten Meal produced to greatest quantity of clippings (Table 269).

Root Growth

No differences in rooting due to SRN fertilizer sources were observed at any time throughout the duration of the study (Tables 270-272).

Nitrate Leaching

2008 – No differences in NO₃-N leaching occurred between the six SRN sources (Table 22). Leaching as a percent of applied ranged from 0.33% (PCU + SCU) to 1.5% (Corn Gluten Meal).

More leaching occurred during days 61 – 120 than during days 1 – 60. This likely occurred due to significant rain events that occurred on 14 Oct, 28 Oct, and 1 Dec.

2009 – No differences in $\text{NO}_3\text{-N}$ leaching due to N source were observed in 2009 (Table 274).

During the first 120 leaching cycle, leaching as a percent of applied ranged from 0.6% (methylene urea and PCU – 120 Day) to 2.4% (PCU + SCU). In the second 120 leaching cycle, leaching as a percent of applied ranged from 1.6% (methylene urea and PCU + SCU) to 8.6% (Florikan). Rainfall was abundant in 2009 contributing 601mm during the first 120 cycle and 854mm during the second 120 day cycle. Most of the leaching occurred during the latter half of the second 120 day cycle where 485mm of rain fell. Over the 50 week study duration, a cumulative 2,056mm of rain fell. Leaching as a percent of applied for this entire period ranged from 3.1% (PCU + SCU) to 9.9% (PCU – 120 day).

2010 – Compared to 2009, 2010 received 37% less rain. However, increased leaching occurred in 2010. No differences between SRN sources were noted for the first three leaching cycles (T1, T2, and T3) (Table 275). Treatment cycle 4 (T4), and the 120 day total following the fertilizer application made on 09 August 2010, and the seasonal totals were significantly different. The PCU – 120 Day and Florikan fertilizers sources leached the greatest quantity (5.5 and 4.5 kg N $1,000^{-2}$, respectively), during treatment cycle 4. XCU, methylene urea, and PCU + SCU leached the least (0.17, 0.56, and 0.70 kg N $1,000^{-2}$ respectively). The majority of the leached $\text{NO}_3\text{-N}$ occurred during the “Post” treatment period – the period following the summer growing season and preceding the following season’s treatment cycles. In 2010-2011, this period received 297mm of rain. Leaching ranged from 4.67 kg N $1,000^{-2}$ (PCU + SCU) to 32.9 kg N $1,000^{-2}$ (PCU – 120 Day). Over the 50 week study duration, a cumulative 1,291mm of rain fell. Leaching as a percent of applied for this entire period ranged from 2.6% (PCU + SCU) to 19.7% (PCU – 120 day).

2011 – The effects of the deterioration of the turf on $\text{NO}_3\text{-N}$ leaching were evident in 2011. During the first 60 day cycle, PCU – 120 Day leaching the greatest amount (9.5 kg N $1,000^{-2}$) and Corn Gluten Meal leached the least (0.5 kg N $1,000^{-2}$) (Table 276). During the second 60 day cycle of 2011, vast quantities of the applied nitrogen leaching from the treated turf. Leaching values ranged from 6.0 kg N $1,000^{-2}$ (Corn Gluten Meal) to 59.7 kg N $1,000^{-2}$ (PCU – 120 Day). Rainfall differences between these two 60-day periods were significant (T1 = 123mm vs. T2 = 382mm). Over the 120 day total, the leaching as a percent of applied nitrogen ranged from 7% (Corn Gluten Meal) to 70% (PCU – 120 Day).

Table 252. Effect of nitrogen source on turf quality in 2008.

Treatment @ 2.0 lbs N 1000 ft ⁻²	Rating Date		
	28 Aug 08	17 Sep 08	10 Oct 08
PCU + SCU (39-0-0)	7.0	7.9 a	7.9 ab
XCU (43-0-0)	7.0	8.0 a	7.9 ab
Methylene Urea (40-0-0)	7.0	7.6 ab	7.4 bc
PCU - 120 Day (43-0-0)	7.0	7.1 b	6.9 c
Florikan (15-2-15)	7.0	8.1 a	8.3 a
Corn Gluten Meal (9-0-0)	7.0	7.6 ab	7.6 ab
<i>Pr>F</i>	<i>ns</i>	0.5	0.7

Treatments applied 19 August 2008.

Quality visually rated on scale of 1 to 9 where 9= best.

Means followed by the same letter(s) in a column are not significantly different according to Fisher’s Protected LSD ($P=0.05$).

Table 253. Effect of nitrogen source on turf color in 2008.

Treatment @ 2.0 lbs N 1000 ft ⁻²	Rating Date		
	28 Aug 08	17 Sep 08	10 Oct 08
PCU + SCU (39-0-0)	8.9 a	7.9 a	7.9 ab
XCU (43-0-0)	7.8 bc	7.9 a	8.0 ab
Methylene Urea (40-0-0)	8.3 ab	7.8 a	7.3 bc
PCU - 120 Day (43-0-0)	7.3 c	7.0 b	6.8 c
Florikan (15-2-15)	8.8 a	8.0 a	8.3 a
Corn Gluten Meal (9-0-0)	7.3 c	7.6 a	8.0 ab
<i>Pr>F</i>	0.6	0.6	0.8

Treatments applied 19 August 2008.

Color visually rated on a scale of 1 to 9 where 9=best.

Means followed by the same letter(s) in a column are not significantly different according to Fisher's Protected LSD ($P=0.05$).

Table 254. Effect of nitrogen source on turf density in 2008.

Treatment @ 2.0 lbs N 1000 ft ⁻²	Rating Date		
	28 Aug 08	17 Sep 08	10 Oct 08
PCU + SCU (39-0-0)	7.0	8.1	8.1
XCU (43-0-0)	7.0	8.0	8.0
Methylene Urea (40-0-0)	7.0	7.8	7.6
PCU - 120 Day (43-0-0)	7.0	7.6	7.3
Florikan (15-2-15)	7.0	8.4	8.4
Corn Gluten Meal (9-0-0)	7.0	7.8	7.6
<i>Pr>F</i>	<i>ns</i>	<i>ns</i>	<i>ns</i>

Treatments applied 19 August 2008.

Density visually rated on a scale of 1 to 9 where 9=best.

Means followed by the same letter(s) in a column are not significantly different according to Fisher's Protected LSD ($P=0.05$).

Table 255. Effect of nitrogen source applications on turf quality in 2009.

Treatment @ 2.0 lbs N 1000 ft ²	Rating Date													
	17 Apr	14 May	19 Jun	25 Jun	10 Jul	24 Jul	7 Aug	24 Aug	4 Sep	23 Sep	8 Oct	21 Oct	29 Oct	13 Nov
PCU + SCU (39-0-0)	6.0	7.9 ab	8.0	6.8	7.8	8.0	7.8	8.3	8.5	8.5	9.0	8.5	8.0	7.8
XCU (43-0-0)	5.5	8.1 a	7.9	6.5	7.8	8.0	8.0	8.0	8.3	8.0	9.0	8.5	8.0	7.8
Methylene Urea (40-0-0)	5.5	7.8 ab	7.3	6.5	7.0	7.8	7.8	8.3	8.5	8.5	9.0	8.5	7.8	8.0
PCU - 120 Day (43-0-0)	5.3	6.9 c	7.4	6.5	7.3	8.3	8.0	8.3	8.3	8.0	9.0	9.0	8.0	7.8
Florikan (15-2-15)	4.8	7.6 ab	7.8	7.0	7.0	8.0	7.5	8.0	8.5	8.0	9.0	8.8	7.8	7.8
Corn Gluten Meal (9-0-0)	5.3	7.3 bc	8.1	6.5	7.5	8.0	7.8	8.3	8.3	8.3	9.0	8.3	7.8	7.8
<i>Pr>F</i>	<i>ns</i>	0.7	<i>ns</i>	<i>ns</i>	<i>ns</i>	<i>ns</i>	<i>ns</i>	<i>ns</i>	<i>ns</i>	<i>ns</i>	<i>ns</i>	<i>ns</i>	<i>ns</i>	<i>ns</i>

Treatments applied every 120 days (15 Apr and 14 Aug).

Quality visually rated on scale of 1 to 9 where 9= best.

Means followed by the same letter(s) in a column are not significantly different according to Fisher's Protected LSD ($P=0.05$).

Table 256. Effect of nitrogen source applications on turf color in 2009.

Treatment @ 2.0 lbs N 1000 ft ²	Rating Date													
	17 Apr	14 May	19 Jun	25 Jun	10 Jul	24 Jul	7 Aug	24 Aug	4 Sep	23 Sep	8 Oct	21 Oct	29 Oct	13 Nov
PCU + SCU (39-0-0)	6.3	8.3 a	8.3	7.3	7.8	7.3	7.3	7.8	9.0 a	8.0	9.0	8.5	8.0	7.0
XCU (43-0-0)	6.3	8.4 a	8.1	7.3	7.8	7.5	7.3	7.3	8.8 a	8.0	9.0	8.3	8.0	7.0
Methylene Urea (40-0-0)	6.3	8.1 a	7.6	6.5	7.3	7.3	7.3	7.8	9.0 a	8.5	9.0	8.3	7.8	7.8
PCU - 120 Day (43-0-0)	6.3	7.1 b	7.9	7.3	8.3	7.8	8.0	8.0	8.0 b	8.0	9.0	9.0	8.0	7.3
Florikan (15-2-15)	5.5	8.1 a	8.0	7.0	7.0	7.8	7.3	7.3	8.3 b	8.0	9.0	8.3	8.0	6.8
Corn Gluten Meal (9-0-0)	6.0	7.4 b	8.5	7.8	8.3	8.0	7.8	7.8	8.3 b	8.3	9.0	8.3	8.0	7.0
<i>Pr>F</i>	<i>ns</i>	0.6	<i>ns</i>	<i>ns</i>	<i>ns</i>	<i>ns</i>	<i>ns</i>	<i>ns</i>	0.5	<i>ns</i>	<i>ns</i>	<i>ns</i>	<i>ns</i>	<i>ns</i>

Treatments applied every 120 days (15 Apr and 14 Aug).

Color visually rated on a scale of 1 to 9 where 9=best.

Means followed by the same letter(s) in a column are not significantly different according to Fisher's Protected LSD ($P=0.05$).

Table 257. Effect of nitrogen source applications on turf density in 2009.

Treatment @ 2.0 lbs N 1000 ft ²	Rating Date													
	17 Apr	14 May	19 Jun	25 Jun	10 Jul	24 Jul	7 Aug	24 Aug	4 Sep	23 Sep	8 Oct	21 Oct	29 Oct	13 Nov
PCU + SCU (39-0-0)	6.3	7.5	8.1	7.0	7.8	8.0	7.8	8.3	9.0	8.8	8.8	8.5	8.5	8.5
XCU (43-0-0)	6.0	7.8	7.8	6.8	7.5	7.8	7.5	8.0	8.8	8.8	9.0	8.8	8.3	8.3
Methylene Urea (40-0-0)	6.0	7.3	7.0	6.5	7.3	7.8	7.5	8.3	8.5	8.8	9.0	8.5	8.3	8.8
PCU - 120 Day (43-0-0)	6.0	6.5	7.3	6.8	7.3	8.3	7.8	8.5	8.8	8.8	9.0	8.8	8.5	8.5
Florikan (15-2-15)	5.0	6.6	7.8	6.5	7.5	8.0	7.8	8.5	8.5	8.8	8.8	9.0	8.5	8.8
Corn Gluten Meal (9-0-0)	5.5	6.8	8.3	7.0	7.8	8.3	8.0	8.3	8.3	8.3	8.8	8.5	8.0	8.3
<i>Pr>F</i>	<i>ns</i>	<i>ns</i>	<i>ns</i>	<i>ns</i>	<i>ns</i>	<i>ns</i>	<i>ns</i>	<i>ns</i>	<i>ns</i>	<i>ns</i>	<i>ns</i>	<i>ns</i>	<i>ns</i>	<i>ns</i>

Treatments applied every 120 days (15 Apr and 14 Aug).

Density visually rated on a scale of 1 to 9 where 9=best.

Means followed by the same letter(s) in a column are not significantly different according to Fisher's Protected LSD ($P=0.05$).

Table 258. Effect of nitrogen source applications on turf quality in 2010.

Treatment @ 2.0 lbs N 1000 ft ²	Rating Date													
	29 Apr	13 May	27 May	10 Jun	24 Jun	9 Jul	26 Jul	6 Aug	19 Aug	3 Sep	16 Sep	30 Sep	14 Oct	29 Oct
PCU + SCU (39-0-0)	6.5ab	7.3	8.0a	8.8 a	9.0	8.0	9.0	9.0	9.0	7.5 ab	7.5	7.8	7.0	8.3
XCU (43-0-0)	6.3ab	7.0	8.0a	8.8 a	9.0	8.0	9.0	8.3	8.8	6.3 c	7.8	7.8	7.0	8.3
Methylene Urea (40-0-0)	6.8a	7.5	7.3b	8.5 a	9.0	8.0	8.5	8.8	9.0	8.0 a	8.0	7.3	7.0	8.0
PCU - 120 Day (43-0-0)	6.3ab	8.3	6.5c	7.8 b	9.0	8.3	8.5	8.5	8.8	8.0 a	8.0	7.3	7.3	7.8
Florikan (15-2-15)	6.0b	7.0	8.0a	8.8 a	9.0	8.0	8.8	9.0	8.8	6.8 bc	7.3	7.8	7.3	8.8
Corn Gluten Meal (9-0-0)	6.0b	7.0	8.0a	9.0 a	9.0	8.0	8.8	8.8	9.0	5.0 d	7.5	7.3	7.5	8.3
<i>Pr>F</i>	0.6	ns	0.4	0.6	ns	ns	ns	ns	ns	1.0	ns	ns	ns	ns

Treatments applied every 120 days (15 Apr and 8 Aug).

Quality visually rated on a scale of 1 to 9 where 9=best.

Means followed by the same letter(s) in a column are not significantly different according to Fisher's Protected LSD ($P=0.05$).

Table 259. Effect of nitrogen source applications on turf color in 2010.

Treatment @ 2.0 lbs N 1000 ft ²	Rating Date													
	29 Apr	13 May	27 May	10 Jun	24 Jun	9 Jul	26 Jul	6 Aug	19 Aug	3 Sep	16 Sep	30 Sep	14 Oct	29 Oct
PCU + SCU (39-0-0)	7.3	8.0	7.8	9.0	9.0	8.0	8.5	8.5	9.0	7.8	7.5	7.0	7.0	7.8
	a	a	ab	a					a	ab				ab
XCU (43-0-0)	7.0	7.5	8.3	9.0	9.0	8.0	9.0	8.0	8.8	7.0	7.8	7.0	7.0	7.8
	a	a	a	a					a	bc				ab
Methylene Urea (40-0-0)	6.8	7.5	7.3	8.3	9.0	7.8	8.5	8.8	9.0	7.8	7.8	7.0	6.8	7.3
	a	a	bc	b					a	ab				bc
PCU - 120 Day (43-0-0)	6.0	6.3	6.8	8.3	9.0	8.0	9.0	8.5	8.0	8.0	8.0	6.8	6.8	7.0
	b	b	c	b					b	a				c
Florikan (15-2-15)	7.3	8.0	8.0	8.8	9.0	8.0	8.5	8.0	8.8	6.5	7.0	7.0	7.0	8.3
	a	a	ab	a					a	c				a
Corn Gluten Meal (9-0-0)	6.0	7.3	8.5	9.0	9.0	8.0	9.0	8.8	9.0	8.0	8.0	7.3	7.5	8.0
	b	a	ab	a					a	a				a
<i>Pr>F</i>	0.5	0.9	0.8	0.5	ns	ns	ns	ns	0.4	0.9	ns	ns	ns	0.6

Treatments applied every 120 days (15 Apr and 8 Aug).

Color visually rated on a scale of 1 to 9 where 9=best.

Means followed by the same letter(s) in a column are not significantly different according to Fisher's Protected LSD ($P=0.05$).

Table 260. Effect of nitrogen source applications on turf density in 2010.

Treatment @ 2.0 lbs N 1000 ft ²	Rating Date													
	29 Apr	13 May	27 May	10 Jun	24 Jun	9 Jul	26 Jul	6 Aug	19 Aug	3 Sep	16 Sep	30 Sep	14 Oct	29 Oct
PCU + SCU (39-0-0)	6.3	7.0	8.5	7.5	9.0	8.5	8.3	9.0	9.0	9.0 a	8.8 ab	7.8	8.5	8.8
XCU (43-0-0)	6.5	7.3	8.0	7.8	9.0	8.3	8.3	8.5	9.0	8.5 ab	8.3 a-c	7.8	8.3	8.8
Methylene Urea (40-0-0)	6.8	7.3	7.5	6.8	9.0	8.0	8.0	8.3	8.8	9.0 a	8.8 ab	8.0	8.3	8.8
PCU - 120 Day (43-0-0)	6.3	6.3	6.5	5.8	9.0	8.3	8.3	8.8	8.8	9.0 a	9.0 a	7.5	8.3	8.8
Florikan (15-2-15)	5.8	7.0	8.5	6.0	9.0	8.3	8.8	8.8	9.0	8.0 b	7.8 c	7.8	8.8	9.0
Corn Gluten Meal (9-0-0)	5.8	6.8	8.5	6.8	9.0	8.3	8.5	8.5	8.8	8.5 ab	8.0 bc	7.8	8.3	8.8
<i>Pr>F</i>	<i>ns</i>	<i>ns</i>	<i>0.8</i>	<i>ns</i>	<i>ns</i>	<i>ns</i>	<i>ns</i>	<i>ns</i>	<i>ns</i>	<i>0.7</i>	<i>0.8</i>	<i>ns</i>	<i>ns</i>	<i>ns</i>

Treatments applied every 120 days (15 Apr and 8 Aug).

Density visually rated on a scale of 1 to 9 where 9=best.

Means followed by the same letter(s) in a column are not significantly different according to Fisher's Protected LSD ($P=0.05$).

Table 261. Effect of nitrogen source applications on turf quality in 2011.

Treatment @ 2.0 lbs N 1000 ft ²	Rating Date								
	2 May	19 May	3 Jun	16 Jun	30 Jun	14 Jul	29 Jul	12 Aug	25 Aug
PCU + SCU (39-0-0)	5.3	4.8	4.8	3.8	4.3	4.0	4.5	3.8	2.8
XCU (43-0-0)	5.0	4.8	5.0	4.3	4.5	4.3	4.5	4.0	3.8
Methylene Urea (40-0-0)	5.0	5.0	4.8	4.5	4.3	4.0	3.5	3.3	2.8
PCU - 120 Day (43-0-0)	4.3	4.3	3.8	3.0	3.3	3.5	3.5	2.8	2.8
Florikan (15-2-15)	5.5	5.0	4.8	4.3	4.3	4.3	4.3	3.8	2.5
Corn Gluten Meal (9-0-0)	5.5	5.5	5.0	4.3	4.3	4.5	4.5	3.3	3.3
<i>Pr>F</i>	<i>ns</i>	<i>ns</i>	<i>ns</i>	<i>ns</i>	<i>ns</i>	<i>ns</i>	<i>ns</i>	<i>ns</i>	<i>ns</i>

Treatments applied once on 12 April.

Quality visually rated on a scale of 1 to 9 where 9=best.

Means followed by the same letter(s) in a column are not significantly different according to Fisher's Protected LSD ($P=0.05$).

Table 262. Effect of nitrogen source applications on turf color in 2011.

Treatment @ 2.0 lbs N 1000 ft ²	Rating Date								
	2 May	19 May	3 Jun	16 Jun	30 Jun	14 Jul	29 Jul	12 Aug	25 Aug
PCU + SCU (39-0-0)	4.8 a	4.5	4.8 a	4.0	4.3	4.8	5.0	5.0	4.0
XCU (43-0-0)	4.5 ab	4.5	5.0 a	4.3	4.5	5.0	5.5	4.5	4.3
Methylene Urea (40-0-0)	4.8 a	5.0	5.3 a	5.0	4.8	4.3	5.0	4.5	3.8
PCU - 120 Day (43-0-0)	3.8 b	4.0	4.0 b	3.8	4.0	4.0	4.8	5.0	4.5
Florikan (15-2-15)	5.3 a	5.0	4.8 a	4.8	4.8	4.5	5.0	5.0	3.8
Corn Gluten Meal (9-0-0)	4.5 ab	4.8	4.8 a	4.0	4.5	4.5	5.5	5.3	4.0
<i>Pr>F</i>	0.9	<i>ns</i>	0.6	<i>ns</i>	<i>ns</i>	<i>ns</i>	<i>ns</i>	<i>ns</i>	<i>ns</i>

Treatments applied once on 12 April.

Color visually rated on a scale of 1 to 9 where 9=best.

Means followed by the same letter(s) in a column are not significantly different according to Fisher's Protected LSD ($P=0.05$).

Table 263. Effect of nitrogen source applications on turf density in 2011.

Treatment @ 2.0 lbs N 1000 ft ²	Rating Date								
	2 May	19 May	3 Jun	16 Jun	30 Jun	14 Jul	29 Jul	12 Aug	25 Aug
PCU + SCU (39-0-0)	5.8	5.8	5.3	4.5	4.3	4.0	4.3	3.5	3.0
XCU (43-0-0)	5.3	6.3	5.5	4.5	4.3	4.3	5.0	3.5	3.8
Methylene Urea (40-0-0)	5.8	6.3	5.5	4.8	4.3	3.8	4.3	3.8	3.3
PCU - 120 Day (43-0-0)	4.8	5.0	4.5	3.8	3.8	3.3	3.5	2.8	3.3
Florikan (15-2-15)	5.8	6.0	5.3	4.5	4.3	3.8	4.5	3.5	3.3
Corn Gluten Meal (9-0-0)	5.8	6.8	5.5	4.8	4.5	4.3	4.8	3.8	3.8
<i>Pr>F</i>	<i>ns</i>	<i>ns</i>	<i>ns</i>	<i>ns</i>	<i>ns</i>	<i>ns</i>	<i>ns</i>	<i>ns</i>	<i>ns</i>

Treatments applied once on 12 April.

Density visually rated on a scale of 1 to 9 where 9=best.

Means followed by the same letter(s) in a column are not significantly different according to Fisher's Protected LSD ($P=0.05$).

Table 264. Effect of nitrogen source applications on centipedegrass shoot mass in 2008.

Treatment @ 2.0 lbs N 1000 ft ⁻²	Shoot mass (g)	
	8 Sep	9 Oct
PCU + SCU (39-0-0)	18.51	6.53
XCU (43-0-0)	22.37	5.71
Methylene Urea (40-0-0)	22.48	6.84
PCU - 120 Day (43-0-0)	13.99	6.34
Florikan (15-2-15)	21.29	5.65
Corn Gluten Meal (9-0-0)	12.81	5.76
<i>LSD</i>	<i>ns</i>	<i>ns</i>

Treatments applied once on 19 August.

Means followed by the same letter(s) in a column are not significantly different according to Fisher's Protected LSD ($P=0.05$).

Table 265. Effect of nitrogen source applications on centipedegrass shoot mass in 2009.

Treatment @ 2.0 lbs N 1000 ft ⁻²	Shoot mass (g)							
	7 May	20 May	3 Jun	15 Jun	24 Jun	8 Jul	23 Jul	5 Aug
PCU + SCU (39-0-0)	4.42	3.26 ab	4.79 ab	12.09bc	16.14b	27.64	23.99	14.73
XCU (43-0-0)	4.59	3.76 ab	6.29 a	16.04ab	18.71ab	22.56	26.12	13.01
Methylene Urea (40-0-0)	4.79	3.03 bc	3.97 b	10.71bc	13.55b	20.87	24.91	12.18
PCU - 120 Day (43-0-0)	2.17	1.06 d	1.57 c	6.42c	16.95b	27.19	27.24	14.62
Florikan (15-2-15)	3.76	4.47 a	5.51 ab	15.21ab	16.84b	19.18	24.25	13.28
Corn Gluten Meal (9-0-0)	2.83	1.86 cd	4.99 ab	20.02a	24.34a	25.72	26.61	11.56
<i>LSD</i>	<i>ns</i>	1.29	1.93	7.56	6.37	<i>ns</i>	<i>ns</i>	<i>ns</i>

Treatments applied every 120 days in turf. First application made on 15 Apr 2009 and second application made on 12 Aug 2009.

Means followed by the same letter(s) in a column are not significantly different according to Fisher's Protected LSD ($P=0.05$).

Table 266. Effect of nitrogen source applications on centipedegrass shoot mass in 2009.

Treatment @ 2.0 lbs N 1000 ft ⁻²	Shoot mass (g)					
	19 Aug	2 Sep	16 Sep	30 Sep	13 Oct	28 Oct
PCU + SCU (39-0-0)	6.63 bc	13.24	9.56	21.71	8.75	2.49
XCU (43-0-0)	6.21 c	13.94	11.78	29.87	9.15	2.63
Methylene Urea (40-0-0)	6.47 c	12.39	10.23	25.75	9.05	2.23
PCU - 120 Day (43-0-0)	8.86 a	9.77	9.77	25.36	8.76	3.37
Florikan (15-2-15)	8.65 ab	16.00	13.83	26.86	7.84	3.23
Corn Gluten Meal (9-0-0)	7.99 a-c	13.88	11.78	24.94	9.73	3.42
<i>LSD</i>	2.07	<i>ns</i>	<i>ns</i>	<i>ns</i>	<i>ns</i>	<i>ns</i>

Treatments applied every 120 days in turf. First application made on 15 Apr 2009 and second application made on 12 Aug 2009.

Means followed by the same letter(s) in a column are not significantly different according to Fisher's Protected LSD ($P=0.05$).

Table 267. Effect of nitrogen source applications on centipedegrass shoot mass in 2010.

Treatment @ 2.0 lbs N 1000 ft ⁻²	Shoot mass (g)					
	20 May	3 Jun	17 Jun	1 Jul	15 Jul	29 Jul
PCU + SCU (39-0-0)	14.58 a	10.94 bc	7.97 b	7.53	10.58	17.95
XCU (43-0-0)	11.54 ab	9.42 cd	9.18 b	7.30	11.01	19.27
Methylene Urea (40-0-0)	7.29 bc	6.03 cd	6.76 b	6.63	12.45	16.95
PCU - 120 Day (43-0-0)	4.27 c	3.89 d	6.46 b	8.21	12.83	19.54
Florikan (15-2-15)	15.16 a	17.90 a	9.33 b	6.92	10.56	20.64
Corn Gluten Meal (9-0-0)	11.65 ab	16.81 ab	14.84 a	8.88	11.34	20.68
LSD.....	5.36	5.93	3.35	ns	ns	ns

Treatments applied every 120 days in turf. First application made on 15 Apr 2010 and second application made on 9 Aug 2010.

Means followed by the same letter(s) in a column are not significantly different according to Fisher's Protected LSD ($P=0.05$).

Table 268. Effect of nitrogen source applications on centipedegrass shoot mass in 2010.

Treatment @ 2.0 lbs N 1000 ft ⁻²	Shoot mass (g)					
	12 Aug	26 Aug	9 Sep	23 Sep	7 Oct	21 Oct
PCU + SCU (39-0-0)	5.60	34.47 b	12.93	1.34	2.31	3.45 ab
XCU (43-0-0)	5.18	36.14 ab	16.53	0.83	2.25	3.41 ab
Methylene Urea (40-0-0)	5.70	25.96 cd	13.22	0.89	2.28	2.56 b
PCU - 120 Day (43-0-0)	6.27	20.96 d	13.71	1.60	2.38	2.68 b
Florikan (15-2-15)	5.83	42.80 a	12.98	1.62	2.86	4.31 a
Corn Gluten Meal (9-0-0)	7.11	32.09 bc	14.22	1.94	3.02	3.48 ab
LSD.....	ns	7.94	ns	ns	ns	1.09

Treatments applied every 120 days in turf. First application made on 15 Apr 2010 and second application made on 9 Aug 2010.

Means followed by the same letter(s) in a column are not significantly different according to Fisher's Protected LSD ($P=0.05$).

Table 269. Effect of nitrogen source applications on centipedegrass shoot mass in 2011.

Treatment @ 2.0 lbs N 1000 ft ⁻²	Shoot mass (g)						
	26 May	9 Jun	23 Jun	7 Jul	21 Jul	4 Aug	18 Aug
PCU + SCU (39-0-0)	0.93	1.63 b	2.60	8.12	9.31	10.73 b	10.69
XCU (43-0-0)	0.82	1.37 b	3.27	10.06	10.49	16.91 b	10.19
Methylene Urea (40-0-0)	0.64	0.89 b	2.07	7.06	10.18	15.60 b	11.65
PCU - 120 Day (43-0-0)	0.66	1.00 b	2.33	9.26	12.69	17.34 b	12.29
Florikan (15-2-15)	0.88	1.21 b	2.77	10.65	12.49	16.34 b	15.23
Corn Gluten Meal (9-0-0)	1.51	4.32 a	6.34	15.51	13.75	25.41 a	14.07
LSD.....	ns	1.63	ns	ns	ns	7.45	ns

Treatments applied once on 12 April.

Means followed by the same letter(s) in a column are not significantly different according to Fisher's Protected LSD ($P=0.05$).

Table 270. Effect of nitrogen source applications on turfgrass rooting in 2009.

Treatment @ 2.0 lbs N 1000 ft	13 August 2009			9 October 2009		
	Root	Ash	% ash	Root	Ash	% ash
PCU + SCU (39-0-0)	0.249	0.027	9.32	0.082	0.012	10.33
XCU (43-0-0)	0.227	0.026	10.64	0.122	0.010	8.02
Methylene Urea (40-0-0)	0.207	0.021	9.74	0.081	0.017	19.78
PCU - 120 Day (43-0-0)	0.284	0.025	8.97	0.079	0.011	15.48
Florikan (15-2-15)	0.210	0.021	9.28	0.092	0.026	27.28
Corn Gluten Meal (9-0-0)	0.223	0.020	8.41	0.089	0.005	4.81
LSD	ns	ns	ns	ns	ns	ns

Treatments applied every 120 days in turf. First application made on 15 Apr 2009 and second application made on 12 Aug 2009.

Means followed by the same letter(s) in a column are not significantly different according to Fisher's Least Significant Test ($P=0.05$), except for second rating of Ash and % Ash in 2009 were separated by Duncan's Multiple Range Test due to unbalanced data. ns= not significant.

Table 271. Effect of nitrogen source applications on turfgrass rooting in 2010.

Treatment @ 2.0 lbs N 1000 ft	11 August 2010			8 October 2010		
	Root	Ash	% ash	Root	Ash	% ash
PCU + SCU (39-0-0)	0.324	0.048	11.98	0.121	0.016	9.16
XCU (43-0-0)	0.320	0.059	15.85	0.212	0.033	15.13
Methylene Urea (40-0-0)	0.340	0.076	20.26	0.218	0.021	8.30
PCU - 120 Day (43-0-0)	0.346	0.061	11.21	0.194	0.022	12.44
Florikan (15-2-15)	0.304	0.036	8.54	0.185	0.037	17.40
Corn Gluten Meal (9-0-0)	0.247	0.018	7.04	0.134	0.009	7.31
LSD	ns	ns	ns	ns	ns	ns

Treatments applied every 120 days in turf. First application made on 15 Apr 2010 and second application made on 9 Aug 2010.

Means followed by the same letter(s) in a column are not significantly different according to Fisher's Least Significant Test ($P=0.05$). ns= not significant.

Table 272. Effect of nitrogen source applications on turfgrass rooting in 2011.

Treatment @ 2.0 lbs N 1000 ft	9 June 2011		
	Root	Ash	% ash
PCU + SCU (39-0-0)	0.100	0.018	14.70 a
XCU (43-0-0)	0.130	0.005	4.04 b
Methylene Urea (40-0-0)	0.099	0.007	6.17 bc
PCU - 120 Day (43-0-0)	0.113	0.014	10.52 ab
Florikan (15-2-15)	0.105	0.008	7.12 bc
Corn Gluten Meal (9-0-0)	0.122	0.003	2.81 c
LSD	ns	ns	6.27

Treatments applied on 12 Apr 2011.

Means followed by the same letter(s) in a column are not significantly different according to Fisher's Least Significant Test ($P=0.05$). ns= not significant.

Table 273. Effect of various nitrogen sources on total NO₃-N leached in 2008.

Treatment @ 2.0 lbs N 1000 ft ⁻²	Total N (kg ha ⁻²)					
	Pre*	Application 19 Aug 08			Post	Total
		60 day T1	60 day T2	120 day Total		
PCU + SCU (39-0-0)	0.07	0.08	0.25	0.32	4.65	4.97
XCU (43-0-0)	0.07	0.08	0.64	0.72	5.09	5.81
Methylene Urea (40-0-0)	0.07	0.09	0.44	0.53	6.76	7.29
PCU - 120 Day (43-0-0)	0.06	0.08	0.30	0.37	6.16	6.53
Florikan (15-2-15)	0.16	0.07	0.89	0.95	9.30	10.25
Corn Gluten Meal (9-0-0)	0.07	0.11	1.33	1.43	11.27	12.70
LSD.....	ns	ns	ns	ns	ns	ns

*Pre=5 Aug-12 Aug, T1=19 Aug-14 Oct, T2=21 Oct – 15 Dec, 120 day total = 19 Aug-15 Dec, Post=17 Dec -30 Mar, Total=19 Aug-30 Mar.

Data corrected for MDL if data ≤0.148 then = 0.148. Means followed by the same letter(s) in a column are not significantly different according to Fisher's Protected LSD (P=0.05).

Table 274. Effect of various nitrogen sources on total NO₃-N leached in 2009.

Treatment @ 2.0 lbs N 1000 ft ⁻²	Total N (kg ha ⁻²)								
	Pre*	Application 15 Apr 09			Application 12 Aug 09			Post	Total
		60 day T1	60 day T2	120 day Total	60 day T3	60 day T4	120 day Total		
PCU + SCU (39-0-0)	1.69	1.81	0.57	2.39	0.21	1.49	1.70	4.45	6.15
XCU (43-0-0)	0.73	0.72	0.42	1.14	0.43	6.15	6.57	12.47	19.04
Methylene Urea (40-0-0)	2.09	0.30	0.27	0.57	0.34	1.19	1.53	4.73	6.26
PCU - 120 Day (43-0-0)	1.92	0.34	0.23	0.57	0.18	6.64	6.83	12.64	19.46
Florikan (15-2-15)	3.19	1.66	0.38	2.04	0.90	7.54	8.44	7.54	15.98
Corn Gluten Meal (9-0-0)	3.28	1.35	0.29	1.65	0.44	6.04	6.49	8.64	15.13
LSD.....	ns	ns	ns	ns	ns	ns	ns	ns	ns

*Pre=6 Apr-14 Apr, T1=21 Apr-9 Jun, T2= 15 Jun-11 Aug, T3 =18 Aug-6 Oct, T4=13 Oct-7 Dec, Post=15 Dec- 30 Mar, Total=21 Apr-30 Mar.

Data corrected for MDL if data ≤0.148 then = 0.148. Means followed by the same letter(s) in a column are not significantly different according to Fisher's Protected LSD (P=0.05).

Table 275. Effect of various nitrogen sources on total NO₃-N leached in 2010.

Treatment @ 2.0 lbs N 1000 ft ²	Total N (kg ha ⁻²)								
	Pre*	Application 15 Apr 10			Application 9 Aug 10			Post	Total
		60 day	60 day	120	60 day	60 day	120 day		
		T1	T2	day	T3	T4	Total		
PCU + SCU (39-0-0)	0.05	4.44	2.23	6.67	0.24	0.17 c	0.42 b	4.67 c	5.08 c
XCU (43-0-0)	0.19	11.92	5.16	17.08	0.16	0.70 c	0.86 b	18.14 b	19.01 bc
Methylene Urea (40-0-0)	0.06	3.01	0.40	3.41	0.27	0.56 c	0.83 b	15.05 bc	15.88 bc
PCU - 120 Day (43-0-0)	0.17	5.71	1.51	7.22	0.17	5.50 a	5.67 a	32.87 a	38.54 a
Florikan (15-2-15)	0.08	9.58	5.75	15.33	0.32	4.54 ab	4.87 a	15.66 bc	20.53 b
Corn Gluten Meal (9-0-0)	0.08	4.92	1.65	6.57	0.14	1.23 bc	1.37 b	11.83 bc	13.20 bc
LSD.....	ns	ns	ns	ns	ns	3.35	3.49	12.34	14.63

*Pre=6 Apr-13 Apr, T1=20 Apr-8 Jun, T2=14 Jun-3 Aug, T3 =10 Aug-5 Oct, T4=12 Oct-7 Dec, Post=14 Dec- 29 Mar, Total=20 Apr-29 Mar.

Data corrected for MDL if data ≤ 0.148 then = 0.148. Means followed by the same letter(s) in a column are not significantly different according to Fisher's Protected LSD ($P=0.05$).

Table 276. Effect of various nitrogen sources on total NO₃-N leached in 2011.

Treatment @ 2.0 lbs N 1000 ft ²	Total N (kg ha ⁻²)					
	Pre*	Application 12 Apr 11			Post	Total
		60 day	60 day	120 day		
		T1	T2	Total		
PCU + SCU (39-0-0)	0.59 c	1.60 bc	20.97 bc	22.57 bc	0.10	22.67 bc
XCU (43-0-0)	2.07 ab	3.36 bc	28.38 bc	31.75 bc	0.08	31.83 bc
Methylene Urea (40-0-0)	1.77 ab	3.59 bc	39.42 ab	43.02 ab	0.10	43.11 ab
PCU - 120 Day (43-0-0)	2.30 a	9.51 a	59.68 a	69.19 a	0.27	69.46 a
Florikan (15-2-15)	1.77 ab	5.36 b	32.55 a-c	37.91 ab	0.31	38.22 ab
Corn Gluten Meal (9-0-0)	0.94 bc	0.51 c	5.96 c	6.46 c	0.05	8.51 c
LSD.....	1.15	3.89	28.18	31.40	ns	31.59

*Pre=5 Apr-11 Apr, T1=19 Apr-7 Jun, T2=13 Jun-9 Aug, Post=16 Aug-30 Aug, Total=19 Apr-30 Aug.

Data corrected for MDL if data ≤ 0.148 then = 0.148. Means followed by the same letter(s) in a column are not significantly different according to Fisher's Protected LSD ($P=0.05$).