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 lawngrass 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 lawngrass 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: 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. The research consisted of multiple projects, some of which were common to all locations. The research ran from 2005 to 2011.

PROJECTS BY LOCATION

Location	Project Title	Project #	Grasses	Start Date	Completion Date
Ft. Lauderdale	Nitrate Leaching From Newly Sodded Grass	1	St. Augustinegrass	Spring 2005	2006
	Nitrate Leaching From Established Grass	2	St. Augustinegrass Bahiagrass	2006	2008
	Nitrate Leaching Due to N Source and Timing	3	St. Augustinegrass	2007	2009
	Soil Test Phosphorus	5b	St. Augustinegrass	2008	2009
Gainesville	Nitrate Leaching From Newly Sodded Grass	1	St. Augustinegrass Zoysiagrass	2005	2008
	Nitrate Leaching From Established Grass	2	St. Augustinegrass Zoysiagrass	2005	2007
	Nitrate Leaching In Winter Months	4	St. Augustinegrass Zoysiagrass	Fall 2006	Winter 2009
	Nitrate Leaching Due to N Source	3	St. Augustinegrass Zoysiagrass	Summer 2008	2011
	Phosphorus Requirements and Leaching	5a	St. Augustinegrass Zoysiagrass	2007	2009
	Phosphorus Leaching	5a	St. Augustinegrass Zoysiagrass	2007	2009
Jay	Nitrate Leaching From Newly Seeded/Sodded Grass	1	St. Augustinegrass Centipedegrass	2005	2007
	Nitrate Leaching From Established Grass	2	St. Augustinegrass Centipedegrass	2005	2007
	Nitrate Leaching In Winter Months	4	St. Augustinegrass Centipedegrass	2006	2009
	Nitrate Leaching Due to Slow Release N	6	Centipedegrass	2008	2011
	Nitrate Leaching Due to N Source / Timing	3			

PROJECT 1
NITRATE LEACHING FROM NEWLY SODDED GRASS
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 NO_3–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 NO_3–N leaching occurred in year 1 compared to year 2 (average 14.6 and 2.3 $mg \cdot L^{-1}$, respectively), regardless of establishment method.

Easton and Petrovic (2004) reported greater NO_3–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 NO_3–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 NO_3-N leaching (4.1 $kg \cdot ha^{-1}$ annually) from sodded 'Floratam' St. Augustinegrass than from a mixed-species landscape (48.3 $kg \cdot ha^{-1}$ 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 NO_3–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 $g \cdot m^{-2}$ on both treatment dates. The authors attributed the sharp reduction in NO_3–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 NO_3–N and a lower percentage of applied N leached from 'Raleigh' St. Augustine-grass than from five other warm-season grass species. Similarly, Bowman et al. (1998) attributed lower NO_3–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 NO_3–N leaching.

RATIONALE

This research was undertaken to determine the extent of NO_3–N leaching losses from newly sodded turf due to N rate and irrigation regime. In Ft. Lauderdale, the project was designed to look at the influence of whether or not the sod production was done on mineral (sand) vs. organic (muck) soils. In Jay, centipedegrass was evaluated as either seeded or sodded. This project was conducted in 3 locations on the following grasses over the following time periods:

Location	Grass Species	Start Date	Completion Date
Ft. Lauderdale	St. Augustinegrass	Spring 2005	2006
Gainesville	St. Augustinegrass/Zoysiagrass	2005	2008
Jay	St. Augustinegrass/Centipedegrass	2005	2007

PROJECT 1
NITRATE LEACHING FROM NEWLY SODDED GRASS

FT. LAUDERDALE– Dr. John Cisar

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 ^{o}C (ranging from 16 – 34 ^{o}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.

	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	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		Organic		Mineral	
	ALT	WO	ALT	WO	ALT	WO	ALT	WO
None…….	n/a	n/a	n/a	n/a	2.7 ± 2.9	0.5 ± 0.5	0.4 ± 0.2	2.8 ± 3.6
0DAI……	n/a	n/a	n/a	n/a	0.3 ± 0.2	1.6 ± 1.5	0.2 ± 0.0	1.4 ± 0.8
30DAI…….	n/a	n/a	n/a	n/a	0.4 ± 0.2	0.5 ± 0.4	0.6 ± 0.3	0.3 ± 0.1

Table 3. Nitrate-N leaching (mean ± 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 ± 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		Organic		Mineral	
	ALT	WO	ALT	WO	ALT	WO	ALT	WO
None……	n/a	n/a	n/a	n/a	2.8 ± 0.08	0.5 ± 0.08	1.9 ± 1.8	0.08 ± 0.07
0DAI…….	n/a	n/a	n/a	n/a	2.0 ± 0.7	2.7 ± 1.1	2.1 ± 0.8	2.4 ± 3.2
30DAI……	n/a	n/a	n/a	n/a	1.4 ± 0.1	0.6 ± 0.3	0.2 ± 0.2	0.4 ± 0.6

Table 5. Orthophosphate leaching (mean ± 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		Organic		Mineral	
	ALT	WO	ALT	WO	ALT	WO	ALT	WO
None…….	n/a	n/a	n/a	n/a	98 ± 39	5.8 ± 3.4	68 ± 84	2.6 ± 3.2
0DAI……..	n/a	n/a	n/a	n/a	45 ± 33	29± 5.9	75 ± 6.5	21 ± 28
30DAI…….	n/a	n/a	n/a	n/a	36 ± 22	5.2 ± 5.2	6.9 ± 7.8	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 [NO_3-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.

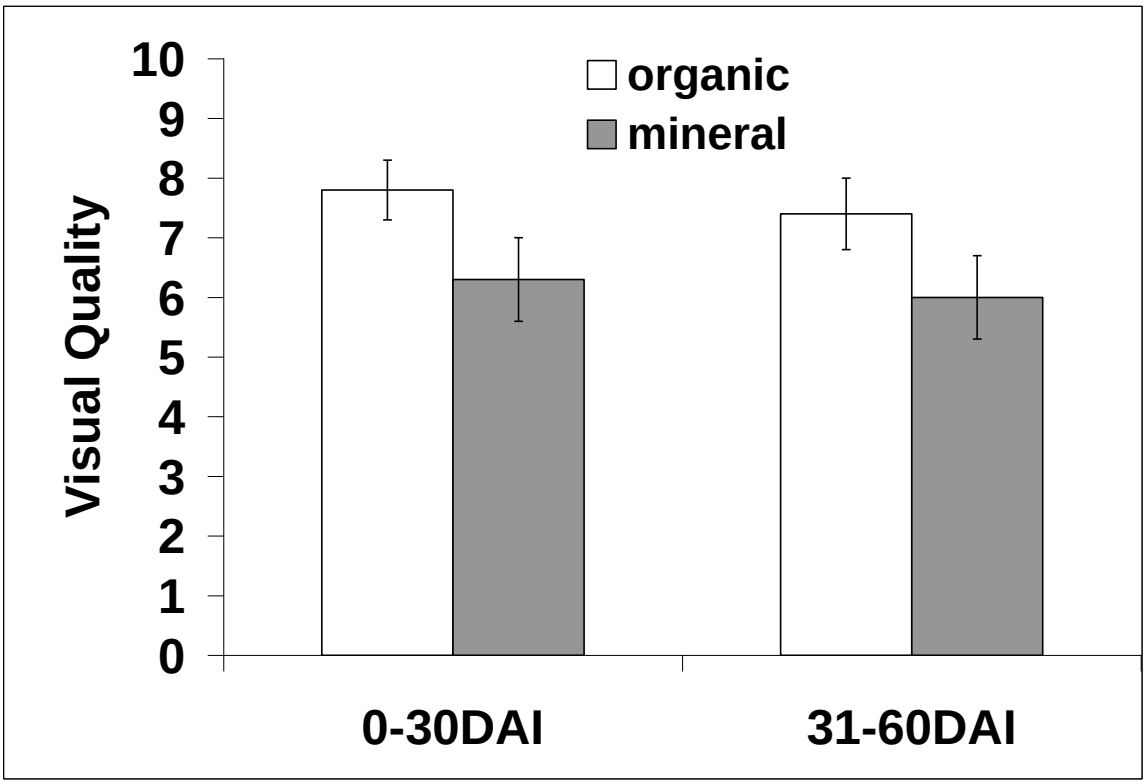

Figure 1. Comparison of visual quality scores (mean ± one standard deviation) from the two sod types for each half of Trial 1.

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 effect 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).

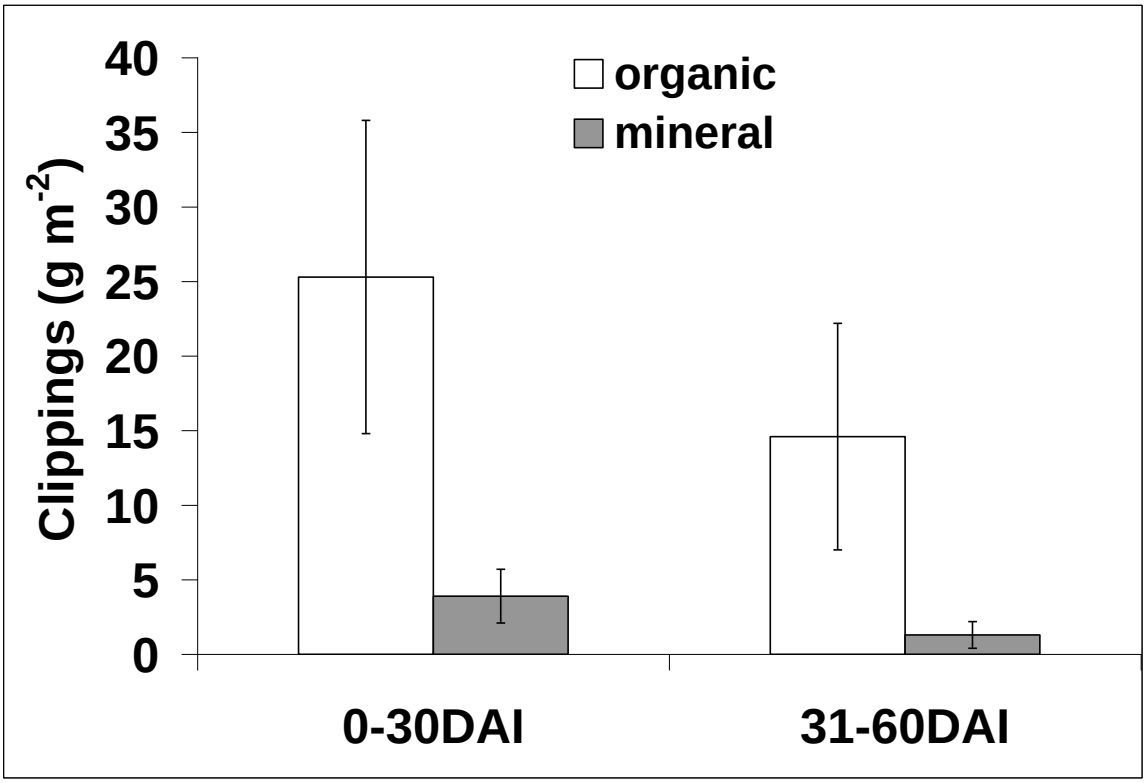

Figure 2. Comparison of mean (and ± one standard deviation) dry clipping yields (g m^{-2}) from the two sod types for each half of Trial 1.

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 ^{o}C (ranging from 10 – 34 ^{o}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	ALT	WO	ALT	WO
None…….	n/a	n/a	n/a	n/a	0.5 ± 0.4	0.2 ± 0.0	0.2 ± 0.0	1.5 ± 2.2
0DAI……..	n/a	n/a	n/a	n/a	4.4 ± 7.3	1.0 ± 1.3	4.2 ± 6.9	1.1 ± 1.5
30DAI…….	n/a	n/a	n/a	n/a	10.2 ± 13.4	8.4 ± 2.8	25.2 ± 25.4	15.2 ± 16.9

Table 11. Nitrate-N leaching (mean ± 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		Organic		Mineral	
	ALT	WO	ALT	WO	ALT	WO	ALT	WO
None……	n/a	n/a	n/a	n/a	34 ± 25	15 ± 1.4	15 ± 0.9	81 ± 112
0DAI…….	n/a	n/a	n/a	n/a	345 ± 571	66 ± 86	312 ± 519	64 ± 91
30DAI……	n/a	n/a	n/a	n/a	656 ± 844	540 ± 192	1753 ± 1744	991 ± 1224

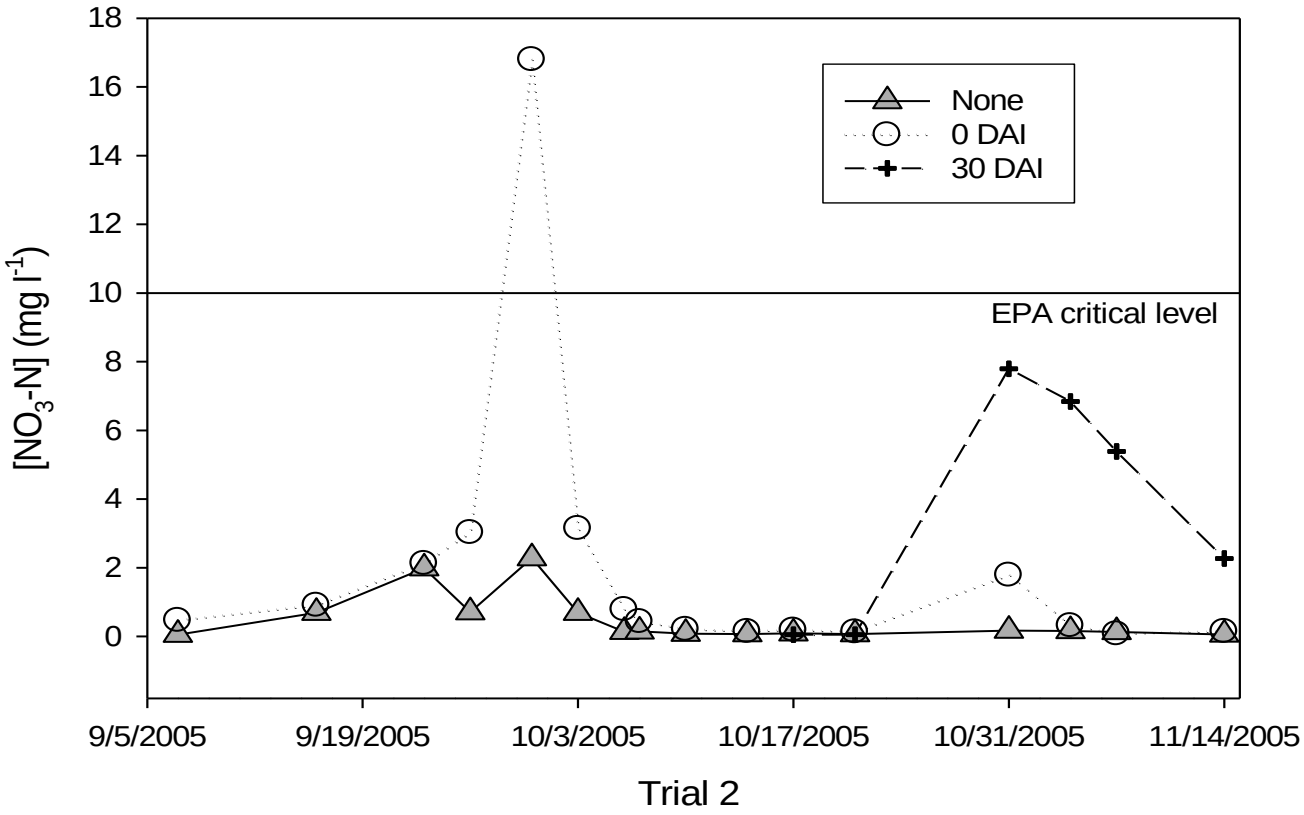

Figure 3. Nitrate-N concentrations during Trial 2 were influenced by fertilizer level.

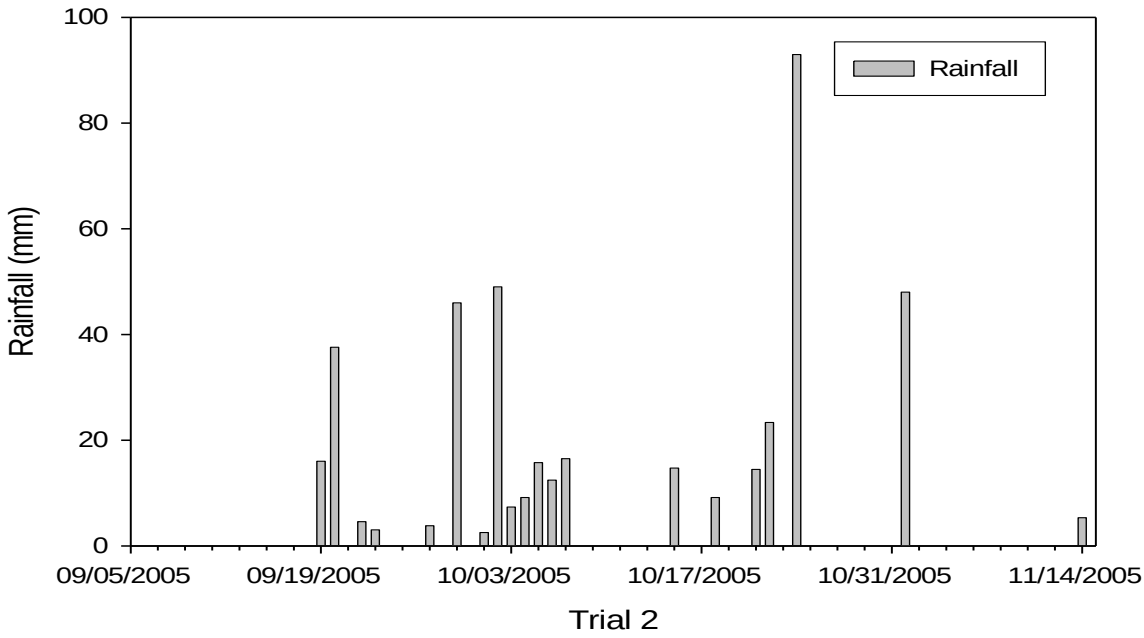

Figure 4. Daily rainfall during Trial 2.

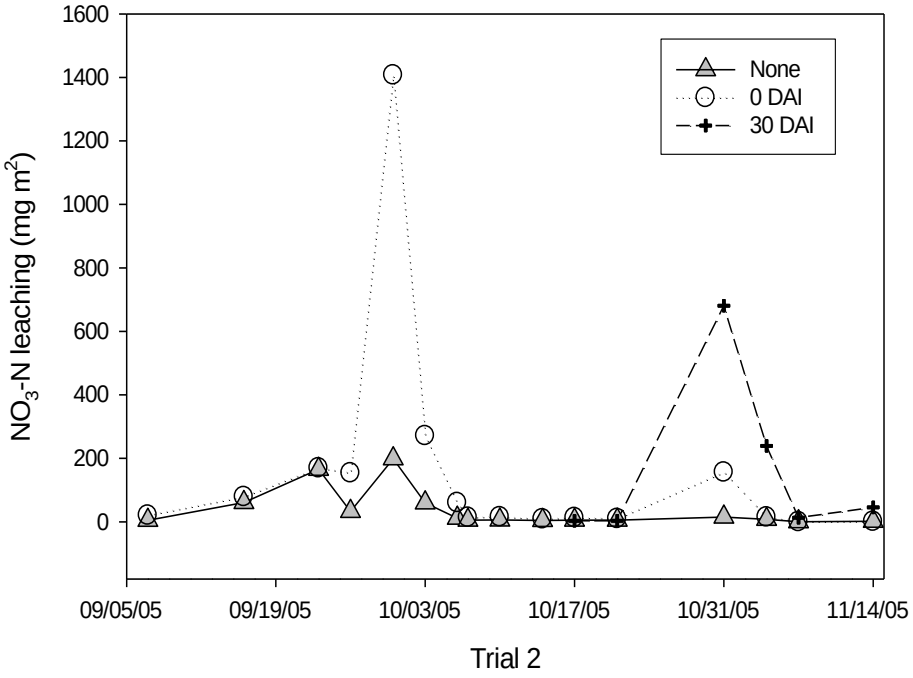

Figure 5. Nitrate-N leaching during Trial 2 was influenced by fertilizer level.

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 ± 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 ± 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		Organic		Mineral	
	ALT	WO	ALT	WO	ALT	WO	ALT	WO
None…….	n/a	n/a	n/a	n/a	101 ± 5.6	78 ± 24	116 ± 24	95 ± 012
0DAI……..	n/a	n/a	n/a	n/a	125 ± 35	116 ± 31	124 ± 58	87 ± 59
30DAI…….	n/a	n/a	n/a	n/a	63 ± 56	85 ± 19	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

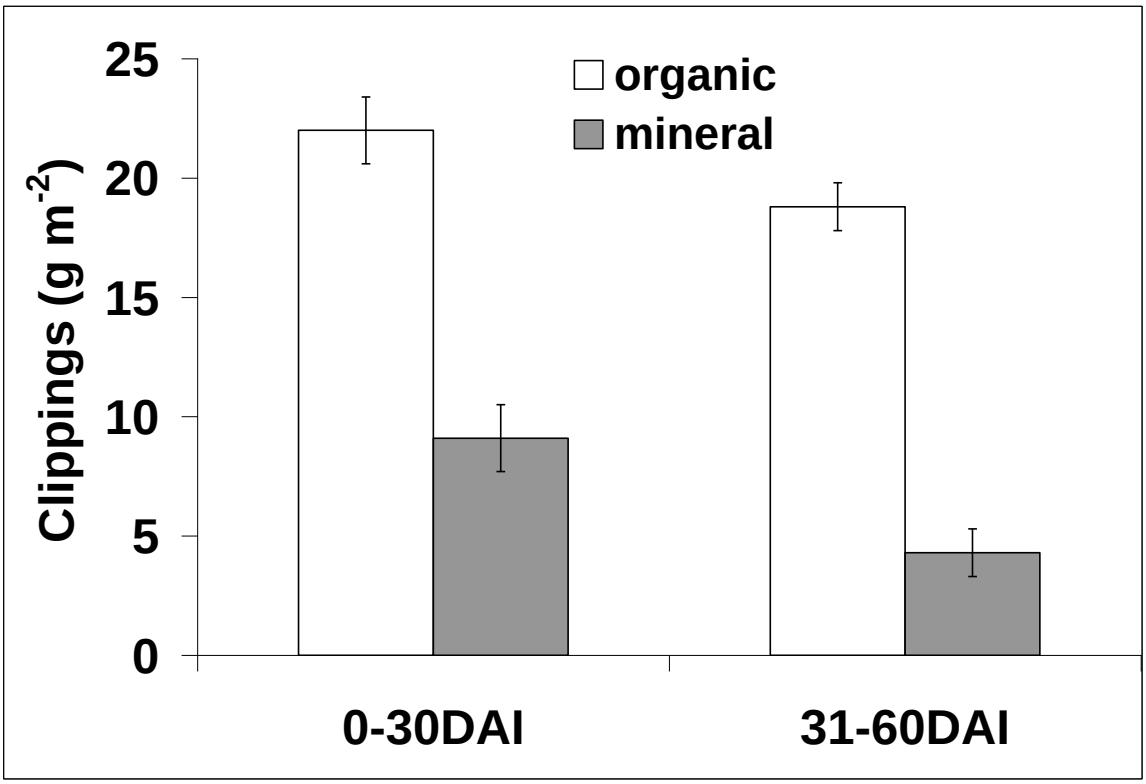

Figure 6. Comparison of mean dry clipping yields (g m^{-2}) from the two sod types for each half of Trial 2.

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.

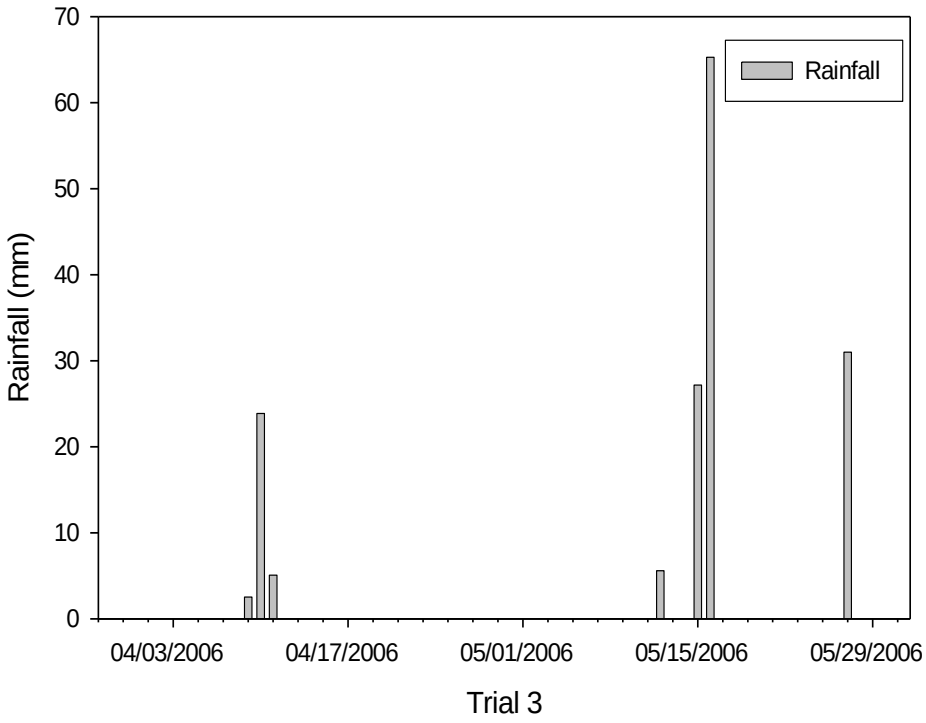

Figure 7. Rainfall over the experimental period for Trial 3.

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 ± 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 ± 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 ± 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	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}, $P<0.05$).

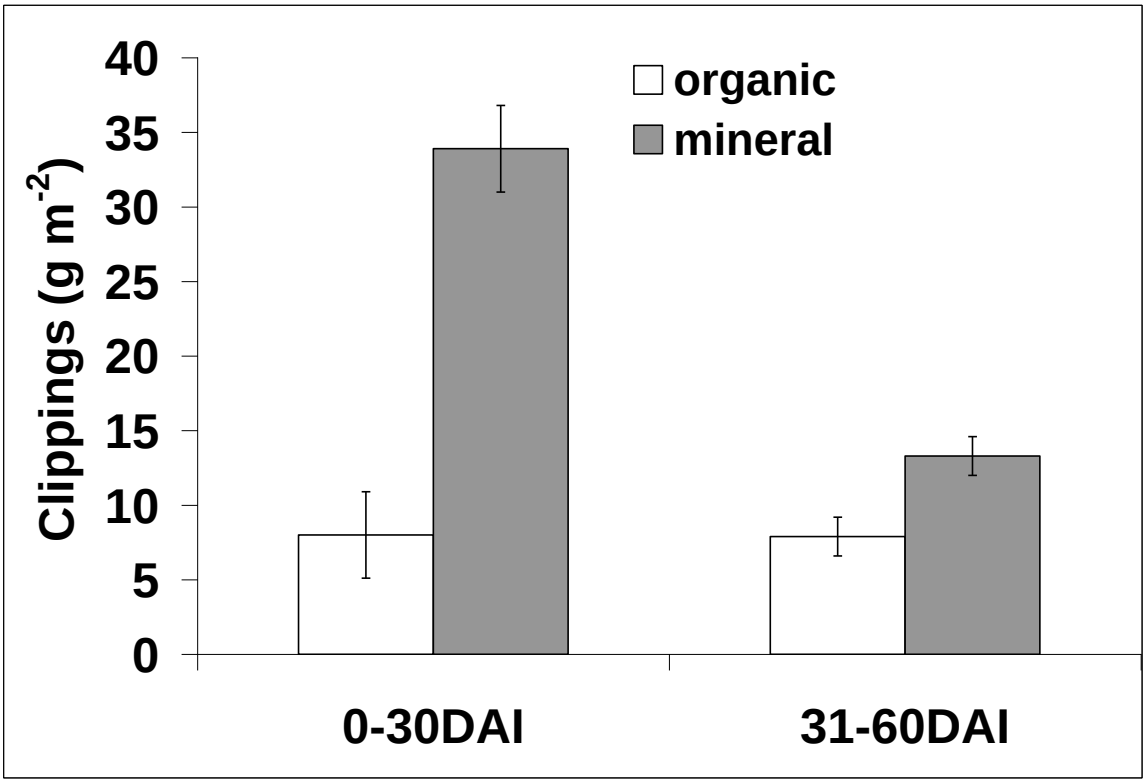

Figure 8. Comparison of mean dry clipping yields (g m^{-2}) from the two sod types for each half of Trial 3.

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.

PROJECT 1
NITRATE LEACHING DURING ESTABLISHMENT

GAINESVILLE – Dr. Laurie Trenholm

MATERIALS AND METHODS

Lysimeters were installed in 2004 and 2005. 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 cm^2) 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 19. Irrigation treatments are described in Table 20.

Table 19. N treatments applied over a 4-yr period to Empire zoysiagrass and Floratam St. Augustinegrass in Citra, FL.

Nitrogen Treatment	Number of Fertilizations †	Nitrogen Rate	Total N Applied
		----------$kg \cdot ha^{-1}$----------	
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 20. 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 NO_3-N leaching losses in 2005 due to any treatment effect (Table 21). In 2008, there were differences in mass loading due to nitrogen treatment. Plots that received N at 98 hg 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 NO_3-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 22), 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 23). 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 24). Again, all scores were well above acceptable.

Table 21. Analysis of variance (ANOVA) for NO_3–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 kg N ha^{-1}	Percent applied nitrate leached %	Average turf quality	Average turf color	Shoot Growth
			2005		
N treatment (NT)……	0.56	0.45	NS	***	*
Irrigation regime (IR)……	0.46	0.38	*	NS	NS
NT x IR……	0.52	0.50	NS	NS	NS
R^2……	0.43	0.25			
			2008		
NT…….	0.009	0.54	***	***	NA
IR…….	0.09	0.10	**	NS	NA
NT x IR…….	0.07	0.18	NS	NS	NA
R^2…….	0.32	0.27			

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

Table 22. 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 (kg ha^{-1})	Nitrate Leached (% applied N)	Total Nitrate Leached (kg ha^{-1})	Nitrate Leached (% 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
Contrasts				
NT1 vs. NT2…….			0.18	0.37
NT1 vs. NT3…….			0.01	0.46
NT1 vs. NT4…….			0.42	0.90
NT2 vs. NT4…….			0.56	0.31
NT3 vs. NT6……			0.88	0.09

*, ** 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 $P = 0.05$.

Correlation analysis showed little association between variables in 2005 (Table 23), with the strongest association between total N leached and percent of applied N leached ($r = 0.51$). The trends were similar in 2008, with associations between total N leached and percent of applied N leached ($r = 0.62$) and total N leached and N rate ($r = 0.54$). Irrigation had little correlation with any other variables.

Table 23. Correlation coefficients (r) and probability values (*P*) for Empire zoysiagrass in 2005 and 2008.

	Treatment	N Rate	Irrigation	Total N Leached	Percent Applied N Leached
			2005		
Treatment……		*r* = 0.48 *P* = 0.0032	*r* = 0.00 *P* = 1.00	*r* = 0.38 *P* = 0.0225	*r* = - 0.35 *P* = 0.036
N Rate…….	*r* = 0.48 *P* = 0.0032		*r* = 0.00 *P* = 1.00	*r* = 0.325 *P* = 0.053	*r* = -0.37 *P* = 0.0276
Irrigation……	*r* = 0.00 *P* = 1.00	*r* = 0.00 *P* = 1.00		*r* = 0.159 *P* = 0.356	*r* = -0.197 *P* = 0.250
Total N Leached..	*r* = 0.38 *P* = 0.0225	*r* = 0.325 *P* = 0.053	*r* = 0.159 *P* = 0.356		*r* = 0.51 *P* = 0.001
Percent Applied N Leached……	*r* = - 0.35 *P* = 0.036	*r* = -0.37 *P* = 0.0276	*r* = -0.197 *P* = 0.250	*r* = 0.51 *P* = 0.001	
			2008		
Treatment……		*r* = 0.48 *P* = 0.0032	*r* = 0.00 *P* = 1.00	*r* = 0.36 *P* = 0.031	*r* = - 0.24 *P* = 0.16
N Rate…….	*r* = 0.48 *P* = 0.0032		*r* = 0.00 *P* = 1.00	*r* = 0.33 *P* = 0.053	*r* = -0.02 *P* = 0.92
Irrigation……..	*r* = 0.00 *P* = 1.00	*r* = 0.00 *P* = 1.00		*r* = 0.31 *P* = 0.066	*r* = -0.34 *P* = 0.05
Total N Leached..	*r* = 0.36 *P* = 0.03	*r* = 0.54 *P* = 0.0007	*r* = -0.31 *P* = 0.066		*r* = 0.62 *P* = 0.001
Percent Applied N Leached……	*r* = - 0.24 *P* = 0.16	*r* = -0.02 *P* = 0.92	*r* = -0.34 *P* = 0.05	*r* = 0.62 *P* = 0.001	

Table 24. 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.

	2005			2008	
Nitrogen Treatment	Average turf quality	Average turf color	Shoot Growth‡	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.

RESULTS - ST. AUGUSTINEGRASS

Total NO_3–N Leached

Analysis of variance indicated that there were no differences in cumulative NO_3^-N leached in either year due to N treatment or IR or their interaction (Table 25). However, single degree of freedom contrasts in 2006 indicated that nitrogen rate affected cumulative NO_3–N leaching (Table 26). 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 NO_3–N leached from plots that received two treatment applications than from those that received one application. In 2007, contrasts showed no differences in NO_3–N leaching between treatments.

The percent of applied N leached did not differ due to treatment effects in either year (Table 25). Single degree of freedom contrasts in 2006 showed differences between treatments 1 and 2 and treatment 2 vs. 5 (Table 27). 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 NO_3–N leaching can result in high percentages given small amounts of N applied.

It is notable that the percentage of NO_3–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, NO_3–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 25. Analysis of variance (ANOVA) for NO_3–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 kg N ha^{-1}	Percent applied N leached %	Average turf quality	Average turf color	Daily Shoot Growth g m^{-2}
			2006		
N treatment (NT)…	0.06	0.10	**	**	NS
Irrigation regime (IR)……..	0.99	0.88	NS	NS	NS
NT x IR……	0.14	0.17	NS	NS	NS
R^2……	0.31	0.12			
			2007		
NT……..	0.23	0.29	***	***	***
IR……	0.30	0.42	NS	NS	NS
NT x IR……	0.15	0.18	*	NS	NS
R^2……	0.21	0.24			

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

Correlation analysis showed a relationship between treatment and total NO_3-N leached (r = 0.50) and treatment and percent of applied N leached (r = 0.62) in 2006. The relationships were not as strong in 2007, with r values of 0.34 and 0.44 for treatment and N leached and percent of applied N leached, respectively. N rate r values were 0.34 and 0.39 for N leached and percent of applied N leached, respectively.

Table 26. Correlation coefficients (r) and probability values (*P*) for Floratam St. Augustinegrass in 2006 and 2007.

	Treatment	N Rate	Irrigation	Total N Leached	Percent Applied N Leached
			2006		
Treatment……		*r* = 0.48 *P* = 0.0032	*r* = 0.00 *P* = 1.00	*r* = 0.50 *P* = 0.002	*r* = - 0.17 *P* = 0.329
N Rate…….	*r* = 0.48 *P* = 0.0032		*r* = 0.00 *P* = 1.00	*r* = 0.62 *P* = 0.0001	*r* = 0.10 *P* = 0.578
Irrigation……..	*r* = 0.00 *P* = 1.00	*r* = 0.00 *P* = 1.00		*r* = 0.002 *P* = 0.99	*r* = 0.26 *P* = 0.879
Total N Leached..	*r* = 0.50 *P* = 0.002	*r* = 0.62 *P* = 0.0001	*r* = 0.002 *P* = 0.99		*r* = 0.56 *P* = 0.0003
Percent Applied N Leached……	*r* = - 0.17 *P* = 0.329	*r* = -0.10 *P* = 0.578	*r* = -0.26 *P* = 0.879	*r* = 0.56 *P* = 0.0003	
			2007		
Treatment……..		*r* = 0.48 *P* = 0.0032	*r* = 0.00 *P* = 1.00	*r* = 0.34 *P* = 0.04	*r* = - 0.44 *P* = 0.007
N Rate……	*r* = 0.48 *P* = 0.0032		*r* = 0.00 *P* = 1.00	*r* = 0.34 *P* = 0.04	*r* = -0.39 *P* = 0.02
Irrigation……..	*r* = 0.00 *P* = 1.00	*r* = 0.00 *P* = 1.00		*r* = 0.19 *P* = 0.266	*r* = 0.12 *P* = 0.002
Total N Leached..	*r* = 0.34 *P* = 0.04	*r* = 0.34 *P* = 0.04	*r* = 0.19 *P* = 0.266		*r* = 0.51 *P* = 0.002
Percent Applied N Leached……	*r* = - 0.24 *P* = 0.16	*r* = -0.02 *P* = 0.92	*r* = -0.34 *P* = 0.05	*r* = 0.62 *P* = 0.001	

Table 27. 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
	($g \cdot m^{-2}$)	(% applied N)	($g \cdot m^{-2}$)	(% 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
Contrasts				
NT1 vs. NT2.....	0.01	0.003	0.24	0.79
NT1 vs. NT3.....	0.003	0.29	0.19	0.04
NT1 vs. NT4.....	0.34	0.76	0.53	0.23
NT1 vs. NT5.....	0.001	0.30	0.10	0.08
NT1 vs. NT6.....	0.52	0.81	0.05	0.01
NT2 vs. NT4.....	0.06	0.01	0.58	0.12
NT2 vs. NT5.....	0.53	0.02	0.40	0.44
NT3 vs. NT5.....	0.99	0.99	0.57	0.34
NT3 vs. NT6.....	0.03	0.41	0.68	0.73

*, **, *** 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 28). Both TQ and TC were highest with treatment 6 and lowest with treatment 2 (Table 29). 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 28. 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 29). In 2007, highest shoot growth resulted from treatment 6 (Table 29).. Treatment 5 had significantly greater growth than treatments 1 and 2.

Table 29. 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 NO_3–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 NO_3–N leaching reported from this research on newly sodded grass are considerably higher than what has been reported to leach from established grasses. Lack of strong relationships and statistical significance due to treatments are due to the high NO_3-N losses at any rate of fertilization following sodding. 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 NO_3–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 NO_3–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 NO_3–N leaching.

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PROJECT 1
ESTABLISHMENT PROJECT
CENTIPEDE SEEDED AND SODDED (2 RUNS EACH)

JAY, FL – Dr. J. Bryan Unruh

MATERIALS AND METHODS

Experimental Site and Design – Seeded

The study was conducted at the University of Florida's West Florida Research and Education Center, (30°46'3N, 87°08'W) on native soil identified by the USGA survey as Fuquay loamy sand. The experiment consisted of 24-4m x 3m) turfgrass plots in a randomized complete block with 4 replications. One of three N rates; 12.232, 24.464, and 48.928 N kg $ha^{-1}yr^{-1}$ in soluble granular form custom blended using 10-10-10, supplemented with 0-46-0, and 0-0-62 for available P and K rates of 48.928 kg $ha^{-1}yr^{-1}$ was applied to half of the 24 plots at day of seeding 16 May 2005 (Trial 1), 03 May 2005 (Trial 2) with the other half receiving one of the three N rates 30 days after seeding 16 June 2005 (Trial 1), 02 June 2006 (Trial 2).

Leachate collection for volume (mL), NOx-N (mg/L), and Ortho-P (ug/L) analysis (Trial 1) was collected biweekly beginning 06 May and ending 07 November 2005 totaling 54 sampling events, (Trial 2) was collected biweekly beginning 14 April 2006 and ending 09 October 2006 totaling 52 sampling events. The 54 and 52 sampling events included 3 and 6 pre-treatment sampling events respectively and 28 post-treatment (>60days after seeding) sampling events. After seeding at a rate of 535.27kg ha^{-1} all plots received a seed cloth covering (non-woven row cover) to maintain constant soil moisture until germination and sufficient growth was established for its removal. Irrigation was supplied by 6 Toro Super 800 rotary irrigation heads in a rectilinear layout with 4-90° and 2-180° arcs having a precipitation rate of 0.762mm per minute utilizing a programmable controller to deliver pulse irrigation of 4 minutes (3.048mm) 3x per day for 21 days, followed by 6.35mm per day for days 22-35, followed by 12.70mm 2x per week thereafter. Irrigation was not suspended for rain events. Additional precipitation and subsequent increases in leachate were quantified and reported as comparators to control data. Once plots were established well they were maintained at a height of cut of 50.8mm using a rotary mower with clippings left in place. Plots killed (23.4ml/1L Glyphosate), tilled, and cleaned of dead residual grasses in April 2006 in preparation for seeding of Trial 2.

Experimental Site and Design – Sodded

The study was conducted at the University of Florida's West Florida Research and Education Center, (30°46'3N, 87°08'W) on native soil identified by the USGA survey as Fuquay loamy sand. The experiment consisted of 24-4m x 3m turfgrass plots in a randomized complete block with 4 replications. One of three N rates; 12.232, 24.464, and 48.928 N kg $ha^{-1}yr^{-1}$ in soluble granular form custom blended using 10-10-10 supplemented with 0-46-0, and 0-0-62 for available P and K rates of 48.928 kg $ha^{-1}yr^{-1}$ was applied to half of the 24 barren plots at day

of sodding 17Apr 2007 (Trial 1), 21 Aug 2007 (Trial 2) with the other half receiving one of the three N rates 30 days after sodding 16 May 2007 (Trial 1), 21 Sep 2007 (Trial 2). Leachate collection for volume (mL), NOx-N (mg/L), and Ortho-P (ug/L) analysis (Trial 1) was collected twice weekly beginning 12 Apr 2007 and ending 16 Jul 2007 totaling 28 sampling events, leachate collection for volume (mL), and NOx-N (mg/L) only (Ortho-P analysis was suspended 06 Aug 2007 due to it not being a treatment and to diminish a laboratory backlog) (Trial 2) was collected twice weekly beginning 16 Aug 2007 and ending 05 Nov 2007 totaling 24 sampling events. The 28 and 24 sampling events included 2 pre-treatment sampling events, 9 and 4 post-treatment (>60days after seeding) sampling events respectfully. Irrigation was supplied by 6 Toro Super 800 rotary irrigation heads in a rectilinear layout with 4-90° and 2-180° arcs having a precipitation rate of 0.762mm per minute utilizing a programmable controller to deliver pulse irrigation of 4 minutes (3.048mm) 3x per day for days 1-7, followed by 6.35mm per day for days 8-14, followed by 12.70mm 2x per week thereafter. To avoid exceeding soil percolation rates, the irrigation regime used 7 separate start times over 6 hours Irrigation was not suspended for rain events. Additional precipitation and subsequent increases in leachate were quantified and reported as comparators to control data. Plot preparation for Trial 1 and 2 involved cutting sod established from previous Establishment Seeded and Establishment Sodded studies respectfully, followed by a fallow period of several weeks to allow volunteers, followed by a one time application of a broad spectrum herbicide (Glyphosate) two weeks prior to sodding plots. Once plots were established well they were maintained at a height of cut of 50.8mm using a rotary mower with clippings left in place.

Collection of Leachate

Using a Toro Dingo skid steer equipped with a 60.96cm power auger, soil was removed to a depth of 106.68cm taking care to keep horizons separated for reconstruction within lysimeters of high density polyethylene (HDPE), having an internal height of 86.36cm, cylinder wall height of 78.74cm, conical section height of 7.62cm, and I.D. of 55.88cm yielding a total volume of 199.333L, supported upon a hot dipped galvanized base having an internal diameter of 57.15cm and constructed such that it has a tank bearing surface ≅ 1935cm^2 and a soil bearing surface ≅ 2355cm^2 with a total height of 25.4cm that raises the tank 10.16cm allowing for the installation of a bulkhead fitting tapped to receive a 9.525mm MNPT x 9.525 OD nylon elbow fitting which is connected via 9.525mm low density polyethylene tubing via trench to a central lysimeter leachate removal/sampling station. Bore holes were prepped by tamping and leveling soil with a 17kg, 858cm^2 hand tamping tool to a finished depth of 106.68cm allowing for 10.16cm of soil cover above the upper rim of the lysimeter. Lysimeters were prepared with a leaching bed of washed 1.905-4.445cm round river rock having a volume of 0.034m^3 covered with non-woven polyolefin cloth 60.96cm in diameter secured with an internal interference fitted hoop of 1.27cm HDPE tubing. A vent line (to prevent pressure differentials from affecting leaching rates when lysimeters are being sampled) of 9.525cm LDPE by sufficient length to reach from the upper portion of the leach field just below the non-woven polyolefin to several inches above finished grass height is temporarily held to the rim of the lysimeter until soil horizons have been reestablished in the lysimeter. Once lowered into the level and prepped bore holes original soil horizons were recreated in 15.24cm lifts within the lysimeter, each being packed by dropping the tamping tool from a consistent height, allowing gravity rather than thrust to compact soil consistently. The area surrounding the lysimeter and undisturbed soil was treated in kind. Any settling at lysimeters was corrected prior to seedbed preparation utilizing a box blade and drag mats. A light tillage and raking was completed for seedbed preparation prior to day of seeding.

Leaching of NO_3-N + NO_2-N and Ortho-PO_4 was evaluated by removing all leachate for volume determination and acquiring a grab sample for NO_3-N + NO_2-N and Ortho-PO_4 analysis from each of the 24 lysimeters on a biweekly basis. This was accomplished by applying a vacuum to a leachate collection trap preceded by an inline 60ml syringe tap that allowed connection directly to the 9.525mm LDPE leachate tube at the leachate removal/sampling station. The collected leachate was measured for volume utilizing 1000ml graduate cylinders and the samples were captured without contamination (appropriately coded if contamination was suspect) by cycling the syringes 3 times utilizing the initial flow of leachate or if volumes were not sufficient to triple rinse with leachate then the syringe was triple rinsed utilizing distilled water prior to applying a vacuum to the collection apparatus

Sample Analysis

Sample analysis was by colorimetric auto analyzer at the UF/IFAS Analytical Research Laboratory, Gainesville, FL utilizing EPA method 353.2 for NO_3-N + NO_2-N, and 365.1 for Ortho-PO_4. MDL's for NOx and Ortho-P were 0.05mg/L, and 2.5µg/L. PQL's for NOx and Ortho-P were 0.5mg/L and 10µg/L. Linear working ranges for NOx and Ortho-P were 0.50-30.00mg/L and 0.01-0.50mg/L. Laboratory estimates of uncertainty for NOx and Ortho-P have an estimated bias of +0.95 and +1.46 and an estimated precision of ±3.61% and ±3.16%. Note: Precision estimates only apply to laboratory instrumentation and do not include any error associated with sample handling or collection variances and were determined by measuring the dispersion of values obtained from a known certified reference standard using typically 20-30 data points. With this, both bias (average % yield – 100) and precision (standard deviation of % yield) were determined (UF/IFAS Analytical Research Laboratory).

Measures of Turfgrass Quality and Seedling Count – Seeded

Turfgrass visual quality, color, and density was assessed approximately every week 17 June 2005 through 25 October 2005 (Trial 1) and biweekly 21 July 2006 through 22 September 2006 (Trial 2) utilizing NTEP turfgrass evaluation guidelines. Scales are 1-9 with a quality rating of 9 being best and 1 being poorest, color rating of 9 being dark green and 1 light green, and density rating of 9 being maximum density. Any rating 6 or greater is considered generally acceptable. Ratings are generally in whole numbers. Seedling counts were determined for (Trial 2) on 29 June 2006 by the quadrat method established by Frederick Edward Clements (1874-1945) (Pound & Clements, 1898). Using a 0.093m^2 quadrat fashioned from 1.27cm schedule 40 PVC pipe and 4-90's with an inner dimension of 30.5cm on each side and divided into nine equal subunits with bisecting strings. Seedling counts were gathered by a blind throw onto the plot counting the seedlings in each of the subunits.

Measures of Turfgrass Quality, Dry Clipping Mass, and Dry Root Mass – Sodded

Turfgrass visual quality, color, and density was assessed approximately every week 15 May 2007 through 14 June 2007 (Trial 1) and every 10days 24 September 2007 through 15 October 2007 (Trial 2) utilizing NTEP turfgrass evaluation guidelines. Scales are 1-9 with a quality rating of 9 being best and 1 being poorest, color rating of 9 being dark green and 1 light green, and density rating of 9 being maximum density. Any rating 6 or greater is considered generally acceptable. Ratings are generally in whole numbers.

Turfgrass clipping samples were collected 77 days post sodding on 3 July 2007 (Trial 1) and 36, 44, 51, and 77 days post sodding on 26 Sep, 4 Oct, 11 Oct, and 6 Nov 2007 (Trial 2) respectfully, representing approximately 7 days of shoot growth from a 2.17m2 area within each plot using a rotary mower set at a mowing height of 50.8mm with a modified grass catching system utilizing a 30.48cm by 40.64cm cloth bag in lieu of the manufacturers grass catching system. Samples were dried using forced hot air averaging 50°C for 48 to 72 hours prior to measuring masses.

At the end of the sampling period for (Trial 2) 5 root samples were collected using a pedal style soil sampler measuring 20mm dia. x 100mm long, one from each quadrant and one from the center of each plot. Soil, and debris separation from roots was accomplished by washing with water in a sieve accompanied by mechanical pressure and agitation. Separated roots were then air dried followed by oven drying at 50°C for 48-72 hours prior to measuring masses. These masses were corrected for retained mineral materials by ashing the samples and subtracting the mass of the remaining debris minus the ash.

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 30).

Table 30. 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
P(F)	NS
Rate (kg/ha)	
12.25.....	80.7
24.50.....	75.3
49.00.....	78.6
P(F)	NS
App. x Rate.....	*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 31). Fertilizer applied 30DAS (June) generally resulted in better turfgrass color, especially during the initial months of each study (Table 32). 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 33). This trend was not observed in the second run of the trial (Table 33). Rate of applied nitrogen had no effect on Centipedegrass density.

Table 31. Nitrogen timing and rate effect on centipede turf quality following seeding in 2005 and 2006.

	2005					2006			
	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
P(F).....	***	*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
P(F).....	*NS*	*NS*	**	*NS*	*NS*		*NS*	*NS*	*NS*
App.x Rate	*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 32. Nitrogen timing and rate effect on centipede turf color following seeding in 2005 and 2006.

	2005					2006			
	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
P(F).....	****	*	**	*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
P(F).....	*NS*	*	*NS*	*NS*	*NS*		*NS*	*NS*	*NS*
App.x Rate.....	*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 <.0001, respectively. NS= P >0.05.

Table 33. Nitrogen timing and rate effect on centipede turf density following seeding in 2005 and 2006.

	2005					2006			
	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
P(F)	*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
P(F)	*NS*	*NS*	*NS*	*NS*	*NS*	*NS*	*NS*	*NS*	*NS*
App x Rate.....	*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 or 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 34). 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 34) and a rate response was observed with higher applied nitrogen resulting in greater leaching (Table 34). 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 9).

Table 34. Seeded Centipedegrass Establishment Study total N value (MDL) leached by month in 2005.

	Total N (kg/ha)							
	Pre	T1	T2	T3	T4	T5	T6	Total Post
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
P(F)	*0.2485*	*0.6050*	*0.2337*	*0.7816*	*0.2772*	*0.8560*	*0.5562*	*0.5312*
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
P(F)	*0.5538*	*0.5904*	*0.4084*	*0.7660*	*0.8227*	*0.6679*	*0.5788*	*0.6261*
App. x Rate	*0.3513*	*0.9072*	*0.7077*	*0.5511*	*0.7266*	*0.7689*	*0.8749*	*0.6977*
R^2	*0.4449*	*0.2480*	*0.3700*	*0.3502*	*0.2400*	*0.4356*	*0.3239*	*0.2936*

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). 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.

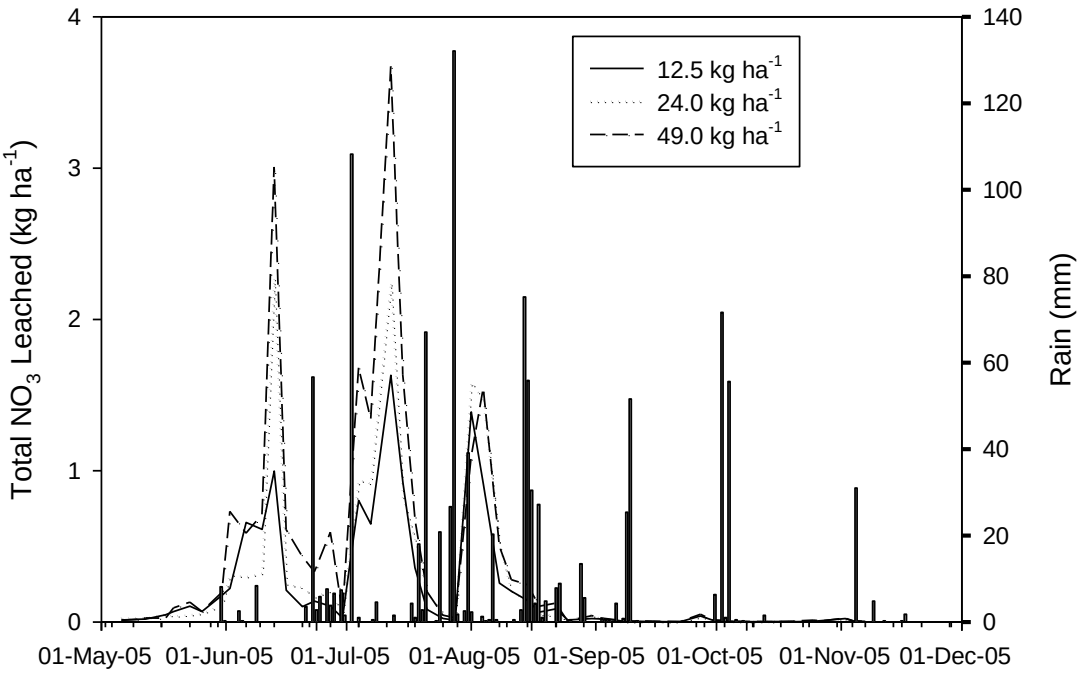

Figure 9: Total NO_3 leached from nitrogen applied in 2005 seeded centipedegrass and the corresponding rainfall.

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 35). 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 35).

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 35). 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 35). There were no significant differences between the total nitrate leached regardless of when the nitrogen was applied or the rate applied (Table 35). The amount of nitrate leached into the soil seems to spike following major rain events for all three rates in 2006 (Figure 10).

Table 35. Seeded Centipedegrass Establishment Study total N value (MDL) leached by month in 2006.

	Total N (kg/ha)						
	Pre	T1	T2	T3	T4	T5	Total Post
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
P(F).....	*0.9034*	*0.4149*	*0.1420*	*0.0643*	*0.6197*	*0.2526*	*0.4629*
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
P(F).....	*0.6422*	*0.7974*	*0.3359*	*0.5040*	*0.1653*	*0.7233*	*0.2197*
App. x Rate.....	*0.9294*	*0.5298*	*0.8782*	*0.6948*	*0.5723*	*0.5039*	*0.8266*
R^2	*0.5104*	*0.3588*	*0.4046*	*0.5720*	*0.6842*	*0.6184*	*0.6759*

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). 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.

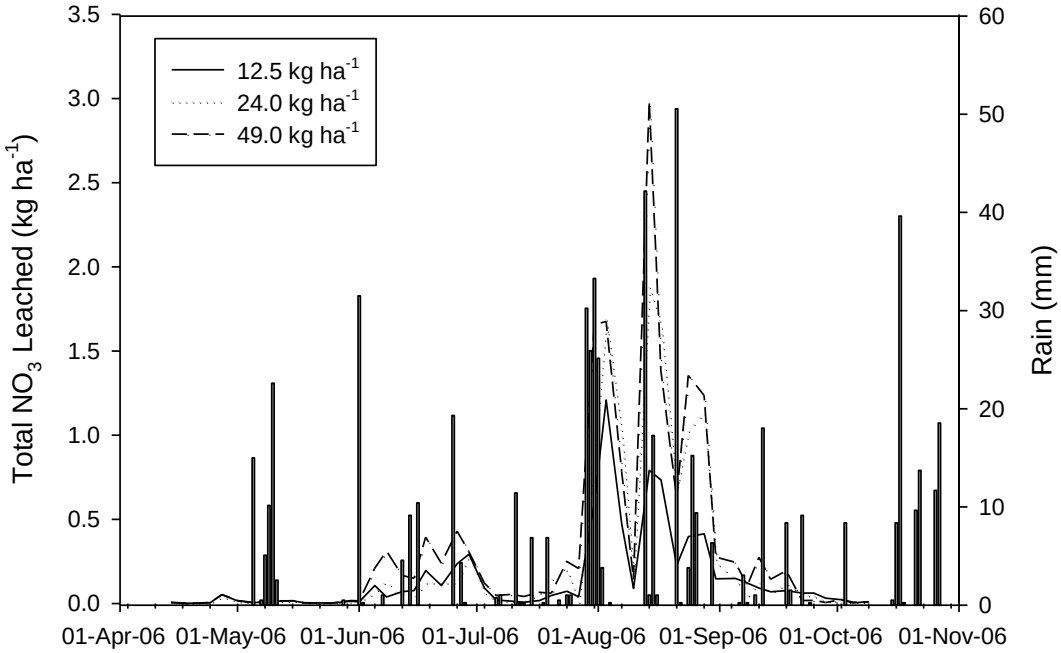

Figure 10: Total NO_3 leached from nitrogen applied in 2006 seeded centipedegrass and the corresponding rainfall.

Nitrate Leaching –Combined Analysis

There were no significant effects of application date or rate on nitrate leaching across both studies (Table 36). 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 36). During the first month of sampling the 2005 showed significantly higher leaching, but this difference was not detected in the remaining periods (Table 36).

Table 36. Seeded Centipedegrass Establishment Study total N value (MDL) leached by month combined across years.

	Total N (kg/ha)						
	Pre	T1	T2	T3	T4	T5	Total Post
Year							
2005.....	0.060 b	4.361 a	0.509	3.791	0.178	0.076	8.957
2006.....	0.079 a	0.077 b	1.503	2.952	6.690	0.603	11.824
P(F).....	*0.0003*	*0.0469*	*0.2037*	*0.7184*	*0.1603*	*0.3084*	*0.6791*
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
P(F).....	*0.2998*	*0.6056*	*0.0833*	*0.1331*	*0.6555*	*0.2479*	*0.3305*
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
P(F).....	*0.8723*	*0.5828*	*0.4995*	*0.4498*	*0.1461*	*0.6934*	*0.1449*
Year x App......	*0.3681*	*0.5967*	*0.2293*	*0.2699*	*0.5785*	*0.2403*	*0.8708*
Year x Rate.....	*0.3840*	*0.5872*	*0.2157*	*0.8870*	*0.1520*	*0.7489*	*0.7388*
App. x Rate.....	*0.6043*	*0.9062*	*0.9049*	*0.4393*	*0.5696*	*0.5060*	*0.9398*
Year x App x Rate.....	*0.3640*	*0.9076*	*0.8322*	*0.8410*	*0.5639*	*0.4876*	*0.6300*
R^2	*0.4885*	*0.4213*	*0.4689*	*0.4798*	*0.7624*	*0.6599*	*0.5898*

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).

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 37). In the 2006 trial the 12.5 kg/ha rate was only significantly higher during T1 (30 DAA) (Table 38). 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 37 and 38). 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 39).

Table 37. Seeded Centipedegrass Establishment Study % of nitrogen from application leached by month in 2005.

	% Nitrogen applied							
	Pre	T1	T2	T3	T4	T5	T6	Total Post
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
P(F)	*0.1883*	*0.6735*	*0.1807*	*0.9149*	*0.4826*	*0.7979*	*0.7704*	*0.7742*
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
P(F)	*0.0917*	*0.6067*	*0.0123*	*0.2873*	*0.3977*	*0.0112*	*0.0934*	*0.3263*
App. x Rate	*0.4809*	*0.9049*	*0.6685*	*0.5998*	*0.9772*	*0.7566*	*0.9320*	*0.7546*
R^2	*0.4694*	*0.2419*	*0.5441*	*0.3374*	*0.1772*	*0.5447*	*0.3517*	*0.2907*

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).

Table 38. Seeded Centipedegrass Establishment Study % of nitrogen from application leached by month in 2006.

	% Nitrogen applied						
	Pre	T1	T2	T3	T4	T5	Total Post
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
P(F)	*0.9371*	*0.6772*	*0.1706*	*0.1254*	*0.7992*	*0.2443*	*0.3907*
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
P(F)	*0.0025*	*0.0034*	*0.3360*	*0.4840*	*0.3214*	*0.5945*	*0.3911*
App. x Rate	*0.9695*	*0.8914*	*0.9582*	*0.9630*	*0.3219*	*0.3883*	*0.6541*
R^2	*0.6364*	*0.5807*	*0.3482*	*0.4625*	*0.6742*	*0.4619*	*0.6106*

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).

Table 39. Seeded Centipedegrass Establishment Study % of nitrogen from application leached by month combined across years.

	% Nitrogen applied						
	Pre	T1	T2	T3	T4	T5	Total Post
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
P(F).....	*0.0284*	*0.0530*	*0.1951*	*0.5801*	*0.1200*	*0.3214*	*0.7126*
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
P(F).....	*0.3100*	*0.6731*	*0.0923*	*0.4162*	*0.7646*	*0.2395*	*0.4300*
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
P(F).....	*0.0004*	*0.5806*	*0.1080*	*0.1384*	*0.2967*	*0.5057*	*0.1354*
Year x App......	*0.3653*	*0.6678*	*0.3011*	*0.3234*	*0.6908*	*0.2314*	*0.7223*
Year x Rate.....	*0.2035*	*0.6228*	*0.5979*	*0.8022*	*0.3203*	*0.6746*	*0.9065*
App. x Rate.....	*0.7381*	*0.9034*	*0.8851*	*0.6111*	*0.3142*	*0.3906*	*0.9902*
Year x App x Rate.....	*0.6143*	*0.9058*	*0.9926*	*0.7096*	*0.3059*	*0.3646*	*0.5080*
R^2	*0.5817*	*0.4036*	*0.4204*	*0.3942*	*0.7725*	*0.4955*	*0.4807*

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).

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 40). 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 40). Centipedegrass shoot weight was increased by increasing application of nitrogen in study 1 and in study 2 by 6 November (Tables 41 and 42). 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 42).

Table 40. 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
P(F).....	*	NS	**
Application date			
PTS	0.389	0.036	9.52
30DAS	0.368	0.032	9.03
P(F).....	*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
P(F).....	*NS*	*NS*	*NS*
Trial X App.	*NS*	*NS*	*NS*
Trial X Rate	*NS*	*NS*	*NS*

App. x Rate	*NS*	*NS*	*NS*
Trial x App. x Rate.....	*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 41. 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
P(F).....	*NS*
Rate (kg/ha)	
12.5	3.33 b
24.0	5.16 ab
49.0	7.61 a
P(F).....	**
App. x Rate	*NS*

PTS= nitrogen application made Prior To Sodding, 30DAS =nitrogen application made 30 Days After Sodding.

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

Table 42. 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
P(F).....	*	*NS*	***	*
Rate (kg/ha)				

12.5	16.97	14.30	12.81	13.15 b
24.0	19.51	19.61	15.06	16.38 ab
49.0	19.28	16.98	16.92	19.37 a
P(F).....	*NS*	*NS*	*NS*	*
App. x Rate.....	*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 = $P>0.05$.

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 43). This effect was not noted during the second run of the experiment (Table 43). 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 43). However, the lowest level of nitrogen yielded acceptable turf quality. Similar results were observed for turf color (Tables 44). Centipedegrass density was largely unaffected by nitrogen timing or nitrogen rate in both runs of the experiment (Tables 45).

Table 43. 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	7.5b	7.3b	7.5	7.3a	7.6	7.5	7.3a	7.6
30DAS.....	7.2	7.8	7.9a	7.8a	7.3	7.0b	7.8	7.3	7.0b	7.8
P(F).....	*NS*	*NS*	*	*	*NS*	*	*NS*	*NS*	*	*NS*
Rate (kg/ha)										
12.5.....	7.1	7.3b	7.2b	7.1b	7.4	7.1	7.6ab	7.4	7.1	7.6ab
24.0.....	7.4	7.8a	7.8a	7.6ab	7.3	7.1	7.5b	7.3	7.1	7.5b
49.0.....	7.3	7.9a	8.0a	7.9a	7.4	7.1	7.9a	7.4	7.1	7.9a
P(F).....	*NS*	*	**	*	*NS*	*NS*	*	*NS*	*NS*	*
App.x Rate	*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 44. 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
P(F).....	*	*	**	*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
P(F).....	*NS*	**	***	**	*NS*	*NS*	**	*NS*	*NS*	**
App.x Rate	*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* <.001, respectively. NS= *P* >0.05.

Table 45. 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
P(F).....	*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
P(F).....	*NS*	*NS*	*NS*	*NS*	*NS*	*NS*	*NS*	*NS*	*NS*	*NS*
App.x Rate	*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.

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 46). 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 11).

***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 47). 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 12).

During the first 30d following the initial application, no differences in nitrogen leaching due to application rates were noted (Table 47). 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 47). 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 47).

During the first 30d following the initial application, no differences in nitrogen leaching due to application timing were noted (Table 47). During the 31-60d time period, 41% more nitrogen leached from the plots receiving fertilizer PTS (Table 47). 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 47).

Table 46. 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
P(F)	*0.3128*	*0.6833*	*0.2520*	*0.7100*	*0.7658*
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
P(F)	*0.6647*	*0.6815*	*0.4572*	*0.5084*	*0.6961*
App. x Rate.....	*0.6075*	*0.3070*	*0.6223*	*0.4706*	*0.3120*
R^2	*0.2469*	*0.4553*	*0.4940*	*0.2283*	*0.4633*

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). 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 47. 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	48.34 a
30DAS (16 May)...	0.05	9.26	24.10 b	1.92	35.32 b
P(F)	*0.2309*	*0.1560*	*0.0213*	*0.9784*	*0.0356*
Rate (kg/ha)					
12.5	0.02	8.81	20.10 b	1.05	29.98 b
24.0	0.04	11.19	28.39 ab	1.45	41.07 ab
49.0	0.05	12.73	38.46 a	3.22	54.46 a
P(F)	*0.5427*	*0.3689*	*0.0047*	*0.0986*	*0.0103*
App. x Rate.....	*0.6524*	*0.0813*	*0.1047*	*0.4488*	*0.0574*
R^2	*0.4193*	*0.5126*	*0.6583*	*0.3960*	*0.6411*

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). 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.

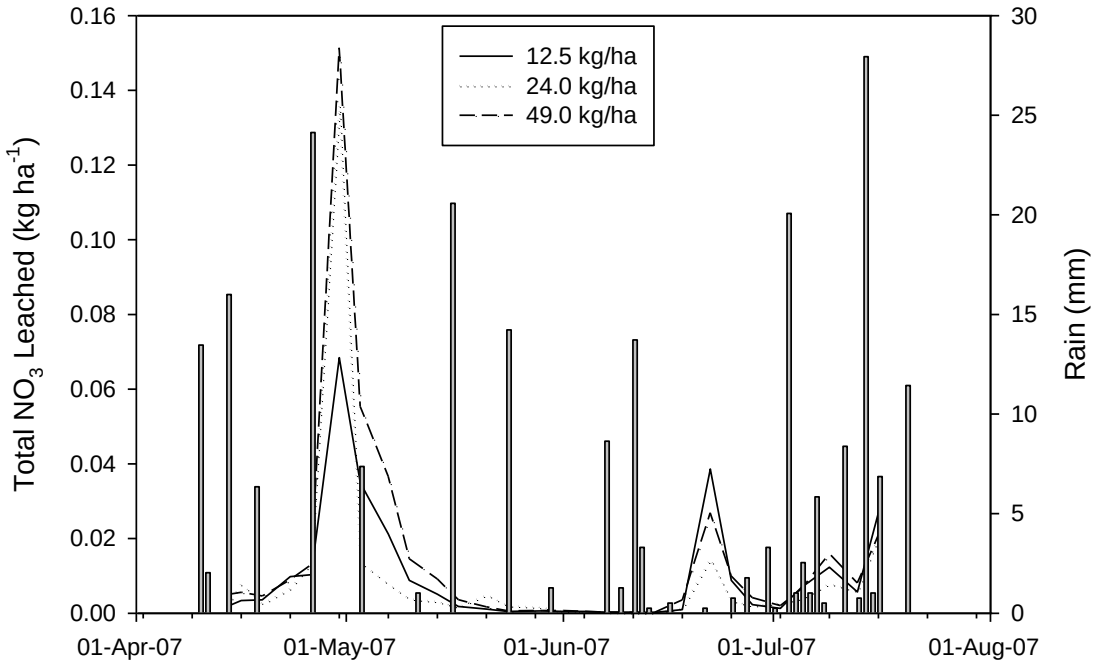

Figure 11: Total NO_3 leached from nitrogen applied in 2007 trial 1 sodding of centipedegrass and corresponding rainfall that occurred.

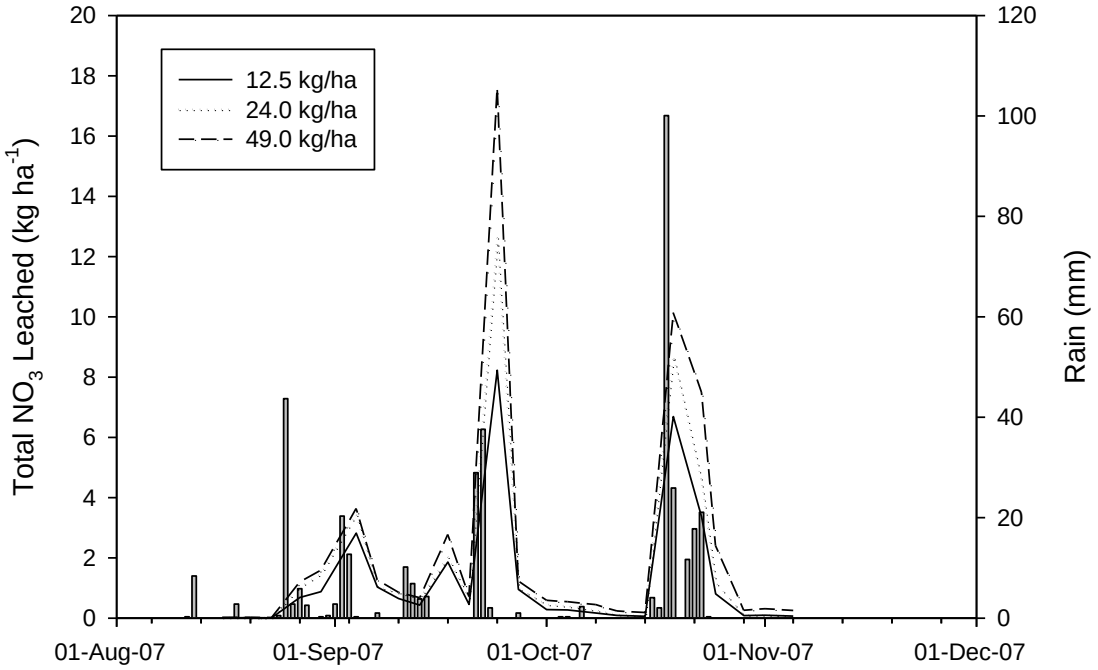

Figure 12: Total NO_3 leached from nitrogen applied in 2007 trial 2 sodding of centipedegrass and corresponding rainfall that occurred.

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 48). 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/rate with 24.5% less and the 12.5 kg/ha rate with 45% less when combined across both trials in 2007 (Table 48).

Table 48. 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	0.093 b	0.416
Trial 2.....	0.035	10.909 a	28.981	1.907 a	41.833
P(F).....	*0.1068*	*0.0047*	*0.0002*	*0.0166*	*0.0003*
Application date					
PTS.....	0.017	6.451	16.935	0.991	24.397
30 DAS.....	0.026	4.754	12.052	1.009	17.852
P(F).....	*0.3465*	*0.1373*	*0.0154*	*0.9650*	*0.0274*
Rate (kg/ha)					
12.5.....	0.014	4.484	10.051	0.576	15.126
24.0.....	0.023	5.776	14.198	0.758	20.759
49.0.....	0.028	6.548	19.232	1.666	27.488
P(F).....	*0.4461*	*0.3224*	*0.0018*	*0.0789*	*0.0048*
Trial x App......	*0.1532*	*0.1584*	*0.0154*	*0.9914*	*0.0290*

Trial x Rate	*0.6618*	*0.4000*	*0.0018*	*0.0869*	*0.0057*
App. x Rate	*0.7545*	*0.0781*	*0.0884*	*0.4495*	*0.0478*
Trial x App x Rate	*0.5533*	*0.0574*	*0.0883*	*0.4294*	*0.0403*
R^2	*0.4977*	*0.8037*	*0.9065*	*0.5697*	*0.8996*

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).

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 49).

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 50).

When combined across both trials significant differences in % nitrogen leaching were detected between the two trials (Table 51). 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 51).

Table 49. 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
P(F)	*0.2705*	*0.4667*	*0.2002*	*0.8077*	*0.4338*
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
P(F)	*0.5711*	*0.7653*	*0.3345*	*0.0170*	*0.5621*
App. x Rate.....	*0.6566*	*0.4206*	*0.6437*	*0.3445*	*0.4109*
R^2	*0.2550*	*0.3435*	*0.4857*	*0.4992*	*0.4114*

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). 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 50. 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
P(F)	*0.1451*	*0.8400*	*0.1336*	*0.4361*	*0.3734*
Rate (kg/ha)					
12.5	0.180	70.449 a	160.779 a	8.392	239.800a
24.0	0.152	46.628 ab	118.277 b	6.055	171.113ab
49.0	0.096	25.981 b	78.488 b	6.571	111.136b
P(F)	*0.4090*	*0.0482*	*0.0026*	*0.6377*	*0.0075*
App. x Rate.....	*0.3960*	*0.3783*	*0.3558*	*0.3231*	*0.3260*
R^2	*0.5556*	*0.4516*	*0.6087*	*0.2823*	*0.5400*

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). 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 51. Establishment of sodded centipedegrass study % of nitrogen leached by month combined across trials.

	% Nitrogen applied				
	Pre	T1	T2	T3	Total Post
Trial					
Trial 1.....	0.034	1.183 b	0.028 b	0.440 b	1.719 b

Trial 2.....	0.143	47.686 a	119.182 a	7.006 a	174.016 a
P(F).....	*0.0910*	*0.0050*	*0.0001*	*0.0034*	*0.0001*
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
P(F).....	*0.3186*	*0.8016*	*0.1229*	*0.4429*	*0.3536*
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
P(F).....	*0.2667*	*0.0336*	*0.0008*	*0.4851*	*0.0032*
Trial x App......	*0.0745*	*0.8767*	*0.1235*	*0.4201*	*0.3796*
Trial x Rate.....	*0.6611*	*0.0386*	*0.0008*	*0.7802*	*0.0037*
App. x Rate.....	*0.5705*	*0.3683*	*0.3435*	*0.3260*	*0.3168*
Trial x App x Rate.....	*0.3002*	*0.3652*	*0.3433*	*0.2945*	*0.3087*
R^2	*0.6249*	*0.7099*	*0.9019*	*0.6317*	*0.8594*

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).

PROJECT 2
NITRATE-N LEACHING FROM ESTABLISHED GRASSES DUE TO N RATE AND IRRIGATION

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 (NO_3–N) levels in excess of the USEPA safe levels of 10 mg NO_3–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 NO_3–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 NO_3–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 NO_3–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 NO_3–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 NO_3–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 NO_3–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 NO_3–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 NO_3–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 NO_3–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.

RATIONALE

Given that Florida currently has regulations at both state and local levels regarding fertilization of lawngrasses and due to a lack of NO_3–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 NO_3–N leaching as a result of lawngrass fertilization. The objectives of this research were to evaluate total NO_3–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. This project was conducted on the grasses listed below during the following times.

Location	Grasses	Start Date	Completion Date
Ft. Lauderdale	St. Augustinegrass/Bahiagrass	2006	2008
Citra	St. Augustinegrass/Zoysiagrass	2005	2007
Jay	St. Augustinegrass/Centipedegrass	2005	2007

PROJECT 2
NITRATE-N LEACHING FROM ESTABLISHED GRASSES DUE TO N RATE AND IRRIGATION

FT. LAUDERDALE – Dr. John Cisar

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. 'Floratam' 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 CO_2-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 NO_3+NO_2 and calculated as NO_3- N leached (mg m^{-2}). Any NO_3 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 NO_3-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 52). The low irrigation rate accounted for approximately 800 mm and the high irrigation rate supplied over 1900 mm of water (Table 52). As a result, there was significantly more percolate for the high

irrigation throughout the year for both turfgrasses (Tables 53 and 54). Increasing N rate reduced percolate for 3 of the six cycles in St. Augustinegrass but not in bahiagrass (Tables 53 and 54) presumably due to greater vigor and density as increased amounts of N were applied to plots.

Table 52. Hydrology data for low and high irrigation regimes (mm) for the 6 cycles (C).

Factor	C1 10/12 – 12/11	C2 12/12 – 3/14	C3 3/15 – 4/16	C4 4/17 – 6/17	C5 6/18 – 8/15	C6 8/15 – 10/16	*TOTALS*
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*
Precipitation…..	*97.3*	*215.9*	*86.4*	*411.7*	*248.4*	*452.9*	*1512.6*

Table 53. 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 54. 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 55 -62) This may be explained by the total amounts irrigation + precipitation exceeding growing season ET rates in south Florida (Table 52). N rate did significantly ($p<0.05$) affect turfgrass quality and color for either grass (Tables 55 and 56). For St. Augustinegrass and bahiagrass all N rates averaged over a cycle provided minimally-acceptable turfgrass quality of 6.0 or higher (Tables 55 and 56). 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. 13). Bahiagrass quality was always above the minimal standard throughout a cycle (Fig. 14). 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 55 and 56). Although increasing N rate increased turfgrass quality and color (Tables 55 – 58), 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 59). For bahiagrass, N rate had no significant effect ($p> 0.05$) on density (Table 60). 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 61). Bahiagrass cumulative clipping yields also increased with increasing N rate (Table 62). Both grasses produced higher cumulative clipping yields during wet season cycles (C4, C5, and C6) with longer day length and warmer temperatures.

Table 55. 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 56. 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 57. 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 58. 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 59. 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 60. 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 61. 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						
kg ha^{-1} 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 62. 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						
kg ha^{-1} 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

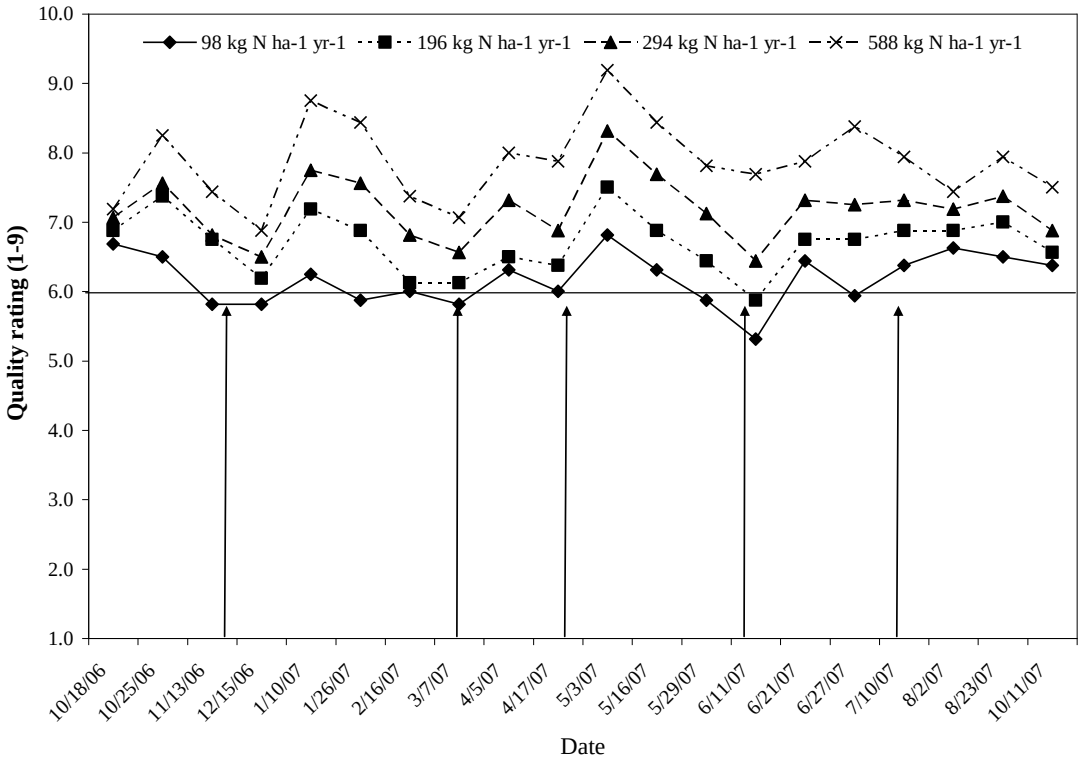

Figure 13. Turfgrass quality ratings for St. Augustinegrass over all cycles
(Arrows indicate fertilizer application)

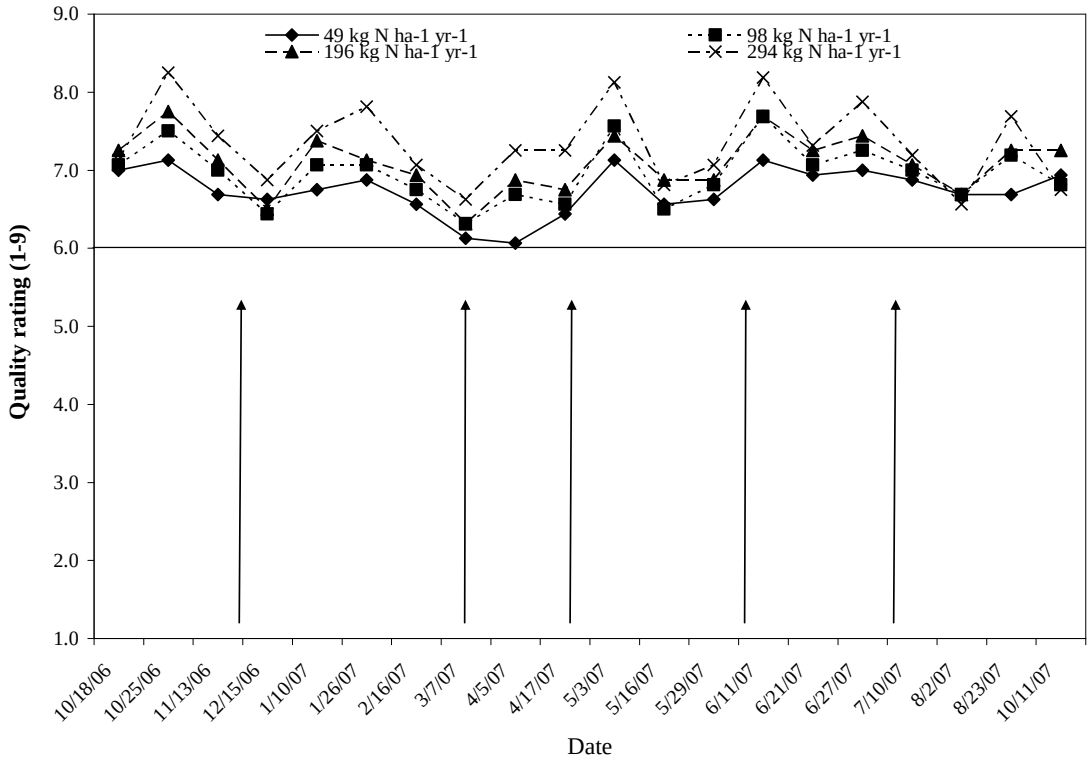

Figure 14. Turfgrass quality ratings for bahiagrass over all cycles
(Arrows indicate fertilizer application)

RESULTS AND DISCUSSION - 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 63-70).

N rate was significant as in Year 1 with higher ratings as N rate increased (Tables 63-68). 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 67 and 68). 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 63. 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 64. 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 65. 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 66. 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 67. 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 68. 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 69. 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 kg ha^{-1} 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 70. 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 kg ha^{-1} 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 > 6.4mm (irrigation turned off) and High irrigation: 13.0 mm three times weekly

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

PROJECT 2
NITRATE LEACHING AND TURF QUALITY IN ESTABLISHED 'FLORATAM' ST. AUGUSTINEGRASS AND 'EMPIRE' ZOYSIAGRASS

GAINESVILLE – Dr. Laurie Trenholm

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 cm^2) 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 NO_3–N fate if a homeowner were to greatly exceed recommended NRs. Results are reported as annual NO_3–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 NO_3–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. 15. 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.

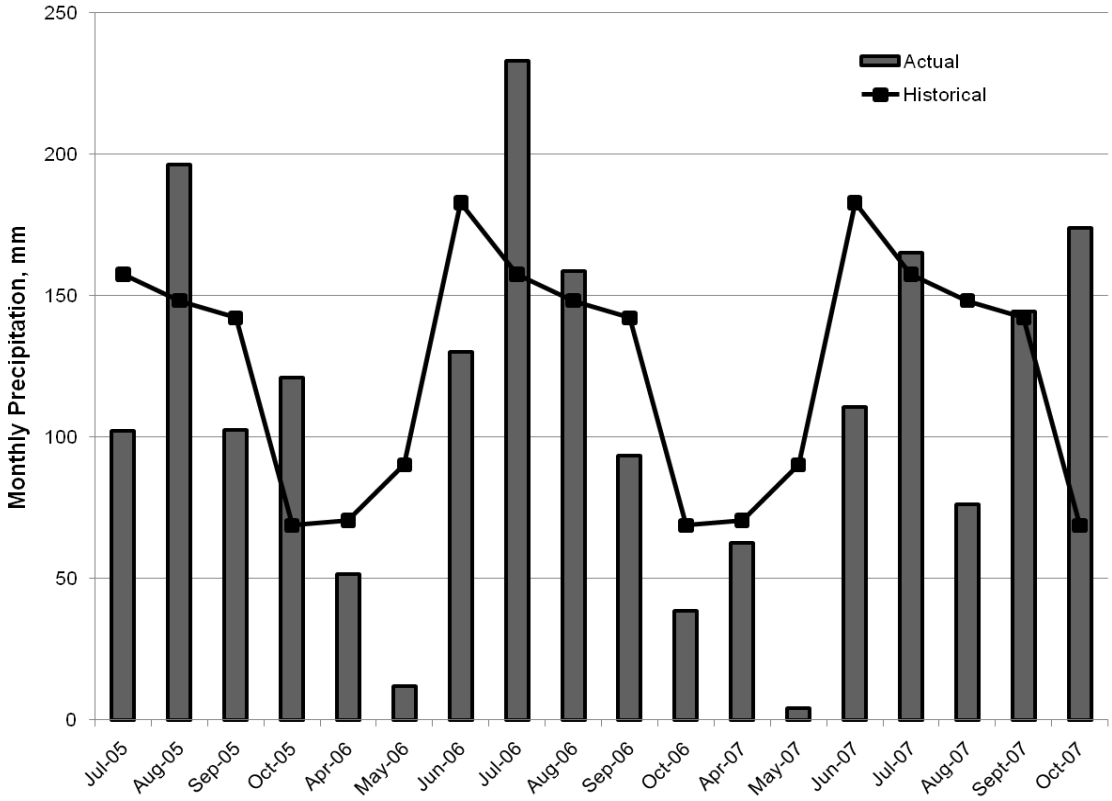

Fig. 15. Monthly precipitation for the months in which research was conducted over the 3-yr study period in Citra, FL.

<u>NO_3–N Leaching</u>

In 2005, NO_3–N mass flux did not differ in response to main effects or interactions (Table 71). 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 71). In 2006, each fertilizer cycle and annual flux had differences in response to the main effect of grass, regardless of interactions (Table 72). In St. Augustinegrass, only the LSFC had differences from NR, while in zoysiagrass, there was a trend towards higher NO_3–N leaching at the highest NR, particularly in the FFC and for annual leaching. In the FFC of 2006, NO_3–N mass flux increased under both IRs as NR increased; however, there were no differences in leaching within NR in response to IR (Table 73). Annual NO_3–N loading was not affected by NR under IR1, while NO_3–N loading increased with NR under IR2. As with the FFC, IR did not affect NO_3–N within NR. Averaged over all other treatments, annual NO_3–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 71. Analysis of variance (ANOVA) for NO_3–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. *P* values listed for all NO_3-N leaching data.

Source of variation	Nitrate-N leached					Turf quality†				
	SFC ‡	ESFC	LSFC	FFC	Annual	SFC	ESFC	LSFC	FFC	Average
				2005						
Nitrogen rate (NR)	NA§	NA	0.65	0.46	0.56	NA	NA	***	NS	**
Grass (G)	NA	NA	0.16	0.31	0.19	NA	NA	***	NS	***
Irrigation (IR)	NA	NA	0.29	0.54	0.37	NA	NA	NS	NS	NS
NR×G	NA	NA	0.31	0.001	0.05	NA	NA	**	***	***
NR×IR	NA	NA	0.93	0.001	0.99	NA	NA	NS	NS	NS
G×IR	NA	NA	0.31	0.31	0.31	NA	NA	NS	NS	NS
NR×G×IR	NA	NA	0.92	0.31	0.50	NA	NA	NS	NS	NS
				2006						
NR	0.32	0.01	0.14	0.03	0.01	***	***	***	***	***
G	0.01	0.001	0.001	0.04	0.001	NS	*	NS	NS	NS
IR	0.01	0.10	0.31	0.26	0.11	*	NS	NS	NS	*
NR×G	0.36	0.02	0.08	0.001	0.06	***	***	***	***	***
NR×IR	0.50	0.96	0.46	0.001	0.06	***	***	***	NS	***
G×IR	0.27	0.31	0.42	0.36	0.10	NS	NS	NS	NS	NS
NR×G×IR	0.08	0.93	0.54	0.27	0.21	NS	NS	NS	NS	NS
				2007						
NR	0.02	0.001	0.002	0.01	0.001	**	***	**	**	**
G	0.01	0.001	0.001	0.01	0.001	*	NS	NS	NS	NS
IR	0.32	0.03	0.01	0.17	0.02	NS	NS	NS	NS	NS
NR×G	0.001	0.001	0.03	0.02	0.001	***	***	***	***	***
NR×IR	0.001	0.17	0.11	0.42	0.001	***	***	***	***	***
G×IR	0.13	0.16	0.18	0.36	0.41	NS	NS	NS	NS	NS
NR×G×IR	0.28	0.27	0.05	0.23	0.03	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 NO_3–N mass flux in 2007 (Table 71). There were no differences in St. Augustinegrass in annual NO_3–N load in response to NR under IR1, while loading was greatest at the highest NR under IR2 (Table 74). There were no differences in NO_3–N loading within NR as influenced by IR. Zoysiagrass had greater annual NO_3–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 NO_3–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} NO_3–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 NO_3–N loading results, particularly in St. Augustinegrass, with some tendency for greater NO_3–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 ET_o. 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 72. Nitrate–N leached from established Floratam St. Augustinegrass and Empire zoysiagrass in response to nitrogen rate (NR) in 2006 and 2007 in Citra, FL.

	Nitrate-N leached									
	St. Augustinegrass					Zoysiagrass				
Annual nitrogen rate	SFC †	ESFC	LSFC	FFC	Annual	SFC	ESFC	LSFC	FFC	Annual
----kg ha^{-1}----	----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 73. 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.

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

† 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 $P = 0.05$

Table 74. 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	Nitrate-N leached		
	IR1†	IR2	*P* Value
------ kg N ha^{-1}------	------ 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	4.1b	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

Regression analysis was done for seasonal total N loading (Figs. 16, 17, 18). The data did not fit a linear or quadratic response in 2005 and 2006 (r^2 = 0.06 and 0.04 for St. Augustinegrass and zoysiagrass, respectively in 2005 and 0.21 and 0.13 for 2006). The fit was better in 2007, with r^2 = 0.32 and 0.68 in St. Augustinegrass and zoysiagrass, respectively. The regression line predicts the increased leaching risk at the higher N rates tested in this study, particularly in zoysiagrass, which is susceptible to injury from disease at high N rates, as evidenced by the higher potential leaching in 2006 and 2007, when the plots receiving the two highest N rates had large patch disease symptoms over much of the plots for parts of the season. In St. Augustinegrass, the increased fit to the linear response was due to disease in the plots that had received 25 lbs of N 1,000 ft^{-2} over the last 2.5 year period, resulting in high disease in the last FC of that year.

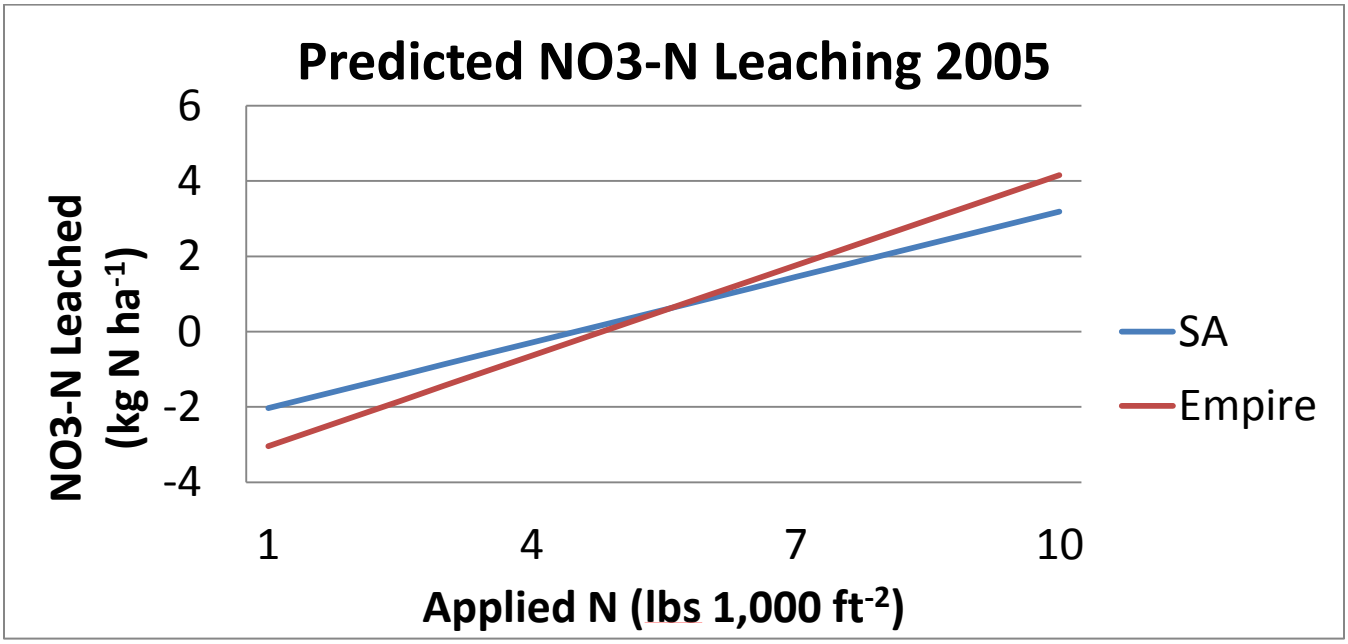
Predicted NO3-N Leaching 2005
NO3-N Leached (kg N ha-1)
6
4
2
0
-2
-4
1
4
7
10
Applied N (lbs 1,000 ft-2)
SA
Empire

Figure 16.

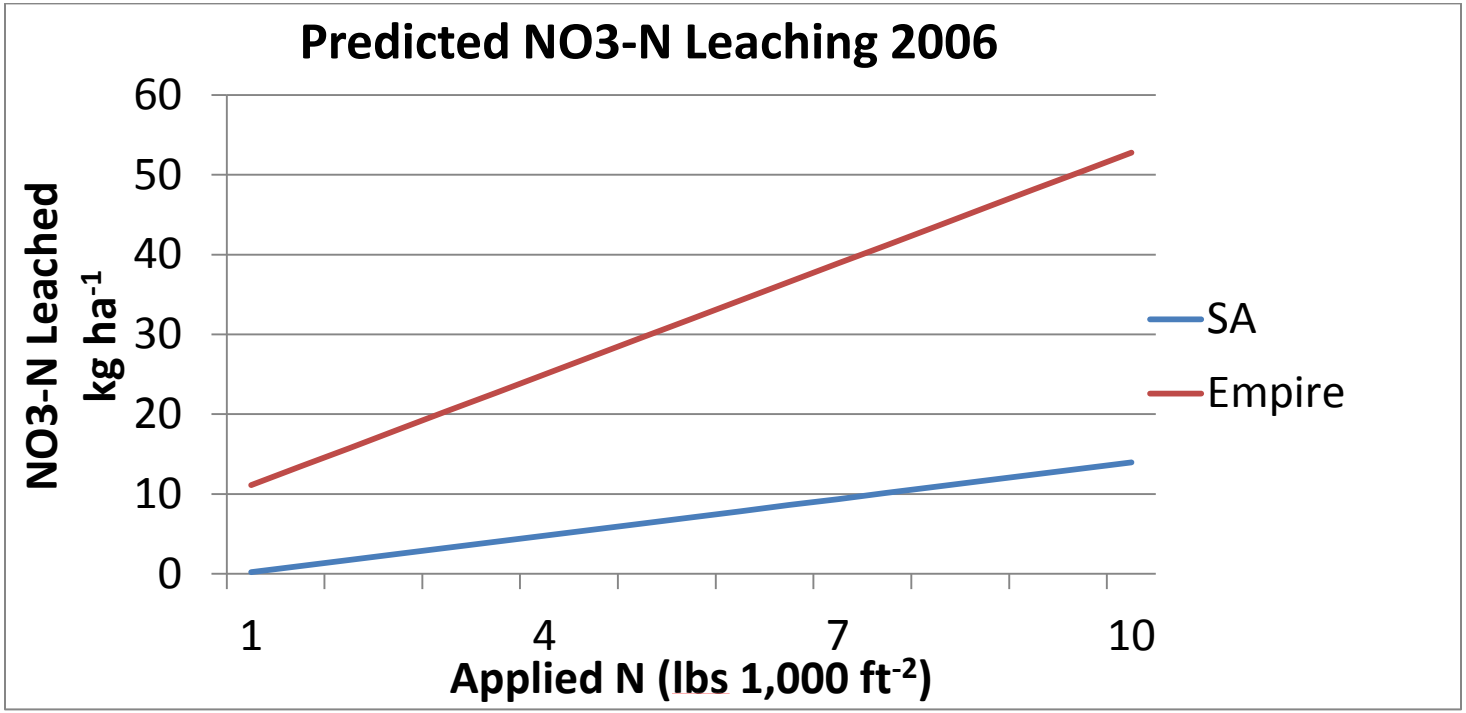
Predicted NO3-N Leaching 2006
NO3-N Leached
kg ha-1
60
50
40
30
20
10
0
1
4
7
10
Applied N (lbs 1,000 ft-2)
SA
Empire

Figure 17.

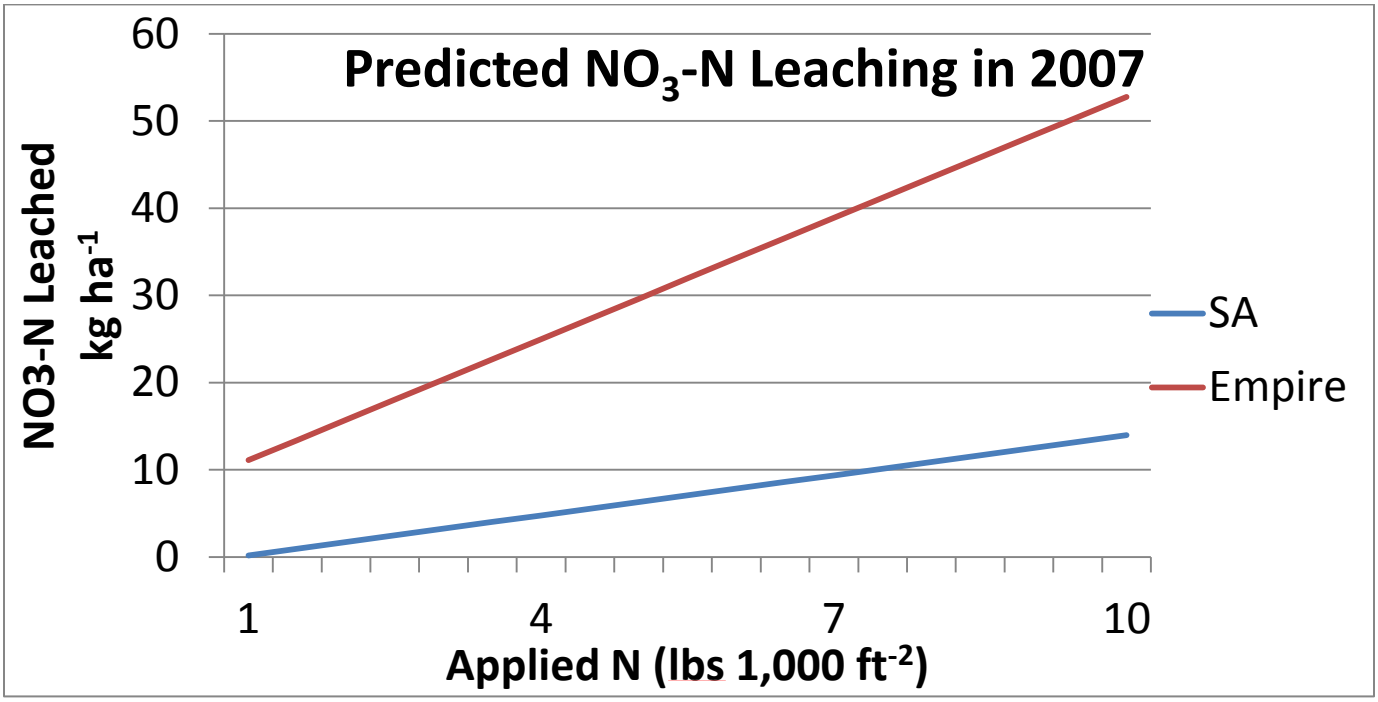
Predicted NO3-N Leaching in 2007
NO3-N Leached
kg ha-1
60
50
40
30
20
10
0
1
4
7
10
Applied N (lbs 1,000 ft-2)
SA
Empire

Figure 18.

Concentration of NO_3–N in percolate ranged from 0.05 to 0.86 mg L^{-1} from St. Augustinegrass for 2006 and 2007 (Table 75), 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 75. Means of NO_3–N concentration in percolate for 2006 and 2007 from established Floratam St. Augustinegrass and Empire Zoysiagrass in Citra, FL.

	Nitrate-N leached			
	2006		2007	
Annual nitrogen rate	St. Augustinegrass	Zoysiagrass	St. Augustinegrass	Zoysiagrass
----kg ha^{-1}----	----------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
ANOVA	2006		2007	
Nitrogen rate (NR)	***		***	
Grass (G)	***		***	
Irrigation (IR)	0.43		**	
NR×G	**		***	
NR×IR	0.85		***	
G×IR	0.42		**	
NR×G×IR	0.37		**	

† 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 NO_3–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 NO_3–N leached (Table 76). This was logical, since green up occurred rapidly in this species. Zoysiagrass had significant correlations with NO_3–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 NO_3–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 NO_3–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 76. Correlation coefficients (r) and probability values (*P*) for NO_3–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.

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

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

There are varying reports of NO_3–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 NO_3–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* Burtt-Davy) putting greens lost 9.1 to 15.2 kg NO_3–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 NO_3–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 NO_3–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 NO_3–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 NO_3–N leaching from zoysiagrass in response to NR and irrigation is consistent with numerous reports of NO_3–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 NO_3–N leached from bermudagrass that received sensor-based irrigation treatments than from plots receiving a daily irrigation regime. Brown et al. (1977) reported that NO_3–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 × grass and NR × IR in 2006 and 2007 (Table 72). 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 77). 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 77). 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 TQ at lower NRs.

Table 77. 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.

	Turf quality†									
	St. Augustinegrass					Zoysiagrass				
Annual Nitrogen Rate	SFC ‡	ESFC	LSFC	FFC	Average	SFC ‡	ESFC	LSFC	FFC	Average
----kg ha^{-1}----					2006					
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
					2007					
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 NO_3–N leaching from fertilization events. Maintenance of a healthy turfgrass cover is critical to reducing NO_3–N leaching, and therefore all turf management practices can be important best management strategies for reducing NO_3–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 ≥196 kg ha^{-1} yr^{-1}. Zoysiagrass showed greater potential for increased NO_3–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 ≤196 kg N ha^{-1} annually, at which rates potential NO_3–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 NO_3–N leaching, particularly from St. Augustinegrass. Further research is needed to determine the impacts of runoff from lawn fertilizers.

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PROJECT 2
EFFECTS OF IRRIGATION AND NITROGEN APPLICATION RATES ON NITROGEN LEACHING FROM ESTABLISHED CENTIPEDE AND ST. AUGUSTINEGRASS TURF

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MATERIALS AND METHODS

Experimental Site and Design

The study was conducted at the University of Florida's West Florida Research and Education Center, (30°46'3N, 87°08'W) on stands of Common Centipedegrass and Floratam St. Augustinegrass grown on native soil identified by the USGA survey as Fuquay loamy sand. The experiment consisted of 64-6m x 3m turfgrass split plots with 4 replications. Whole plots (Irrigation Regime and Turfgrass variety) measure 12m x 12m; and split plots measure 3m x 6m. Sod was established the week of 01 May 2005. Treatments were applied (2005 Yr 1) 08 Jun, 09 Aug, (2006 Yr 2) 14 April, 14 Jun, 11 Aug, (2007 Yr 3) 16 Apr, 14 Jun, and 14 Aug. Grass splits received 4 N rates. Common Centipedegrass 6.103, 12.206, 24.413, and 48.826 N kg $ha^{-1}yr^{-1}$, and Floratam St. Augustinegrass 16.259, 32.713, 65.085, and 97.652 N kg $ha^{-1}yr^{-1}$ from soluble urea, applied as a spray with a volume of 1222 L per hectare. (Yr 1 & 2) both grasses were supplemented with granular applications of 0-46-0, and 0-0-62 for available P and K rates of 48.928 kg $ha^{-1}yr^{-1}$ (Year 3) received K only plus one treatment of sol-u-cal and minors per soil analysis 29 Mar 2007. Leachate collection for volume (mL), NOx-N (mg/L), and Ortho-P (ug/L) analysis (Yr 1, Tx 1) was collected twice weekly began 06 May 2005 and ended 08 Aug 2005 for 28 sampling events, (Yr 1, Tx 2) began 11 Aug 2005 and ended 07 Nov. 2005 for 26 sampling events. The 28 and 26 sampling events included 10 pre-treatment (pre first seasonal application of liquid urea) sampling events, and 8 post-treatment (>60days after last application of liquid urea) sampling events, (Yr 2, Tx 1) began 14 Apr 2006 and ended 12 Jun 2006 for 18 sampling events, (Yr 2, Tx 2) began 15 Jun 2006 and ended 10 Aug 2006 for 17 sampling events, (Yr 2, Tx 3) began 14 Aug 2006 and ended 09 October 2006 for 17 sampling events. The 18, 17, and 17 sampling events for 2006 included 1 pre-treatment, and 0 post-treatment events, (Yr 3, Tx 1) began 12 Apr 2007 and ended 14 Jun 2007 for 19 sampling events, (Yr 3, Tx 2) began 18 June 2007 and ended 13 August 2007 for 17 sampling events. (Yr 3, Tx 3) Leachate collection for volume (mL), and NOx-N (mg/L) only (Ortho-P analysis was suspended 06 Aug 2007 due to it not being a treatment and to diminish a laboratory backlog) began 16 August 2007 and ended 15 October 2007 for 18 sampling events The 19, 17, and 18 sampling events for 2006 included 2 pre-treatment and 1 post-treatment sampling events. For turf establishment irrigation was supplied by 4 Toro Super 800 rotary irrigation heads per plot in a square layout with 4-90° arcs having a precipitation rate of 0.762mm per minute utilizing a programmable controller to deliver pulse irrigation of 4 minutes (3.048mm) 3x per day for days 1-7, followed by 6.35mm per day for days 8-14, followed by 12.70mm twice weekly. To avoid exceeding soil percolation rates trial irrigation regimes used 7 separate start times over 6 hours for the twice weekly at 12.70mm regime and the once weekly at 25.40mm regime. Irrigation was not suspended for rain events. Additional precipitation (from rainfall events) and subsequent increases in leachate were quantified and reported as comparators to non rain event data. Plot preparation followed the installation of plot lysimeters utilizing light tillage, a box blade and drag mats with any settling at lysimeters corrected prior to placement of sod further utilizing a box blade and drag mats. Once plots were established they were maintained at a height of cut of 50.8mm for centipede and 76.2mm for St. Augustine using a rotary mower with clippings left in place.

Collection of Leachate

Using a Toro Dingo skid steer equipped with a 60.96cm power auger, soil was removed to a depth of 106.68cm taking care to keep horizons separated for reconstruction within lysimeters of high density polyethylene (HDPE), having an internal height of 86.36cm, cylinder wall height of 78.74cm, conical section height of 7.62cm, and I.D. of 55.88cm yielding a total volume of 199.333L, supported upon a hot dipped galvanized base having an internal diameter of 57.15cm and constructed such that it has a tank bearing surface ≅ 1935cm^2 and a soil bearing surface ≅ 2355. cm^2 with a total height of 25.4cm that raises the tank 10.16cm allowing for the installation of a bulkhead fitting at the apex of the conical bottom, tapped to receive a 9.525mm MNPT x 9.525mm OD nylon elbow fitting which is connected via 9.525mm low density polyethylene tubing via trench to central lysimeter leachate removal/sampling stations, each servicing 16 lysimeters each. Bore holes were prepped by tamping and leveling soil with a 17kg, 858cm^2 hand tamping tool to a finished depth of 106.68cm allowing for 10.16cm of soil cover above the upper rim of the lysimeter. Lysimeters were prepared with a leaching bed of washed 1.905-4.445cm round river rock having a volume of 0.034m^3 covered with non-woven polyolefin cloth 60.96cm in diameter secured with an internal interference fitted hoop of 1.27cm HDPE tubing. A vent line (to prevent pressure differentials from affecting leaching rates when lysimeters are being sampled) of 9.525cm LDPE of sufficient length to reach from the upper portion of the leach field just below the non-woven polyolefin to several inches above finished grass height was temporarily held to the interior rim of the lysimeter until soil horizons could be reestablished within the lysimeter. Once lowered into the level and prepped bore holes original soil horizons were recreated in 15.24cm lifts within the lysimeter each being packed by dropping the tamping tool from a consistent height, allowing gravity rather than thrust to compact soil consistently. The area surrounding the lysimeter and undisturbed soil was treated in kind. Any settling at lysimeters was corrected prior to seedbed preparation utilizing a box blade and drag mats.

Leaching of NO_3-N + NO_2-N and Ortho-PO_4 was determined by removing all leachate for volume determination and acquiring a grab sample for NO_3-N + NO_2-N and Ortho-PO_4 analysis from each of the 64 lysimeters on a twice weekly basis. (Year 1, Year 2) Sampling was by applying a vacuum to a 2000ml filtering flask (leachate collection trap) preceded by an inline 60ml syringe tap that allowed connection directly to the 9.525mm LDPE leachate tube at the leachate removal/sampling station. The collected leachate was measured for volume utilizing 1000ml graduated cylinders and the samples were usually captured without contamination (appropriately coded if contamination was suspect) by cycling the syringes 3 times utilizing the initial flow of leachate or if volumes were not sufficient to triple rinse with leachate then the syringe was triple rinsed utilizing distilled water prior to applying a vacuum to the collection apparatus. (Year 3) Sampling was by applying a vacuum to a secondary leachate collection trap equipped with a bottom drain, having a capacity greater than any one lysimeter leaching bed and connected via 9.525mm clear PVC tubing to a low volume primary trap constructed such that our 20ml sample vial was the trap. Thus, by triple rinsing the trap head with as little as 60ml of distilled water, connecting directly to the lysimeter leachate tube at the removal/sampling station and fitting our clean sample vial as the trap we were able to collect a contaminate free grab sample from any volume of leachate and by draining the secondary trap to a suspended load cell equipped weighing bucket, volume was inferred from mass, given 1g of pure H_2O at 4°C and 760mm Hg equals 1ml and leachate would vary insignificantly (<1%) at sampling temperatures and pressures.

Sample Analysis

Sample analysis was by colorimetric auto analyzer at the UF/IFAS Analytical Research Laboratory, Gainesville, FL utilizing EPA method 353.2 for NO_3-N + NO_2-N, and 365.1 for Ortho-PO_4. MDL's for NOx and Ortho-P were 0.05mg/L, and 2.5µg/L. PQL's for NOx and Ortho-P were 0.5mg/L and 10µg/L. Linear working ranges for NOx and Ortho-P were 0.50-30.00mg/L and 0.01-0.50mg/L. Laboratory estimates of uncertainty for NOx and Ortho-P have an estimated bias of +0.95 and +1.46 and an estimated precision of ±3.61% and ±3.16%. Note: Precision estimates only apply to laboratory instrumentation and do not include any error associated with sample handling or collection variances and were determined by measuring the dispersion of values obtained from a known certified reference standard using typically 20-30 data points. With this, both bias (average % yield – 100) and precision (standard deviation of % yield) were determined (UF/IFAS Analytical Research Laboratory).

Measures of Turfgrass Quality, Dry Clipping Mass, and Dry Root Mass

Turfgrass visual quality, color, and density assessments were conducted 17 Jun 2005 through 14 Oct 2005 (Year 1), 27 Apr 2006 through 22 Sep 2006 (Year 2), and 02 May 2007 through 15 Oct 2007 (Year 3) on two week intervals or less unless changes were insignificant (which accounts for assessment periods greater than 2 weeks), utilizing NTEP turfgrass evaluation guidelines. Scales are 1-9 with a quality rating of 9 being best and 1 being poorest, color rating of 9 being dark green and 1 light green, and density rating of 9 being maximum density. Any rating 6 or greater is considered generally acceptable. Ratings are generally in whole numbers. Turfgrass clipping samples were collected; 23 and 55 days post year 1 Tx1 08 Jun 2005, and Tx2 09 Aug 2005, every 7-10 days beginning 02 May 2006 (Year 2 Tx1 14 Apr 2006, Tx2 14 Jun 2006, Tx3 11 Aug 2006), approximately every 7 days beginning 02 May 2006 (Year 3 Tx1 16 Apr 2007, Tx2 14 Jun 2007, Tx3 14 Aug 2006). Clippings represented approximately 7 days of shoot growth from a 3.25m^2 areas within each 3m x 6m plot using a rotary mower set at a mowing height of 50.8mm for centipede and 76.2mm for St. Augustine with a modified grass catching system utilizing a 30.48cm by 40.64cm cloth bag in lieu of the manufacturers grass catching system. Samples were dried using forced hot air averaging 50°C for 48 to 72 hours prior to measuring masses.

Following each growing season (Year 1 30 Jan 2006, Year 2 14 Nov 2006, Year 3 18 Oct 2007), 5 root samples were collected using a pedal style soil sampler measuring 20mm dia. x 100mm long, one from each quadrant and one from the center of each plot. Soil, and debris separation from roots was accomplished by washing with water in a sieve accompanied by mechanical pressure and agitation. Separated roots were then air dried followed by oven drying at 50°C for 48-72 hours prior to measuring masses. These masses were corrected for retained mineral materials by ashing the samples and subtracting the mass of the remaining debris minus the ash.

ROOT AND SHOOT GROWTH (2005, 2006 AND 2007)

Centipede turf had greater root dry weight and ash then St. Augustine turf in all three years (Tables 78-80). 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 78-80). 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 78). 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 79). Ash was increased by the 32.83 and 65.17 kg/ha rates (Table 79). No differences in nitrogen rate on root and ash were detected in 2007 (Table 80).

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 81-83). There was no effect of irrigation on shoot growth in all three years (Table 81-83). 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 81). In both 2006 and 2007 both St. Augustine and centipede turf shoot growth increased as the rate of nitrogen applied increased (Table 81-83).

Table 78. 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 79. 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
P(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
P(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
P(F).....	*	*	*NS*
Turf x Irrigation	*NS*	*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). ** and * = P<0.01 and P<0.05, respectively. NS = not significant.

Table 80. 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
P(F).....	***	**	NS
Irrigation			
1.27 cm.....	0.389	0.054	13.65
2.54 cm.....	0.361	0.046	13.15
P(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
P(F).....	*NS*	*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). *** and ** = *P*<0.001 and *P*<0.01, respectively. NS = not significant.

Table 81. 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)	St. Aug	Cent	St. Aug	Cent	St. Aug	Cent	St. Aug	Cent
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 82. 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		11.66 b		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)	St. Aug	Cent	St. Aug	Cent	St. Aug	Cent	St. Aug	Cent	St. Aug	Cent	St. Aug	Cent
16.17.....	1.41 b	5.06 ab	1.47 d	5.40 ab	2.31 c	10.95b	2.95 c	9.41 b	6.02 d	12.78c	1.54 b	5.26 b
32.83.....	1.59 b	1.96 b	2.54 c	3.02 b	4.59 c	9.16 b	7.31 c	6.53 b	15.33c	10.51c	2.92 b	4.12 b
65.17.....	2.32 a	3.06 b	4.58 b	4.63 b	12.39b	14.03b	23.66b	10.94b	38.52b	20.36b	7.04 a	5.15 b
98.00.....	2.47 a	8.53 a	5.90 a	9.18 a	26.68a	23.68a	34.53a	19.78a	51.76a	40.81a	7.94 a	8.59 a
P(F).....	****	*	****	*NS*	****	***	****	***	****	****	****	**
Turf x Irrigation	*NS*		*NS*		*NS*		*NS*		*NS*		*NS*	
Turf x Rate.....	*		*NS*		*		****		****		**	
Irrigation x Rate ...	*NS*		*NS*		*NS*		*NS*		*NS*		*NS*	
Turf x Irr. X rat.....	*NS*		*NS*		*NS*		*NS*		*NS*		*NS*	

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 = Centipedegrass. ****, ***, ** and * = $P<0.0001$, $P<0.001$, $P<0.01$, and $P<0.05$, respectively. NS = not significant.

Table 83. 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	
P(F).....	**		NS		NS	
Irrigation						
1.27 cm.....	4.87		2.57		5.72	
2.54 cm.....	4.23		1.77		6.75	
P(F).....	*NS*		*NS*		*NS*	
Rate (kg/ha)	St. Aug	Cent	St. Aug	Cent	St. Aug	Cent
16.17	1.88 b	4.76 b	0.99 b	5.04	1.86 d	5.91 b
32.83	2.53 b	2.31 b	0.86 b	1.50	3.54 c	4.10 b
65.17	3.81 a	4.19 b	1.20 a	1.95	6.45 b	6.51 b
98.00	4.04 a	12.91 a	1.31 a	4.53	8.36 a	13.15 a
P(F).....	****	***	***	*NS*	****	**
Interactions						
Turf x Irrigation	*NS*		*NS*		*NS*	
Turf x Rate.....	***		*NS*		*NS*	
Irrigation x Rate	*NS*		*NS*		*NS*	
Turf x Irr. X rate.....	*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 88). 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 84 and 85). Slightly higher density was observed with increasing nitrogen rates (Table 86).

In 2005 and 2006, increasing nitrogen rate produced better turf quality, color, and density (Tables 84-89). By the end of the 2006 growing season, good turf quality was obtained with single application rates ≤ 98.00 kg ha^{-1}. Plots receiving 16.17 kg ha^{-1} had quality slightly below an acceptable level (Table 87). 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 90-92).

Table 84: Effect of irrigation and N-application rate on established St. Augustine 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	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 85: Effect of irrigation and N-application rate on established St. Augustine 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	7.7	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
P(F)	*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 bc	6.8	7.1	7.6	7.6 b	7.2 b	6.9 b	6.3 b
65.17	7.8	7.6 ab	6.9	7.3	7.8	7.9 a	7.6 a	7.1 ab	6.6 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
P(F)	*NS*	**	*NS*	*NS*	*NS*	***	***	*	*
Irr. x Rate	*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 86: Effect of irrigation and N-application rate on established St. Augustine 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	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
P(F)	*NS*	*NS*	*NS*	*NS*	*NS*	*NS*	*NS*	*NS*	*NS*
Rate (kg/ha)									
16.17	8.4	8.2 b	8.3	8.3 b	8.8	8.9	9.0	9.0	9.0
32.83	8.4	8.5 ab	8.4	8.4 ab	8.8	9.0	9.0	9.0	9.0
65.17	8.4	8.8 a	8.6	8.7 a	9.0	9.0	9.0	9.0	9.0
98.00	8.3	8.8 a	8.6	8.7 a	8.9	9.0	9.0	9.0	9.0
P(F)	*NS*	**	*NS*	*	*NS*	*NS*	*NS*	*NS*	*NS*
Irr. x Rate	*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*<0.01 and *P*<0.05, respectively. NS = not significant.

Table 87: 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 88: 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 89: 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 90: 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	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	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	5.4b	5.0	4.6c	6.1b	6.1b	6.9c	6.4b	6.7
32.83	2.4	3.1	4.3	4.8	4.6	5.1	5.7	5.9ab	5.6	5.6b	6.6b	6.6b	7.4bc	6.7b	6.9
65.17	2.4	3.0	4.1	4.6	4.4	5.4	6.3	6.5a	6.0	6.3a	7.6a	7.6a	7.9ab	7.4a	7.6
98.00	2.1	2.8	3.8	4.7	4.4	4.9	6.0	6.6a	5.8	6.3a	7.9a	7.9a	8.0a	7.4a	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 91. 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
P(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	6.5b	6.6b	6.9b	6.4b	6.4b	7.4b	6.5 c	7.0
32.83	3.3	6.8	5.8	6.3	5.9	6.5	6.4	6.9ab	6.9b	7.3b	6.9b	6.9b	7.4b	6.8 bc	7.0
65.17	3.4	6.9	5.8	6.5	6.2	6.8	6.8	7.2a	7.9a	8.3a	7.8a	7.8a	8.1a	7.4 ab	7.3
98.00	3.1	6.8	5.1	5.8	6.2	6.9	6.9	7.5a	8.1a	8.4a	8.2a	8.2a	8.3a	7.4 a	7.3
P(F).....	*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*

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 92: 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	5.9b	6.2	5.9c	6.1b	6.3b	6.4b	6.4c	6.7c
32.83	4.4	3.4	4.8	5.1	4.8 a	5.3	6.0	6.8a	6.3	6.5bc	6.4b	6.6b	7.3a	6.7bc	7.1bc
65.17	4.4	3.4	4.6	4.8	4.4 ab	5.7	6.4	7.1a	6.6	7.4a	7.5a	7.8a	7.8a	7.5a	7.9a
98.00	4.1	3.0	4.2	4.8	4.0 b	5.0	6.3	7.1a	6.4	6.9ab	7.5a	8.0a	7.7a	7.4ab	7.7ab
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

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 93).

***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 98 and 100). 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 21). 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 21).

When comparing the percentage of applied nitrogen between nitrogen application Rates, the 0.33 lb 1,000 ft-2 1,000 ft^{-2} consistently leaching 0.7%; 0.67 and 1.33 lb 1,000 ft-2 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 93. Effect of irrigation and N-application rate on total N (MDL) on St. Augustine turf in 2005.

	Total N (kg/ha)						
	Pre	T1	T2	T3	T4	T5	Total Post
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
P(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
P(F).....	*	*NS*	*NS*	*NS*	*NS*	*NS*	*NS*
Irrigation x Rate	*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 94. Effect of irrigation and N-application rate on total N (MDL) on St. Augustinegrass turf in 2006.

	Total N (kg/ha)							
	Pre	T1	T2	T3	T4	T5	T6	Total Post
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
P(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
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 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 95. 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	0.129 a	0.128	14.483
2.54 cm	0.495	2.467	3.064	7.366	0.460	0.078 b	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.

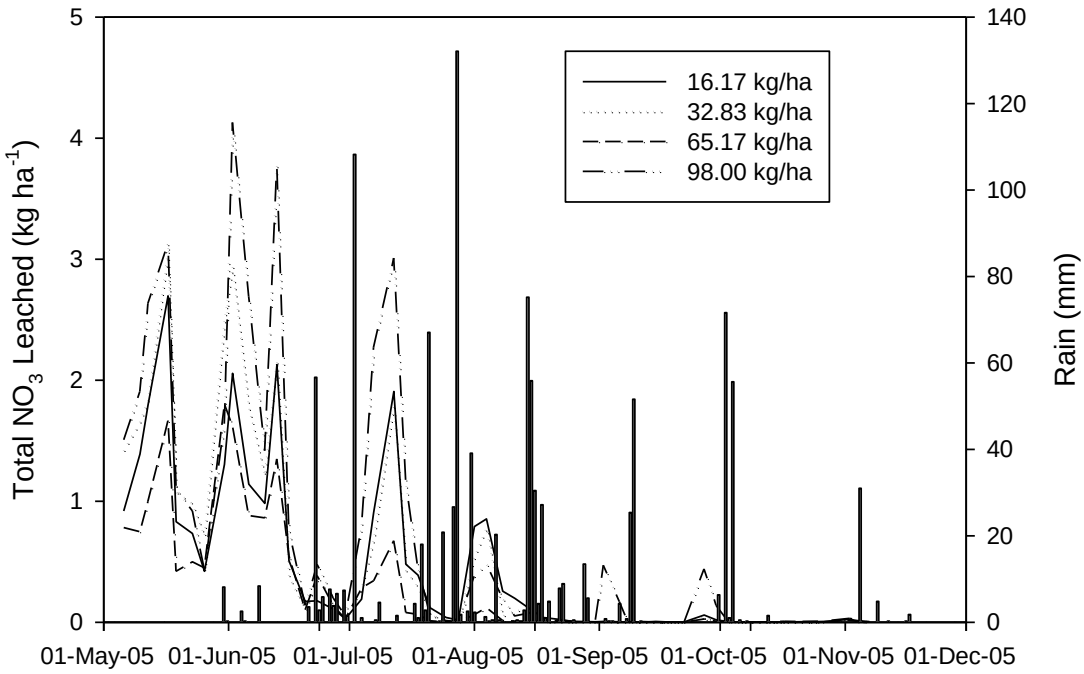

Figure 19: Total NO_3 leached from different nitrogen rates applied to established St. Augustinegrass in 2005 and the corresponding rainfall that occurred.

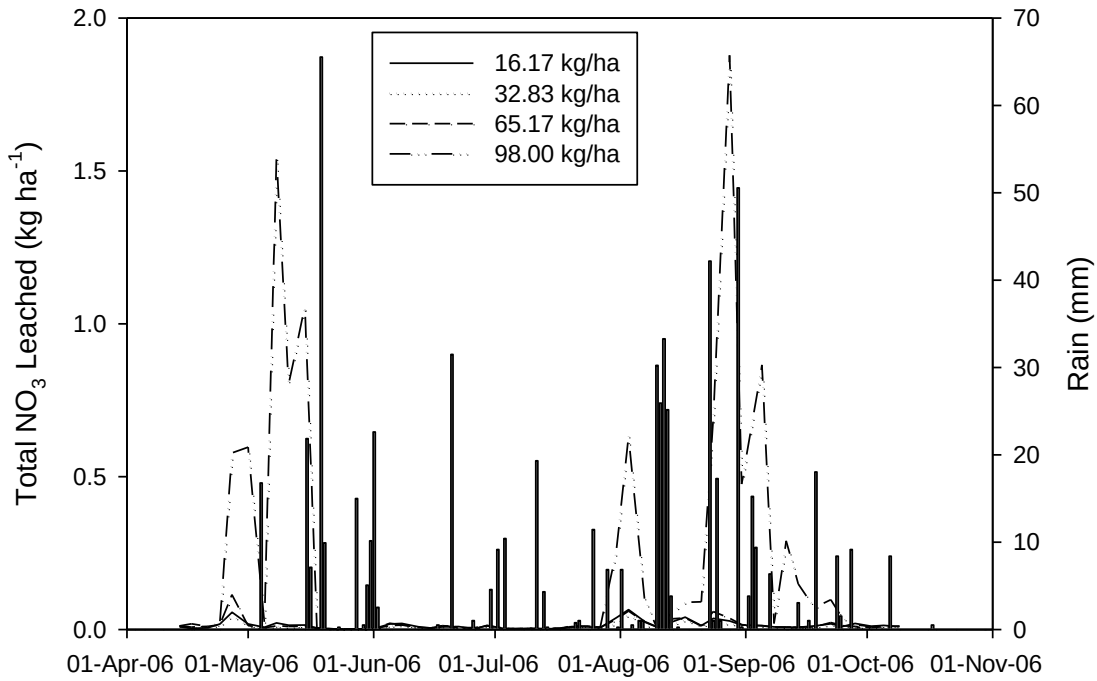

Figure 20: Total NO_3 leached from different nitrogen rates applied to established St. Augustinegrass in 2006 and the corresponding rainfall that occurred.

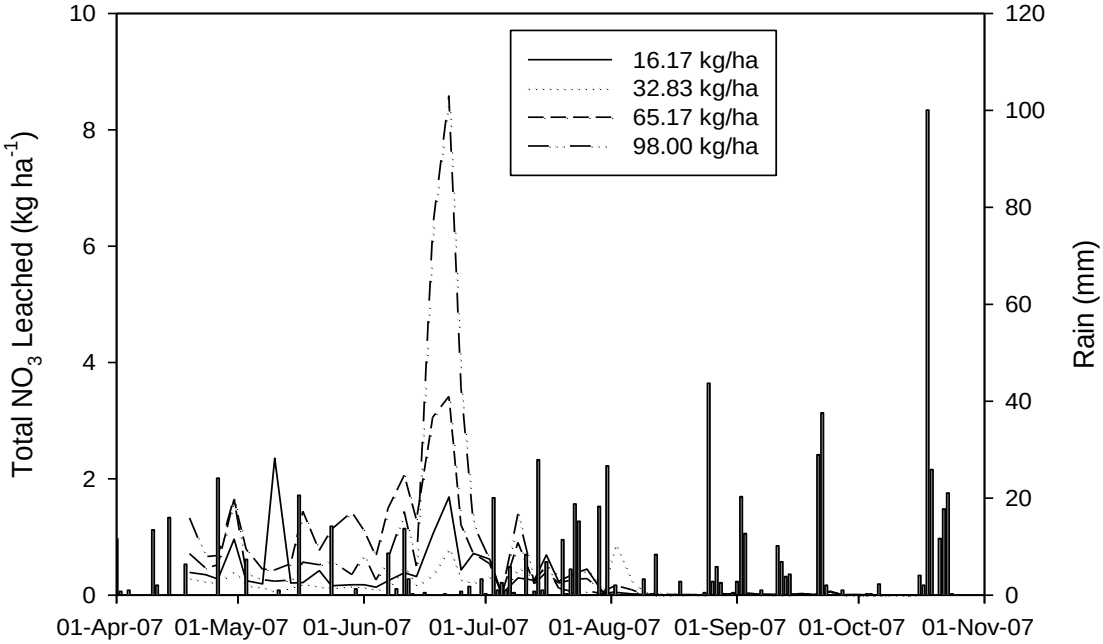

Figure 21: Total NO_3 leached from different nitrogen rates applied to established St. Augustinegrass in 2007 and the corresponding rainfall that occurred.

Table 96. 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
P(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
P(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
P(F)	*	*NS*	*NS*	*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*	*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 97. 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	28.80 a	7.76	5.89	18.08	9.38 a	1.28 a	0.66 a	40.07
32.83	18.73 a	2.69	2.56	8.86	4.73 ab	0.42 b	0.23 b	18.36
65.17	5.41 b	2.69	2.86	7.02	0.91 b	0.17 b	0.11 c	11.93
98.00	7.09 b	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 98-103). However, a single, weekly irrigation event yielded a slight improvement in color and quality in May 2007 (Table 104-106).

Nitrogen Rate: A notable quality, color, and density response was observed in all three years of the study (Tables 98-106). 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 104). The lower nitrogen rates resulted in poorer turf color during spring green-up in 2006 and 2007 (Tables 102 and 105, respectively). Turf density waned over the three years and was most negatively affected by low nitrogen (≤ 12.25 kg ha^{-1}) in spring 2007 (Table 106).

Table 98: 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
P(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 bc	7.0 bc	6.9 c	7.1 bc	7.6 bc	7.9 c	7.9 c	7.4 c	7.4 bc
24.50	6.9 b	7.2 b	7.4 b	7.4 b	7.9ab	8.3 b	8.3 b	7.9 b	7.8 b
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
P(F)	**	****	****	***	**	****	****	****	****
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, and *P*<0.01, respectively. NS = not significant.

Table 99: 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
P(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 bc	6.8 c	6.8 b	7.0 b	7.6	7.5 c	7.6 c	7.1 c	7.4 b
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
P(F)	****	****	****	****	*NS*	****	****	****	****
Irr. x Rate	*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 100: 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
P(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 ab	7.3 b	7.3 b	7.4 b	7.9 c	8.2 c	8.6 b	8.7 b	9.0
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
P(F)	*	***	**	**	****	****	****	****	*NS*
Irr. x Rate	*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 101: 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
P(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
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, *P*<0.001, and *P*<0.01, respectively. NS = not significant.

Table 102: 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
P(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
P(F).....	**	**	*	*NS*	****	****	***	****	****	****
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, *P*<0.001, *P*<0.01, and *P*<0.05, respectively. NS = not significant.

Table 103: 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
P(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
P(F).....	*NS*	*	*NS*	**	**	****	****	***	****	***
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). ****, ***, **, and * = *P*<0.0001, *P*<0.001, *P*<0.01, and *P*<0.05, respectively. NS = not significant.

Table 104: 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					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	5.6 b	6.9	6.6 b	6.6 b	6.3	7.2	7.0	6.9	7.1	7.6	7.5	7.5	7.8	7.3	7.5
2.54 cm	6.1 a	7.0	6.9 a	6.9 a	6.3	7.2	6.8	7.0	7.3	7.8	7.7	7.7	7.6	7.3	7.7
P(F)	*	*NS*	*	*	*NS*	*NS*	*NS*	*NS*	*NS*	*NS*	*NS*	*NS*	*NS*	*NS*	*NS*
Rate (kg/ha)															
6.13	5.1 c	6.4 c	6.2 c	6.2 c	6.0 b	6.2 d	6.1 c	6.0 c	6.1 d	6.8 c	6.6 d	6.6 d	6.9 d	6.6 d	6.9 c
12.25	5.5 bc	6.4 c	6.4 c	6.4 c	6.1 b	6.6 c	6.3 c	6.3 c	6.6 c	7.1 c	7.1 c	7.1 c	7.3 c	6.9 c	7.0 c
24.50	6.0 b	6.9 b	6.7 b	6.7 b	6.3 b	7.5 b	7.1 b	7.2 b	7.7 b	8.1 b	8.1 b	8.1 b	8.1 b	7.4 b	7.8 b
49.00	6.6 a	8.0 a	7.8 a	7.8 a	7.1 a	8.5 a	8.1 a	8.3 a	8.3 a	8.7 a	8.5 a	8.5 a	8.6 a	8.2 a	8.7 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 105. 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	6.6 b	6.6 b	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	6.9 a	6.9 a	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	6.4 b	6.4 c	6.2 c	6.2 c	6.0 b	6.0 c	6.3 c	5.9 d	6.1 d	6.8 c	6.4 d	6.4 d	6.9 c	6.6 c	6.9 c
12.25	6.8 b	6.4 c	6.3 c	6.3 c	6.1 b	6.1 c	6.3 c	6.2 c	6.5 c	7.1 c	6.8 c	6.8 c	7.1 c	6.9 c	7.0 c
24.50	6.8 b	7.1 b	6.7 b	6.7 b	6.1 b	7.3 b	6.9 b	7.0 b	7.4 b	8.2 b	8.0 b	8.0 b	7.9 b	7.3 b	7.6 b
49.00	8.4 a	7.9 a	7.7 a	7.7 a	6.7 a	8.4 a	8.1 a	8.3 a	8.3 a	8.8 a	8.5 a	8.5 a	8.6 a	8.2 a	8.4 a
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 106: 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	5.6 c	6.9 c	6.2 c	6.2 c	6.0 c	6.1 d	6.1 c	6.0 c	6.1 c	6.7 c	6.9 d	6.5 d	6.9 d	6.6 d	6.9 c
12.25	6.1 b	7.1 bc	6.4 bc	6.4 bc	6.0 c	6.6 c	6.3 c	6.3 c	6.6 b	7.1 c	7.3 c	7.1 c	7.3 c	7.0 c	7.0 c
24.50	6.0 bc	7.3 b	6.7 b	6.7 b	6.4 b	7.8 b	7.2 b	7.3 b	7.8 a	8.1 b	8.0 b	8.0 b	8.0 b	7.4 b	7.9 b
49.00	6.8 a	8.0 a	7.7 a	7.7 a	7.3 a	8.4 a	8.3 a	8.3 a	8.1 a	8.6 a	8.5 a	8.5 a	8.6 a	8.3 a	8.7 a
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.

Nitrate Leaching – 2006

***Irrigation Frequency**:* The effect of irrigation frequency was not significant in 2005, 2006 and 2007 or when analyzed across years (Tables 107-110). 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 107 and 109). 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 108). 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 110). 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 107. Effect of irrigation and N-application rate on total N (MDL) on centipede turf in 2005.

	Total N (kg/ha)						
	Pre	T1	T2	T3	T4	T5	Total Post
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
P(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
P(F).....	*NS*	*NS*	*NS*	*NS*	*NS*	*NS*	*NS*
Irrigation x Rate	*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 108. Effect of irrigation and N-application rate on total N (MDL) on centipede turf in 2006.

	Total N (kg/ha)							
	Pre	T1	T2	T3	T4	T5	T6	Total Post
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
P(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
P(F).....	*NS*	*	*	*NS*	*NS*	*NS*	*NS*	*NS*
Irrigation x Rate	*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 109. 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
P(F).....	*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
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). NS = *P*>0.05.

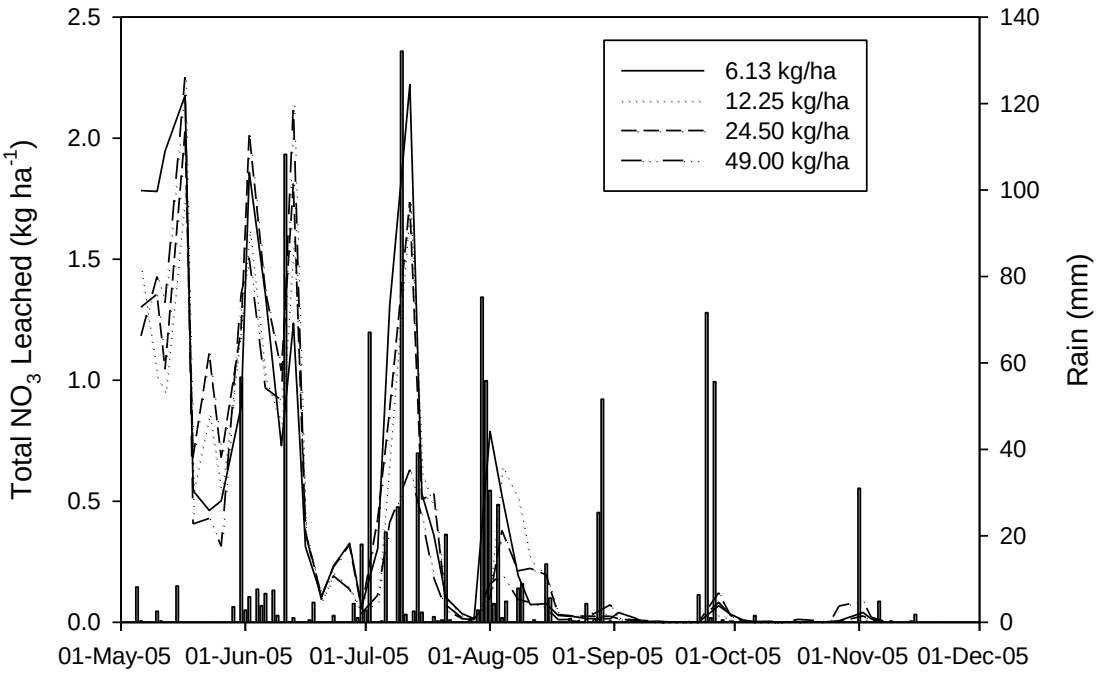

Figure 22: Total NO_3 leached from different nitrogen rates applied to established St. Augustinegrass in 2005 and the corresponding rainfall that occurred.

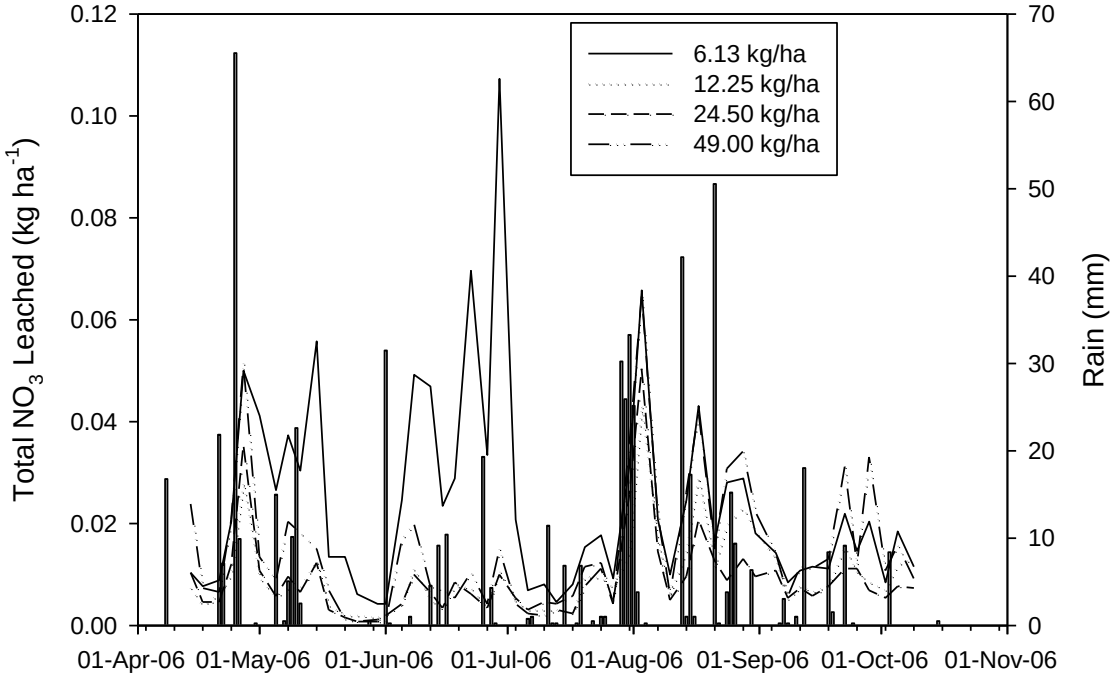

Figure 23: Total NO_3 leached from different nitrogen rates applied to established centipedegrass in 2006 and the corresponding rainfall that occurred.

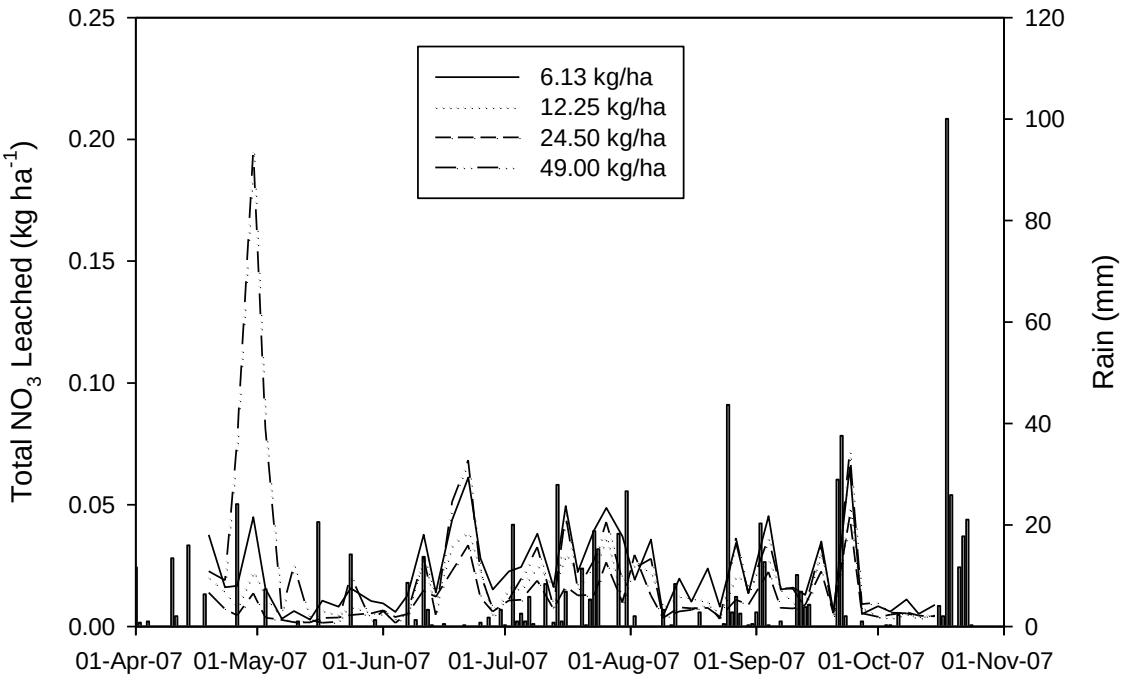

Figure 24: Total NO_3 leached from different nitrogen rates applied to established Centipedegrass in 2007 and the corresponding rainfall that occurred.

Table 110. 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	3.334 a	0.276	0.113	8.822 a
2006	0.009 b	0.129	0.071	0.058 b	0.143 b	0.159	0.092	0.651 b
2007	0.081 b	0.176	0.084	0.226 b	0.167 b	0.129	0.127	0.910 b
P(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
P(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
P(F)	*NS*	*NS*	*	*NS*	*NS*	*NS*	*NS*	*NS*
Year x Irr.	*NS*	*NS*	*NS*	*NS*	*NS*	*NS*	*NS*	*NS*
Year x Rat	*NS*	*NS*	*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*	*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 111. 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
P(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
P(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
P(F)	****	****	****	****	*	****	****	***
Year x Irr.	NS	NS	NS	NS	NS	NS	NS	NS
Year x Rat	****	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	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.

STATEWIDE ANALYSIS OF PROJECT 2
EFFECT OF N RATE ON NITRATE-N LEACHING IN ESTABLISHED GRASSES

EXECUTIVE SUMMARY

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 NO_3-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 NO_3-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 NO_3-N leaching and it is important that proper turf management practices are followed to maintain a healthy stand of turf.

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 NO_3-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 NO_3-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. 'Floratam' 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 NO_3-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 NO_3-N leaching data are reported for the 3-yr period and annually and percent of applied N leached is reported by year.

Table 112. 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 Figures 25, 26 and 27 for each of the locations over the trial period. Events that produced greater than 25 mm in a day are considered excessive.

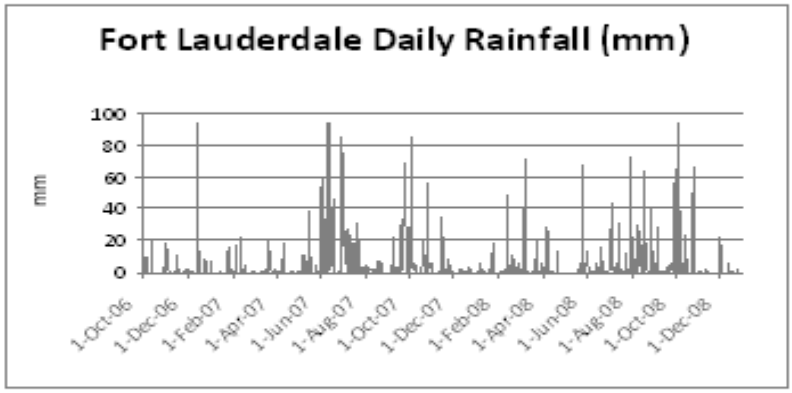

Fig. 1 Daily rainfall (mm) in Ft. Lauderdale during the study period.

Figure 25.

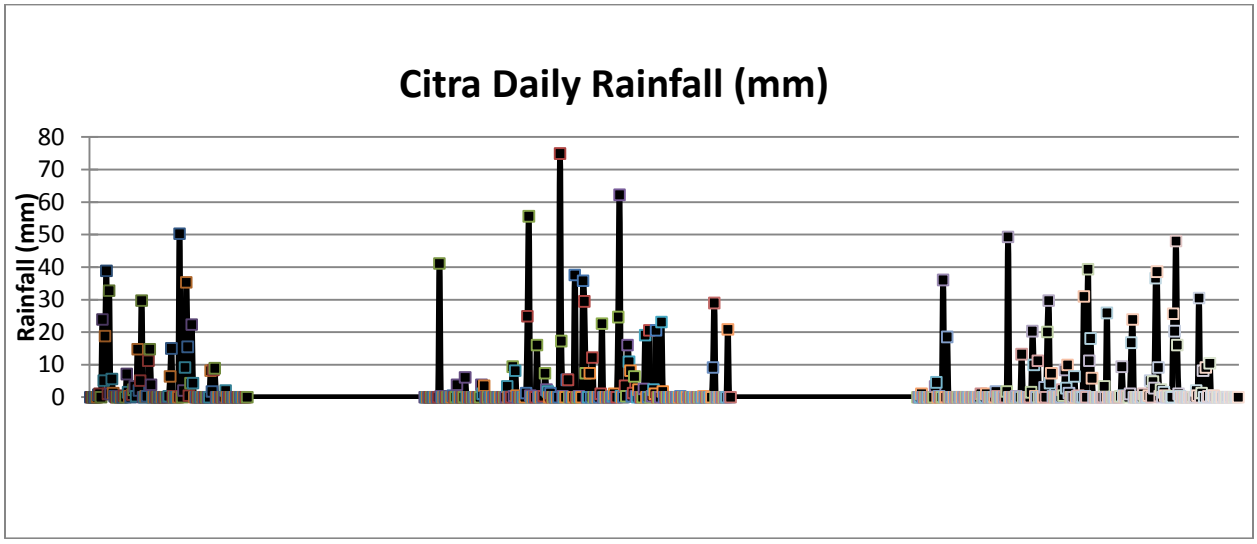

Figure 26.

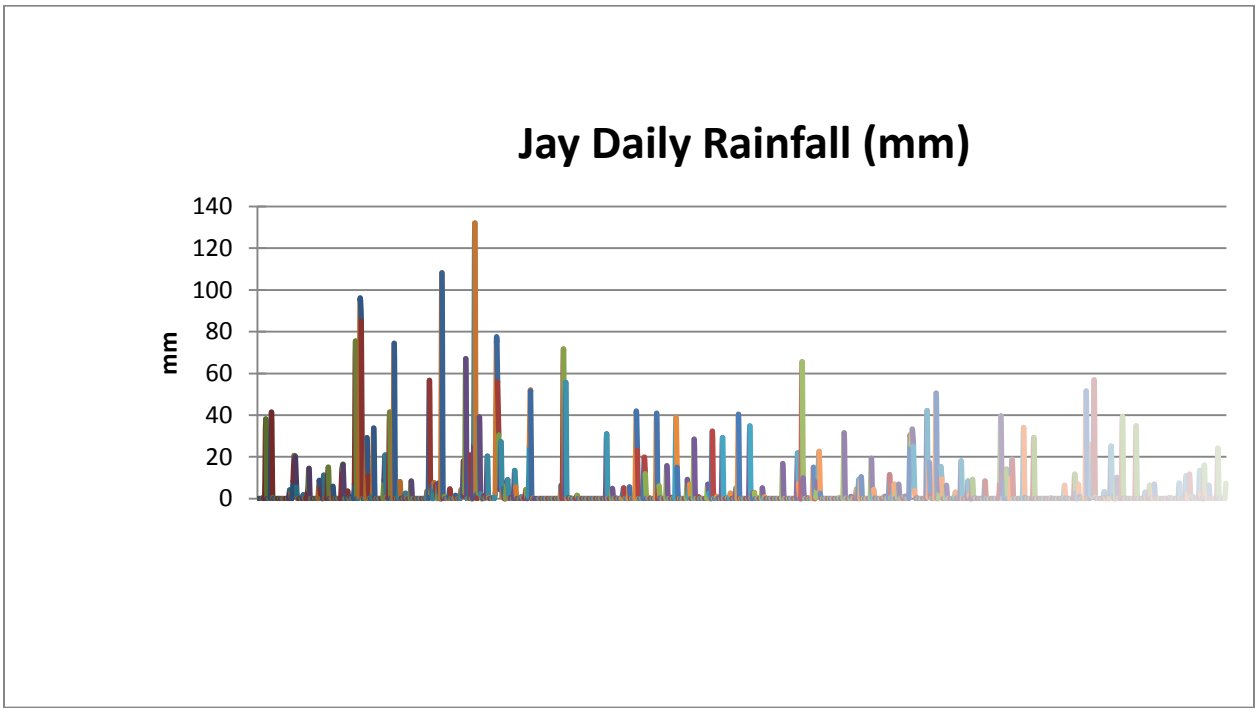

Figure 27.

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 113). Highest loading was in the Jay location, with no differences between Ft. Lauderdale and Citra (Table 113). In year 2, the only difference was due to N rate (Table 113), 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 114.

Table 113. Analysis of variance of main effects and interactions on NO_3-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
Location (L)	**	0.12	*	**	**	0.12	0.16
Nitrogen Rate (NR)	0.45	*	0.62	0.37	***	***	0.91
L*NR	0.11	0.42	0.46	0.36	**	0.15	0.82
Irrigation (I)	0.62	0.12	0.80	0.92	0.53	0.16	0.34
L*I	0.86	0.12	0.85	0.93	0.63	*	0.48
NR*I	0.30	0.89	0.40	0.50	0.19	0.83	0.62
L*NR*I	0.52	0.15	0.37	0.47	0.44	0.07	0.45
R^2	0.48	0.18	0.27	0.38	0.48	0.26	0.19
Contrasts - NR							
196 vs 49 kg ha^{-1}	0.08	0.97	*	0.13			
196 vs 98 kg ha^{-1}	0.32	0.96	0.80	0.32			
196 vs 294 kg ha^{-1}	0.06	0.94	0.50	0.06			
196 vs 343 kg ha^{-1}	0.70	0.08	0.39	0.96			
196 vs 490 kg ha^{-1}	0.91	***	0.96	0.47			
196 vs 588 kg ha^{-1}	0.68	0.98	0.16	0.79			
R^2	0.27	0.50	0.37	0.26			

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 or *P* value listed.

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 NO_3-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 NO_3-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 NO_3-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 NO_3-N loading by location for year 2 indicated that leaching was greater in Citra than in Ft. Lauderdale (Table 113).

Single degree of freedom contrasts between NRs are displayed in Table 114. In year 1 and over the 3-year study period, there were no differences in NO_3-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 NO_3-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 114. 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 NO_3-N leached in year 2 only (Fig 28), 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, NO_3-N leaching did not increase in a linear fashion with NR.

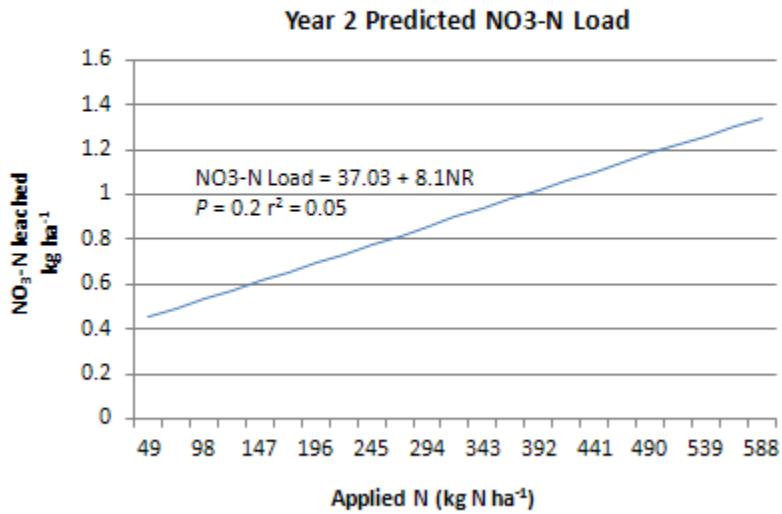

Figure 28.

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 NO_3-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 form 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 NO_3-N leaching. Frank et al. (2006) reported higher total NO_3-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 NO_3-N levels in excess of the USEPA safe levels of 10 mg NO_3-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 NO_3-N losses for this treatment totaled 32 kg NO_3-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 NO_3-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 NO_3-N leached from bermudagrass (*Cynodon dactylon* L. x *C. transvaalensis* Burtt-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 NO_3-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 NO_3-N leaching include N source (Easton and Petrovic, 2004; Guillard and Kopp, 2004; Saha et al., 2007). Some published reports have noted differences in NO_3-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 NO_3-N leaching. Maturity of the grass has been noted by numerous researchers as impacting NO_3-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 113). 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 114). This is a typical response from lower NRs, as low levels of applied NO_3^--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 114). 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, NO_3-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 NO_3-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 NO_3-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 NO_3-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 NO_3-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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PROJECT 3
NITRATE LEACHING DUE TO N SOURCE AND TIMING ON ST. AUGUSTINEGRASS

FT. LAUDERDALE – Dr. John Cisar

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.

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. 'Floratam'. 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 115. 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 CO_2 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 115. 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 (NO_3-N Colorimetric, EPA Method 353.2). Data reported in mg NO_3-N leached m^{-2}.

St. Augustinegrass clipping yield, visual ratings, and NO_3-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 116).

Table 116. Hydrology data by cycle for N Source and Frequency Test.

	Hydrology Factors		
Cycle (C) x rate	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 115). In cycle 1 PCU and BS were slow to induce satisfactory ratings (Table 117). Cumulative turf quality increases during cycle 2 suggest residual N release from preceding applications may be sufficient to sustain adequate turf quality (Table 117). 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 118). 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 117). 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 117 and 118).

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 117).

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 118). 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 ≥ 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 118).

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 117 and 118), 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 118). 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 117 and 118).

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 117). 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 118). 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 117. Turfgrass quality ratings from 30 April through 30 October, 2007 as influenced by N source.

Source§	St. Augustinegrass Quality Rating Dates													
	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	Avg.¶
	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 ----------					
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 ----------													
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 117 and 119). 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 118. Clipping yields from 29 April through 30 October, 2007 influenced by N source.

Source§	St. Augustinegrass Harvest Dates													
	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	Avg. ¶
	---------- Growth Rate (g m^{-2} d^{-1}) ----------													
60-d Cycle	-------- Cycle 1 --------			---------- Cycle 2 ----------					---------- Cycle 3 ----------					
DAT†	**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‡	0.32bcd	0.32b-e	0.27d	1.09bc	0.35de‡	0.40de
BS1	0.17cde	0.57de	0.08de‡	0.68cde	2.1b	0.93bcd	0.34bcd	0.50bcd‡	0.36bcd	0.46bcd	0.34cd	0.77cd	0.25def‡	0.58bc
UPCU1	0.18cde	0.40de	0.06de‡	0.75cde	1.75bcd	1.22bc	0.32bcd	0.46bcd‡	0.45ab	0.60ab	0.72b	1.24b	0.43bcd‡	0.66b
Urea	0.27bc	0.65cde	0.09cde‡	1.74ab	1.82bcd	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 ----------					
DAT†	**32**	**52**	**59**	**72**	**80**	**89**	**102**	**117**	**7**	**17**	**32**	**42**	**56**	
CRL2	0.25bcd	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	1.05bcd	2.00bc	1.25bc	0.56b	0.73b‡	0.43abc	0.34b-e	0.64bc	1.48b	0.63ab	0.77ab
BS2	0.20cde	0.75bcd	0.11bcd	0.60cde	1.05de	0.80bcd	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	1.03bcd	0.28c-f	0.37b-d‡	0.32bcd	0.56b	1.16a	1.95a	0.86a	0.83ab
180-d Cycle	---------- Cycle 1 ----------													
DAT†	**32**	**52**	**59**	**72**	**80**	**89**	**102**	**117**	**131**	**141**	**156**	**166**	**180**	
CRL3	0.43a	0.80bcd	0.11bcd	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	0.22bcd	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 119. Turfgrass color ratings from 29 April through 30 October, 2007 as influenced by N source.

Source§	St. Augustinegrass Color Rating Dates													
	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	Avg. ¶
	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 120. Turfgrass density influenced by N source and application frequency.

Source	Rating Dates			
Code§	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 120). One month after the initiation of the trial, turfgrass density was improved by increasing N with the first application date (Table 120). By the end of the 6 month trial period, turfgrass density declined somewhat compared to the initial rating (Table 120). 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 120). The best average treatment for density over the entire period was the UPCU2 treatment (Table 120). The UPCU2 treatment was statistically better than all treatments except the BS2, and PCU2 treatments (also quarterly application frequency).

NO_3-N Leaching

Regardless of the application rate or timing frequency the SRNS tested had significantly ($P<0.05$) lower levels of NO_3-N leaching. Only CRL at 147 kg N ha^{-1} resulted in NO_3-N losses in excess of 1% applied N (Table 121). 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 NO_3-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 NO_3-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 NO_3-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 121. NO_3-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			Total NO_3-N Leached	Total N Applied	NOx-N Leached
	---------- mg m^{-2} ----------						-- % --
		-- 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}.

CONCLUSIONS

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 NO_3-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. 29 and 30)

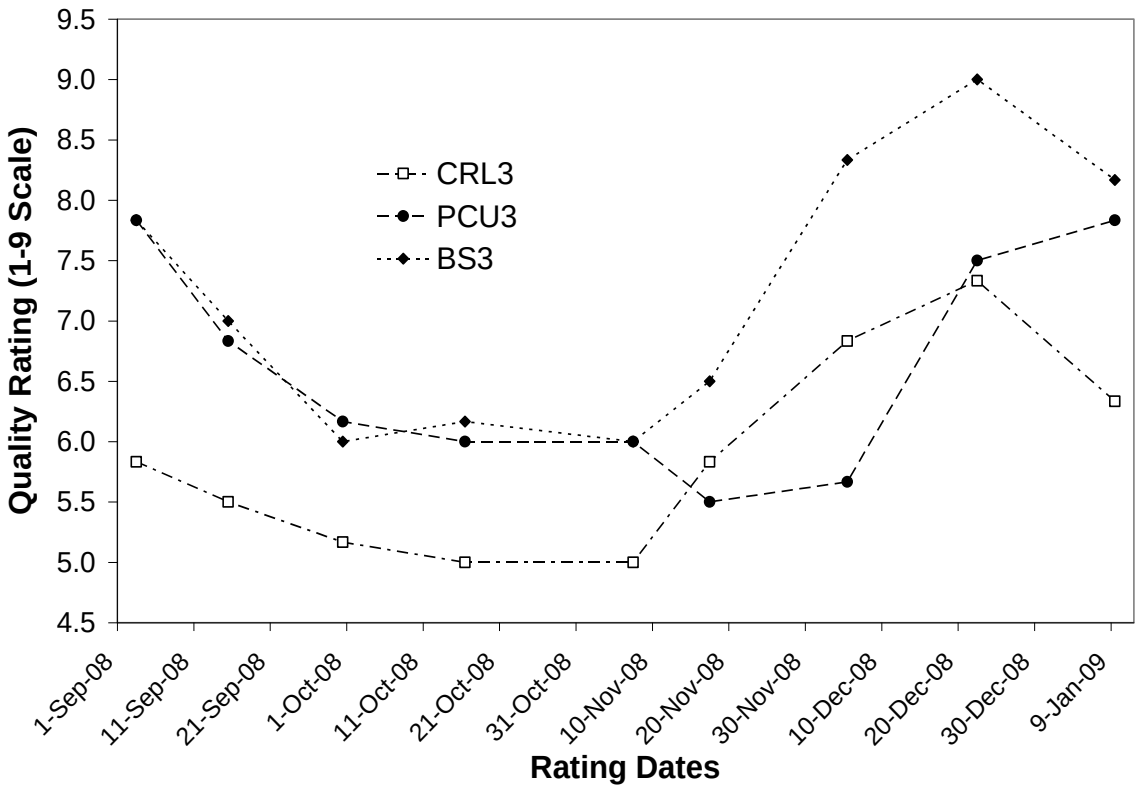

Figure 29**.** St. Augustinegrass quality from September 1, 2008 through January 9, 2009 for slow-release N sources applied at 147 kg N ha^{-1}. Arrow indicates fertilization events.

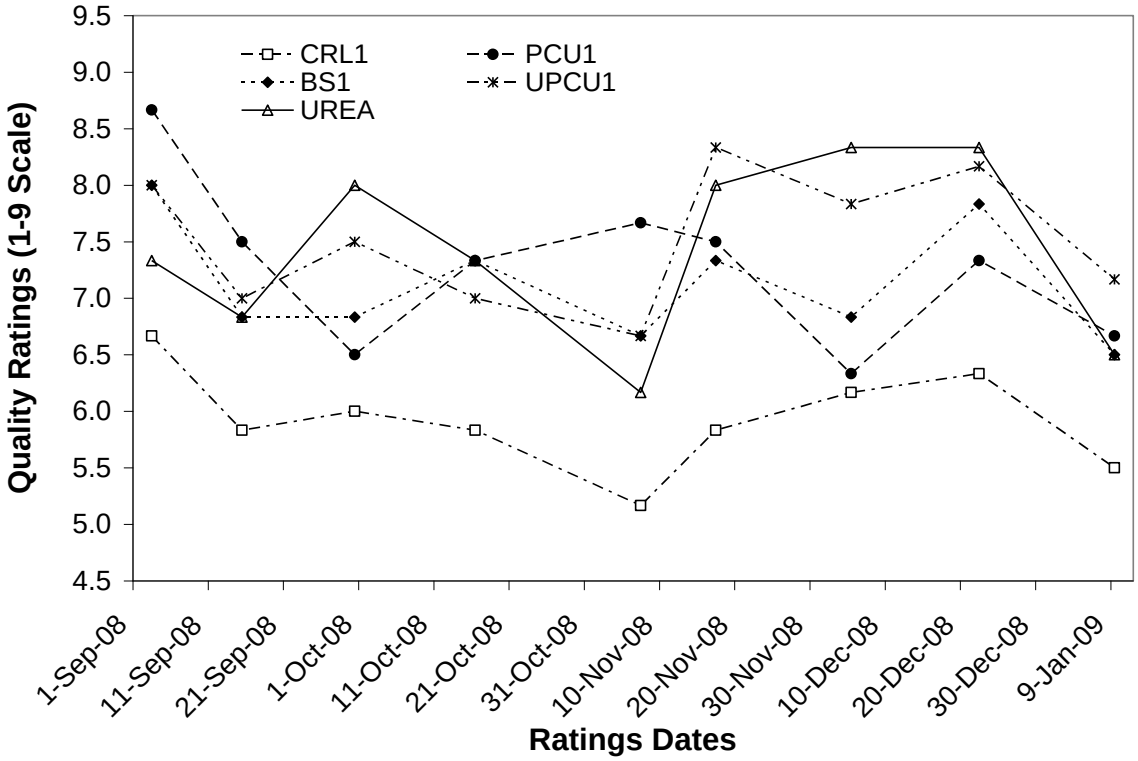

Figure 30**.** St. Augustinegrass quality from September 1, 2008 through January 9, 2009 for slow-release N sources applied at 49 kg N ha^{-1}. Arrow indicates fertilization events.

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 122-126). Quality and color scores increased as N increased. Acceptable scores were achieved on all rating dates with 4 lbs. N.

Table 122. 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 123. 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 124. Effects of Irrigation regime and Nitrogen fertilization on quality of St. Augustinegrass.

Factor	04/18	05/05	05/28	06/20	07/02
Irrigation	----------Quality (1-10)----------				
Regime					
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 125. Effects of Irrigation regime and Nitrogen fertilization on color of St. Augustinegrass

Factor	04/18	05/05	05/28	06/20	07/02
Irrigation	----------Color (1-10)----------				
Regime					
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 126. 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 127. 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 128. 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 129. Effects of Irrigation regime and Nitrogen fertilization on quality of Bahiagrass

Factor	04/18	05/05	05/28	06/20	07/02
Irrigation	----------Quality (1-10)----------				
Regime					
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 130. Effects of Irrigation regime and Nitrogen fertilization on color of Bahiagrass

Factor	04/18	05/05	05/28	06/20	07/02
Irrigation	----------Color (1-10)----------				
Regime					
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 131. Effects of Irrigation regime and Nitrogen fertilization on clipping yield of Bahiagrass

Factor	04/15	05/05	05/29	06/09	07/03
Irrigation	----------g/m^2----------				
Regime					
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 132) 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 NO_3-N analysis.

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

Table 132. 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 133a-133b). 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 133a-133b). Turfgrass color ratings had similar treatment responses (Tables 134a-134b). 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 135a-135b). The controlled release source PCU had the most clippings at the end of the reporting period while having the least early on (Tables 135a-135b).

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 34).

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 35). 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 136a-e). Most of the leaching occurred during the first month after application (Table 136a). 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 133a. 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 133b. 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.

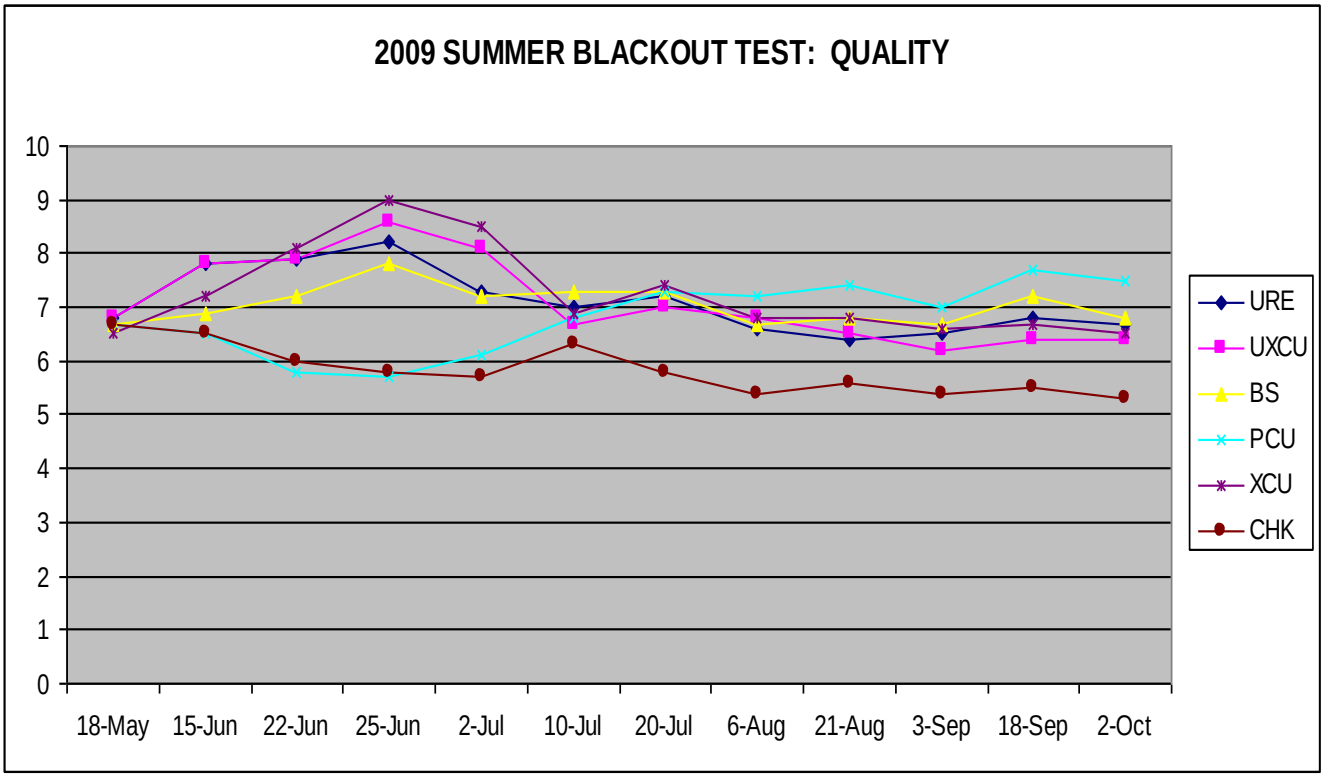

Figure 31. N Timing Blackout Test: Overall visual quality from 18 May—2 Oct. 2009.

Table 134a. 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 134b. 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.

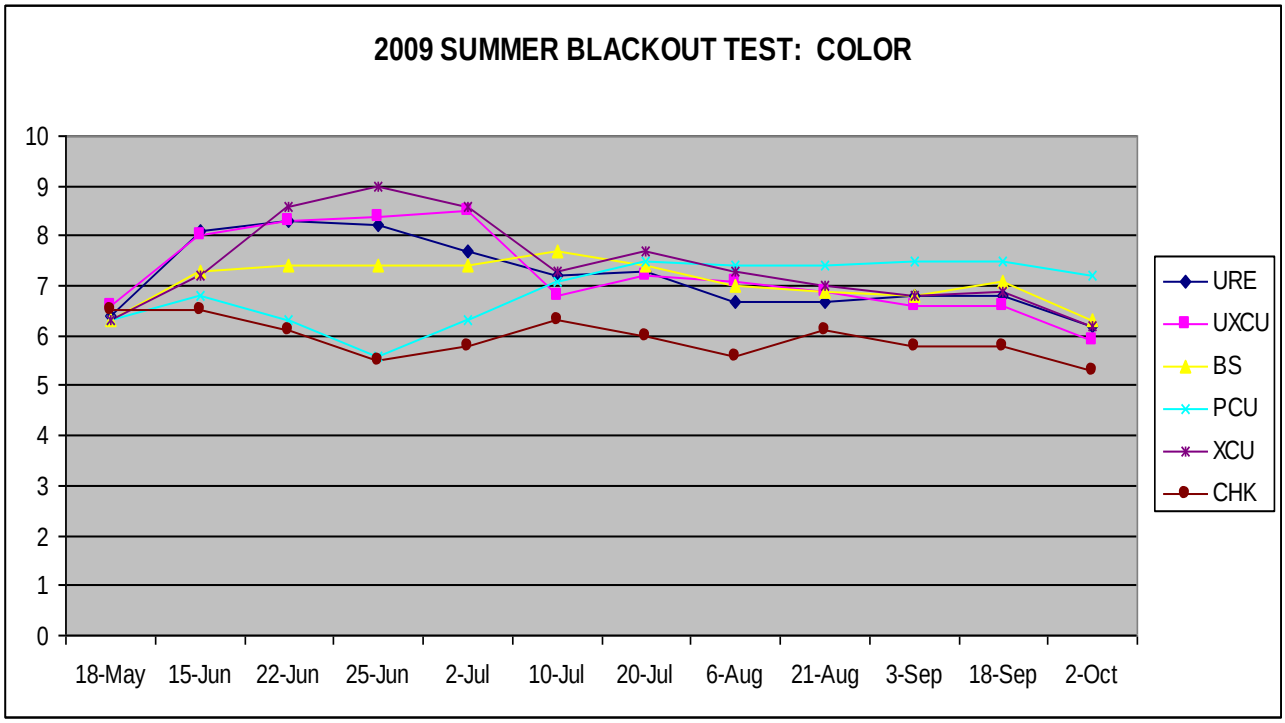

Figure 32. N Timing Blackout Test: Overall visual color from 18 May—2 Oct. 2009.

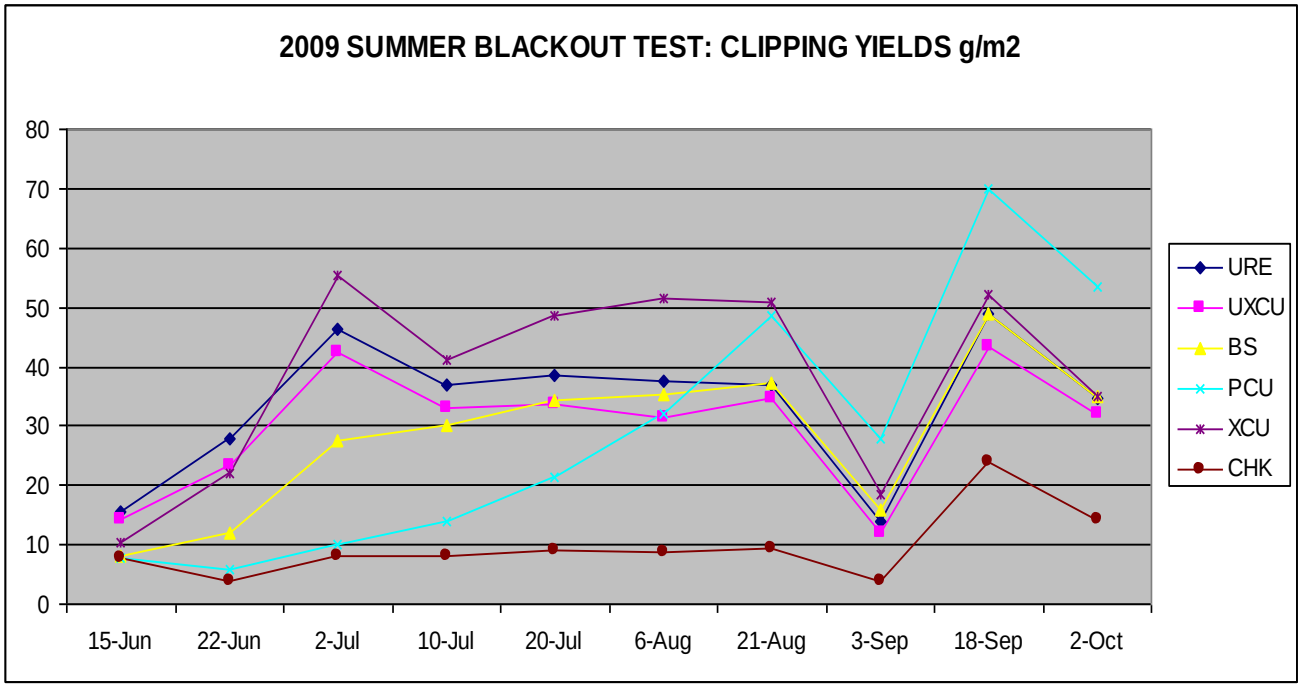

Figure 33. N Timing Blackout Test: Clipping tissue growth from 15 June—Oct. 2, 2009.

Table 135a. 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 135b. 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.

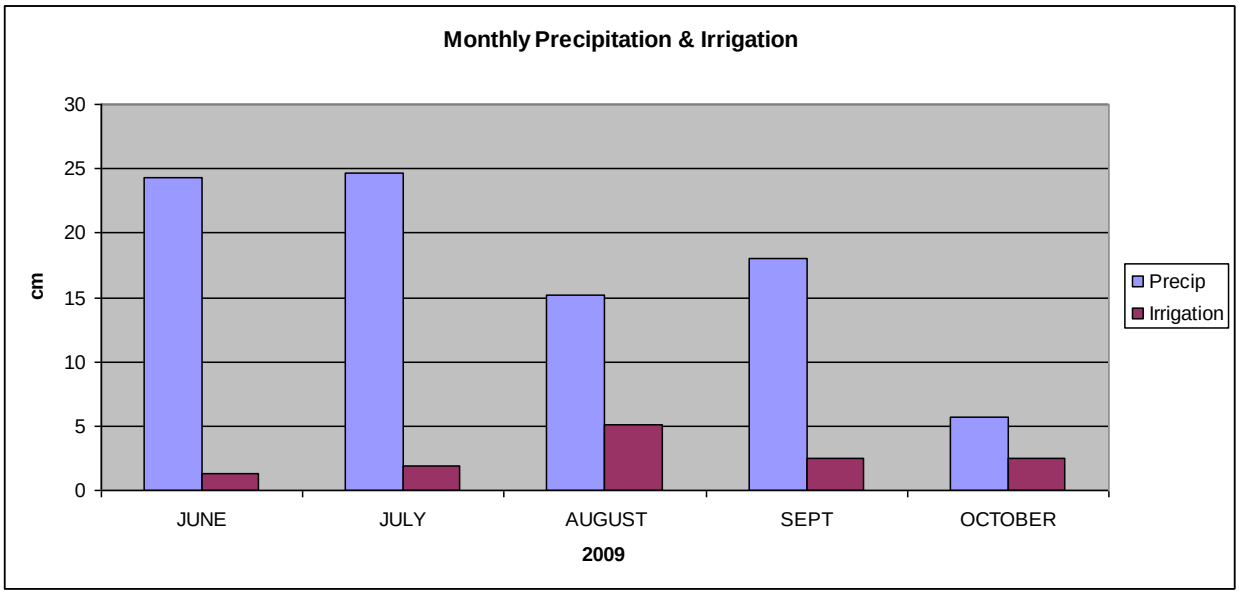

Figure 34. N Timing Blackout Test: Rainfall and irrigation June—October 2009.

Table 136a. N Timing: NO_3-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 136b. N Timing: NO_3-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 136c. N Timing: NO_3-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 136d. N Timing: NO_3-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 136e. N Timing: NO_3-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.

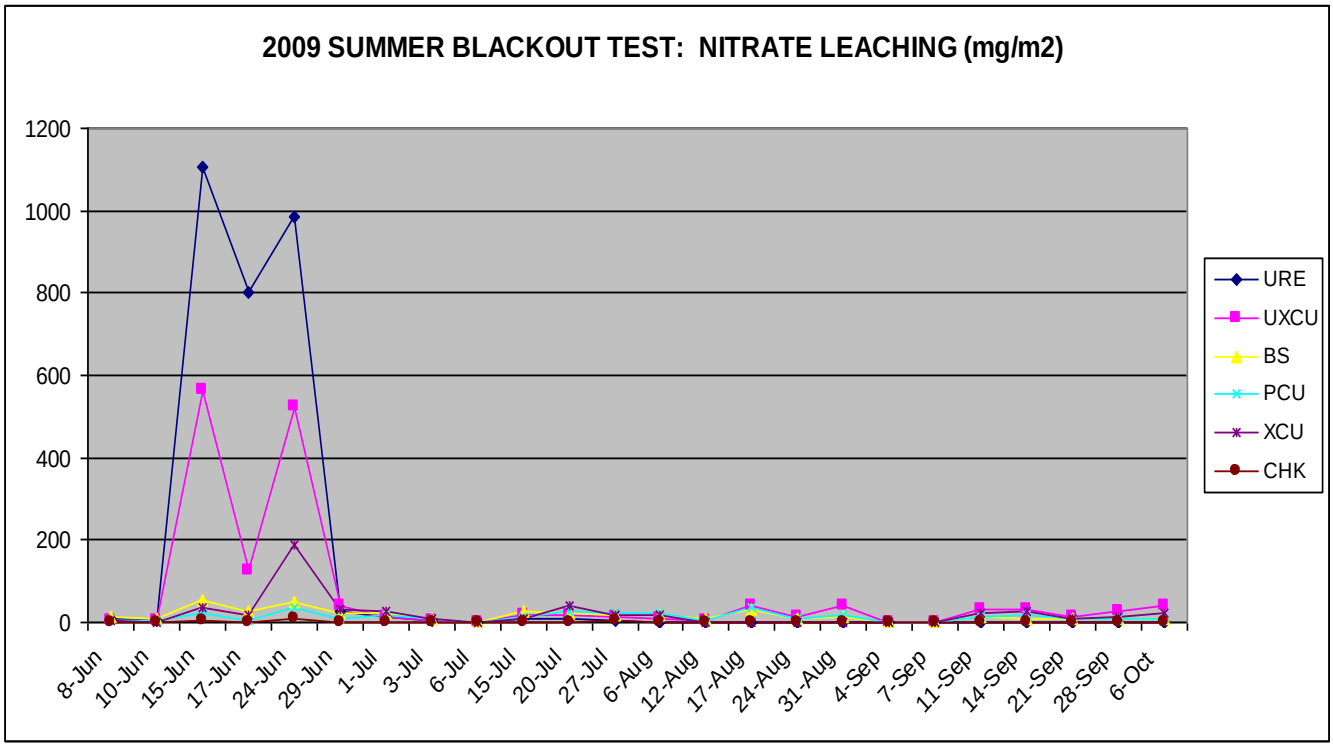

Figure 35. N Timing Blackout Test: Nitrate Leaching from 8 June – October 6, 2009.

PROJECT 3
NITRATE LEACHING AND TURF QUALITY IN ESTABLISHED ST. AUGUSTINEGRASS AND ZOYSIAGRASS DUE TO N SOURCE

GAINESVILLE – Dr. Laurie Trenholm

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 NO_3–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 NO_3–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 NO_3–N loading from soluble sources. Wu et al. (2010) reported greater NO_3–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 NO_3–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 NO_3–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 NO_3–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 NO_3–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 NO_3–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 uea @ 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 137. Analysis of variance (ANOVA) and means for NO_3–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	*	0.28	0.06	0.07
	N	***	0.32	***	***
	Grass*N	***	0.16	***	***

*, *** 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 138. Analysis of variance (ANOVA) and means for NO_3–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……	0.07	0.28	0.30	0.41	0.13	0.15	0.17
N…….	***	0.68	0.79	0.54	0.13	0.07	0.09
Grass*N……	***	0.68	0.91	0.37	0.28	0.24	0.21

*** 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 139. Analysis of variance (ANOVA) and means for NO_3–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……	0.22	0.19	0.09	0.98	0.33	0.23	0.46
N…….	0.81	0.49	0.63	0.12	0.14	0.12	0.80
Grass*N…….	0.82	0.65	0.50	0.99	0.63	0.57	0.83

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 140. Analysis of variance (ANOVA) and means for NO_3–N leaching in response to N source in established Floratam St. Augustinegrass and Empire zoysiagrass in 2011 in Citra, FL. Start revising here.

Treatment	Winter †	FC1	FC2	FC3	FC4	Annual Total	Percent of Applied N
N SOURCE			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
GRASS							
St. Augustinegrass	0.5	0.1 b	0.2	0.3	2.7	3.8 ab	2.0
Ammonium Nitrate….							
Urea……	0.4	0.1 b	0.1	0.2	0.6	1.4 b	0.7
30% SRN…….	1.1	0.5 b	0.3	0.2	1.1	3.2 ab	1.6
50% SRN…….	0.5	0.2 b	0.1	0.2	0.5	1.5 ab	0.8
PCU @ 49 kg ha^{-1} every 60 days……..	0.8	1.8 ab	0.1	0.3	0.5	3.5 ab	1.8
PCU @ 98 kg ha^{-1} every 120 days……	5.8	4.1 a	1.0	0.3	0.6	11.7 a	6.0
Milorganite……	0.5	0.2 b	0.1	0.4	0.4	1.7 ab	0.9
Control…….	0.4	0.1 b	0.1	0.2	0.4	1.3 b	
Zoysiagrass							
Ammonium Nitrate….	11.0 ab	4.3 bc	0.7 b	2.1	6.9	25.0 ab	12.8
Urea……	6.9 ab	3.2 bc	2.7 b	3.9	3.1	19.8 ab	10.1
30% SRN…….	7.5 ab	2.5 bc	2.4 b	1.3	1.0	14.6 ab	7.5
50% SRN…….	1.8 ab	2.3 bc	2.5 b	2.2	4.7	13.5 ab	6.9
PCU @ 49 kg ha^{-1} every 60 days…….	4.5 ab	1.0 bc	1.9 b	3.5	2.4	13.4 ab	6.8
PCU @ 98 kg ha^{-1} every 120 days……	12.5 a	10.2 a	7.2 a	3.6	3.5	37.0 a	18.9
Milorganite…….	11.3 ab	6.2 ab	3.2 b	7.1	5.1	32.8 a	16.8
Control……	0.4 b	0.1 c	0.1 b	0.3	0.3	1.1 b	
ANOVA							
Grass……	0.10	0.14	0.17	0.16	0.12	0.12	0.12
N……	0.08	**	**	0.70	0.46	*	0.07
Grass*N…….	0.23	0.15	*	0.78	0.72	0.16	0.36

*, ** 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 141. 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 0.001probability 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 142. 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 0.001probability 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 rom 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 143. 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 0.001probability 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 144. 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 0.001probability 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 145). 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 145. 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
	Control……..	2.8 d	3.4 e	3.8 e	3.3 e
Zoysiagrass	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 146. 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

Grass	Treatment	FC1	FC2	FC3	Average Color
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 147). 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 147. 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 0.001probability 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 148. 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

Grass	Treatment	FC1	FC2	FC3	FC4	Average Quality
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 0.001probability 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 149). 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 ft-2 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 149. 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 0.001probability 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 large 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, NO_3-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 ft^{-2} on an established, healthy turf. Consideration could also be given to allow application of up to 2 lbs N per 1,000 ft^{-2} 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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PROJECT 3
INFLUENCE OF NITROGEN SOURCE AND TIMING ON NO_3-N LEACHING WHEN APPLIED TO CENTIPEDEGRASS AND ST. AUGUSTINEGRASS

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EXPERIMENTAL SITE AND DESIGN

The study was conducted at the University of Florida's West Florida Research and Education Center, (30°46'3N, 87°08'W) on stands of Common Centipedegrass and Floratam St. Augustinegrass grown on native soil identified by the USGA survey as Fuquay loamy sand. The experiment consisted of 64-6m x 3m turfgrass split plots with 4 replications. Whole plots (Turfgrass variety) measure 12m x 12m; and split plots measure 3m x 6m. Sod was established the week of 20 July 2008. Six N sources with one source being applied at 60 and 120 day intervals plus one untreated control comprised the study. The six 60 day interval N sources were applied at a rate of 49 kg ha^{-1}, with one of the 60 day N sources also being applied at a rate of 98 kg ha^{-1} on a 120 day interval. In (2008 Yr 1) only one application of N was applied on 19 Aug due to late season implementation year 2 and 3 applications were on (2009 Yr 2 Run 1) 15 Apr, 12 Jun, (2009 Yr 2 Run 2) 13 Aug, 09 Oct, (2010 Yr 3 Run 1) 15 Apr, 11 Jun, (2010 Yr 3 Run 2) 09 Aug, 08 Oct and (2011 Yr 4) comprised only one run with applications on 12 Apr, 09 Jun. Split plots on 60 day intervals received one of 6 N sources 33.5-0-0 (Ammonium Nitrate), 46-0-0 (Urea), 16-0-8 (LESCO 30% SRN), 19-0-19 (Harrells 50% SRN), 41-0-0 (Harrells), or 6-2-0 (Milorganite) at a 49 kg ha^{-1} rate and on a 120 day interval one split received 98 kg ha^{-1} of N from 41-0-0 (Harrells). Leachate collection for volume (mL), and NOx-N (mg/L) analysis (Yr 1) was collected weekly began 05 Aug 2008 and ended 15 Dec 2008 for 20 sampling events, which included 2 pre-treatment events prior to the 18 treatment sampling events. Sampling for volume and NOx-N was suspended after the 120 day trial period until 17 Feb 2009 when requested by DEP (Mike Thomas) to resume weekly sampling for volume (mL), NOx-N (mg/L) and quarterly sampling for Ortho-PO_4 analysis. This resulted in Yr 1 post-treatment data weekly from 17 Feb 2009 through 30 Mar 2009 totaling 7 sampling events post treatment and the first quarterly sampling for Ortho-P on 17 Feb 2009. (Yr 2, Run 1) began 06 Apr 2009 and ended 11 Aug 2009 for 19 sampling events, which included 2 pre, 17 treatment, and 0 post sampling events. Second quarter sampling for Ortho-P was 09 Jun 2009. (Yr 2, Run 2) began 18 Aug 2009 and ended 30 Mar 2010 for 33 sampling events, which included 0 pre, 17 treatment and 16 post sampling events. Third and fourth quarter 2009 and first quarter 2010 sampling for Ortho-P was within this period on 22 Sep 2009, 07 Dec 2009, and 09 Mar 2010. (Yr 3, Run 1) began 06 Apr 2010 and ended 03 Aug 2010 for 18 sampling events, which included 2 pre, 16 treatment, and 0 post sampling events. Second quarter sampling for Ortho-P was 01 Jun 2010. (Yr 3, Run 2) began 10 Aug 2010 and ended 29 Mar 2011 for 34 sampling events, which included 0 pre, 18 treatment and 16 post sampling events. Third and fourth quarter 2010 and first quarter 2011 sampling for Ortho-P was within this period on 07 Sep 2010, 07 Dec 2010, and 08 Mar 2011. (Yr 4) began 05 Apr 2011 and ended 30 Aug 2011 for 22 sampling events, which included 2 pre, 17 treatment, and 3 post sampling events. Second quarter sampling for Ortho-P was 07 Jun 2011. Irrigation was supplied by 4 Rain Bird Super 7005 rotary irrigation heads in a square layout with 4-90° arcs having a precipitation rate of 0.508mm per minute utilizing a programmable controller, programmed for day intervals of 3 to 4 days (interval was changed to 3 days if there were symptoms of wilt when high ET's resulted in rapid depletion of soil moisture in the root zone, otherwise a 4 day interval was utilized), delivered with 4 starts between 0200 and 0630 (to minimize wind effects and evaporation losses while diminishing surface run off by not exceeding

soil percolation rates) with run times being adjusted to 60% (centipedegrass) and 80% (St. Augustinegrass) of previous weeks ET when wilting (insufficient irrigation) or excessive leachate (excessive irrigation) was observed. Additional precipitation (from rainfall events) and subsequent increases in leachate were quantified and reported as comparators to non rain event data. No irrigation was available from 21 Aug 2008 to 22 Sep 2008 due to irrigation well be off line. Plots were maintained at a height of cut of 50.8mm using a rotary mower with clippings left in place.

Collection of Leachate

Using a Toro Dingo skid steer equipped with a 60.96cm power auger, soil was removed to a depth of 106.68cm taking care to keep horizons separated for reconstruction within lysimeters of high density polyethylene (HDPE), having an internal height of 86.36cm, cylinder wall height of 78.74cm, conical section height of 7.62cm, and I.D. of 55.88cm yielding a total volume of 199.333L, supported upon a hot dipped galvanized base having an internal diameter of 57.15cm and constructed such that it has a tank bearing surface ≅ 1935cm^2 and a soil bearing surface ≅ 2355cm^2 with a total height of 25.4cm that raises the tank 10.16cm allowing for the installation of a bulkhead fitting tapped to receive a 9.525mm MNPT x 9.525mm OD nylon elbow fitting which is connected via 9.525mm low density polyethylene tubing via trench to a central lysimeter leachate removal/sampling station. Bore holes were prepped by tamping and leveling soil with a 17kg, 858cm^2 hand tamping tool to a finished depth of 106.68cm allowing for 10.16cm of soil cover above the upper rim of the lysimeter. Lysimeters were prepared with a leaching bed of washed 1.905-4.445cm round river rock having a volume of 0.034m^3 covered with non-woven polyolefin cloth 60.96cm in diameter secured with an internal interference fitted hoop of 1.27cm HDPE tubing. A vent line (to prevent pressure differentials from affecting leaching rates when lysimeters are being sampled) of 9.525cm LDPE by sufficient length to reach from the upper portion of the leach field just below the non-woven polyolefin to several inches above finished grass height is temporarily held to the rim of the lysimeter until soil horizons have been reestablished in the lysimeter. For this and future studies the vent tubes were rerouted (June 2008)to improve plot maintenance by coupling to, and routing exposed vent tubes through the side wall of the lysimeter via trench to the central lysimeter stations. Once lowered into the level and prepped bore holes original soil horizons were recreated in 15.24cm lifts within the lysimeter, each being packed by dropping the tamping tool from a consistent height, allowing gravity rather than thrust to compact soil consistently. The area surrounding the lysimeter and undisturbed soil was treated in kind. Any settling at lysimeters was corrected prior to plot preparation for sodding utilizing a LASER transit controlled wheeled box blade. Plots slope 0.5% to the south and west.

Leaching of NO_3-N + NO_2-N and Ortho-PO_4 was determined by removing all leachate for volume determination and acquiring a grab sample weekly for NO_3-N + NO_2-N analysis and quarterly (beginning 17 Feb 2009) for Ortho-PO_4 analysis from each of the 64 plots lysimeters. Sampling was by applying a vacuum to a secondary leachate collection trap equipped with a bottom drain, having a capacity greater than any one lysimeter leaching bed and connected via 9.525mm clear PVC tubing to a low volume primary trap constructed such that our 20ml sample vial was the trap. Thus, by triple rinsing the trap head with as little as 60ml of distilled water, connecting directly to the lysimeter leachate tube at the removal/sampling station and fitting our clean sample vial as the trap we were able to collect a contaminate free grab sample from any volume of leachate and by draining the secondary trap to a suspended load cell equipped weighing bucket, volume was inferred from mass, given 1g of pure H_2O at 4°C and 760mm Hg equals 1ml and leachate would vary insignificantly (<1%) at sampling temperatures and pressures. Upon DEP's request for quarterly sampling for Ortho-PO_4 beginning 17 Feb 2009 a new primary vacuum trap head was designed to accept the barrel of a separate sterile 60mL single use syringe equipped with a luer lock 45µm filter and syringe cap for a

leachate trap. When removed from the vacuum head, the syringe was fitted with its plunger and assembled into a press to extract a filtered sample for Ortho-PO_4, a duplicate when needed and a NOx sample as well or a NOx sample, its duplicate and an Ortho-PO_4 sample as well. The syringe vacuum head was triple rinsed the same as the 20mL scintillation vial vacuum head.

Sample Analysis

Sample analysis was by colorimetric auto analyzer at the UF/IFAS Analytical Research Laboratory, Gainesville, FL utilizing EPA method 353.2 for NO_3-N + NO_2-N, and 365.1 for Ortho-PO_4. MDL's for NOx and Ortho-P were 0.05mg/L, and 2.5µg/L until 01 Dec 2008 when they changed to 0.148mg/L and 3.0µg/L. PQL's for NOx and Ortho-P were 0.5mg/L and 10µg/L and remained unchanged after 01 Dec 2008. Linear working ranges for NOx and Ortho-P were 0.50-30.00mg/L and 0.01-0.50mg/L. Laboratory estimates of uncertainty for NOx and Ortho-P have an estimated bias of +0.95 and +1.46 and an estimated precision of ±3.61% and ±3.16%. Note: Precision estimates only apply to laboratory instrumentation and do not include any error associated with sample handling or collection variances and were determined by measuring the dispersion of values obtained from a known certified reference standard using typically 20-30 data points. With this, both bias (average % yield – 100) and precision (standard deviation of % yield) were determined (UF/IFAS Analytical Research Laboratory).

Measures of Turfgrass Quality, Dry Clipping Mass, and Dry Root Mass

Turfgrass visual quality, color, and density assessments were conducted, 28 Aug 2008 through 10 Oct 2008 (Yr 1), 17 Apr 2009 through 07 May 2009 (Yr 2 Run 1), 24 Aug 2009 through 13 Nov 2009 (Yr 2 Run 2), 29 Apr 2010 through 06 Aug 2010 (Yr 3 Run 1), 19 Aug 2010 through 29 Oct 2009 (Yr 3 Run 2), 02 May 2011 through 25 Aug 2011 (Yr 4) on two week intervals or less, unless dormant or changes were insignificant (which accounts for assessment periods greater than 2 weeks), utilizing NTEP turfgrass evaluation guidelines. Scales are 1-9 with a quality rating of 9 being best and 1 being poorest, color rating of 9 being dark green and 1 light green, and density rating of 9 being maximum density. Any rating 6 or greater is considered generally acceptable. Ratings are generally in whole numbers. Winter injury and %weeds were assessed on (Yr 1-2) 17 Apr 2009, (Year 2-3) 19 Mar 2010, 13 Apr 2010, (Year 3-4) 17 Mar 2011.

Turfgrass clippings were collected (Yr 1) at 20, and 51 days post-treatment (long sampling interval was due to irrigation well being down from 21 Aug 2008 to 22 Sept 2008 and drought conditions resulting in very little growth), (19 Aug 2008), (Yr 2 Run 1) at 22,35,49,61,70,84,99, and 112 days post-treatment (15 Apr 2009), (Yr 2 Run 2) at 7,21,35,49,62, and 77 days post-treatment (12 Aug 2009), (Yr 3 Run 1) at 35,49,63,77,91, and 105 days post-treatment (15 Apr 2010), (Yr 3 Run 2) at 3,17,31,45,59, and 73 days post-treatment (09 Aug 2010), (Yr 4) at 44,58,72,86,100,114, and 128 days post-treatment (12 Apr 2011) Clippings represented approximately 7 days shoot growth with an attempt to sample every 2 weeks from a 2.17m^2 areas within each 4m x 3m plot using a rotary mower set at a mowing height of 50.8mm with a modified grass catching system utilizing a 30.48cm by 40.64cm cloth bag in lieu of the manufacturers grass catching system. Samples were dried using forced hot air averaging 50°C for 48 to 72 hours prior to measuring masses.

Following each 120 day treatment period (run) in years 2, 3, and 4, 5 root samples were collected using a pedal style soil sampler measuring 20mm dia. x 100mm long, one from each quadrant and one from the center of each plot. Soil, and debris separation from roots was accomplished by washing with water in a sieve accompanied by mechanical pressure and agitation. Separated roots were then air dried followed by oven drying at 50°C for 48-72 hours prior to measuring masses. These masses were corrected for retained mineral materials by ashing the samples and subtracting the mass of the remaining debris minus the ash.

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:

1. No treatment = zero N fertilizer
2. Low Control (Ammonium Nitrate 34-0-0) @ 49 kg N ha^{-1}/60 days (1/60)
3. Quick Release/High Control (Urea 46-0-0) @ 49 kg N ha^{-1}/60 days (1/60)
4. 30% Slow Release (John Deere Landscapes 16-0-8) @ 49 kg N ha^{-1}/60 days (1/60)
5. 50% Slow Release (Harrells 19-0-19) @ 49 kg N ha^{-1}/60 days (1/60)
6. Polymer Coated product (Polyon 41-0-0) @ 49 kg N ha^{-1}/60 days (1/60)
7. Polymer Coated product (Polyon 41-0-0) @ 98 kg N ha^{-1}/120 days (2/120)
8. 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 150). 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 151 – 153). On the initial rating date in 2009 (17 Apr), no differences in turf quality and density due to fertilizer source were observed (Tables 151 and 153). Fertilizer treatments did influence spring color where all fertilizer except the biosolid had better color than the untreated control (Table 152).
As expected, soluble N sources yielded rapid improvements in green-up and turf quality following each application (Tables 151 and 152). 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 153). 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 154 – 156).

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 154). 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 157). 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 158). 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 159).

All fertilizer treatments resulted in acceptable centipedegrass quality (Table 157), color (Table 158), and density (Table 159).

Shoot Mass

2008 – Fertilizer sources had no effect on St. Augustinegrass shoot mass in 2008 (Table 160). 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 161). 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 162). 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 163). 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 165). 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 166).

Root Growth

Throughout the duration of the study, differences in rooting attributed to fertilizer source were not significant (Tables 167-170). 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 171).

During the first 120 days following application, the 30% SRN material leached significantly more NO^-_3-N than the other products (Table 171). 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 NO^-_3-N leaching than the untreated control. The 30% SRN source leached 42% of the applied nitrogen.

Given the levels of NO^-_3-N collected from the untreated plots over the 120 sampling period (12.5 kg N ha^{-1}), the NO^-_3-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 (Table 172 and 173). 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 NO^-_3-N than centipedegrass on all 60 day cycles, 120 day totals, post 60 day periods, and seasonal totals (Tables 174 and 175). 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 174).

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 175). 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 175). Seasonal leaching totals from St. Augustinegrass ranged from 7.6 (PCU @ 1.0 lb) to 46.2 (urea) kg N ha^{-1} (Table 175). 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%) (Table 175).

2011 – Leaching from St. Augustinegrass continued to be greater than leaching from centipedegrass in 2011 (Table 176). However, there was a significant Species X Fertilizer Source interaction during the first 60 days of the 2011 season (Table 177). 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 NO^-_3-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 177). 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 177).

TASK 3 QUALITY DATA

Table 150. 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
LSD	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*
Treatment (lbs N 1000 ft^{-2})									
Untreated	7.3 b	7.0 d	7.1 c	7.3 c	6.6 c	6.9 c	7.0	7.8 cd	7.1 d
Am. Nitrate (34-0-0) @ 1 lb N	8.2 a	8.3 a	8.0 a	8.8 a	8.0 a	8.0 a	7.0	8.4 a	8.2 a
Urea (46-0-0) @ 1 lb N	8.2 a	7.8 bc	7.7 ab	8.6 a	7.6 ab	7.6 ab	7.0	8.1 ab	8.1 ab
30% SRN (16-0-8) @ 1 lb N	8.0 a	8.1 ab	7.6 ab	8.5 ab	7.8 ab	7.6 ab	7.0	8.3 a	8.1 a
50% SRN (19-0-0) @ 1 lb N	7.9 a	7.7 c	7.7 ab	8.2 b	7.6 ab	7.6 ab	7.0	7.8 b-d	7.9 a-c
PCU (41-0-0) @ 1 lb N	7.2 b	7.1 d	7.1 c	7.3 c	6.8 c	6.8 c	7.0	7.6 d	7.5 cd
PCU (41-0-0) @ 2 lbs N	7.3 b	7.1 d	7.3 bc	7.6 c	6.8 c	7.2 bc	7.0	7.6 d	7.6 b-d
BSD (6-2-0) @ 1 lb N	7.5 b	7.6 c	7.5 b	7.5 c	7.4 b	7.3 bc	7.0	7.9 bc	7.9 a-c
LSD	*0.3*	*0.4*	*0.4*	*0.4*	*0.5*	*0.5*	*ns*	*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 151. 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	29 Oct	13 Nov
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	6.9	7.1 b
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	7.9	8.0 a
LSD	*1.6*	*0.7*	*0.6*	*0.5*	*0.7*	*0.8*	*0.9*	*ns*	*0.6*	*0.6*	*0.5*	-	*ns*	*0.7*
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	5.0 c	5.3 c
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	7.6 a	7.8 ab
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	8.1 a	7.9 a
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	8.0 a	8.0 a
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	8.3 a	8.4 a
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	7.6 a	8.0 a
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	7.8 a	8.0 a
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	6.8 b	7.0 b
LSD	*ns*	*0.4*	*0.5*	*0.9*	*0.4*	*0.6*	*0.7*	*0.5*	*0.4*	*0.6*	*0.6*	-	*0.8*	*0.8*

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 152. 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	21 Oct	29 Oct	13 Nov
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 b	7.3 b	7.0	7.4
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 a	8.1 a	7.7	7.7
LSD	*ns*	*0.5*	*0.6*	*0.6*	*0.7*	*0.7*	*0.9*	*Ns*	*0.6*	*0.7*	*0.7*	*0.6*	-	*ns*
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 c	4.8 d	4.9	4.6 d
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 ab	8.0 b	7.8	7.9 b
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 ab	8.0 b	7.9	7.9 b
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 b	8.3 ab	7.6	7.9 b
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 ab	8.5 a	7.9	8.3 ab
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 a	8.3 ab	7.6	7.9 b
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 ab	8.6 a	7.9	8.5 a
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 ab	7.3 c	7.4	7.4 c
LSD	*0.5*	*0.5*	*0.5*	*0.5*	*0.4*	*0.6*	*0.7*	*0.6*	*0.6*	*0.7*	*0.7*	*0.5*	-	*0.5*

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 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 153. 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	21 Oct	29 Oct	13 Nov
Species														
St. Augustinegrass	6.4b	6.6b	6.7b	6.0b	6.7b	6.9b	6.9	7.3	7.4b	7.7	7.7	8.1	8.0	8.1
Centipedegrass	7.1a	7.4a	8.3a	7.3a	7.3a	8.0a	7.7	7.5	8.1a	8.1	8.3	8.3	8.4	8.1
LSD	*0.6*	*0.7*	*0.4*	*0.6*	*0.6*	*0.8*	*ns*	*ns*	*0.5*	*ns*	*ns*	-	*ns*	-
Treatment (lbs N 1000 ft^2)														
Untreated	6.6	6.3e	5.9c	5.3c	5.4c	5.9d	5.8d	5.3f	5.6c	5.6b	5.6d	5.6	5.5d	5.9
Am. Nitrate (34-0-0) @ 1 lb N	6.8	7.6a	8.4a	7.8a	7.8a	8.1a	7.8ab	8.5a	8.5a	8.0a	8.1bc	8.6	8.6ab	8.4
Urea (46-0-0) @ 1 lb N	6.9	7.5a	8.3a	7.9a	7.6a	8.1a	7.5b	8.4ab	8.3a	8.1a	8.6ab	8.8	8.8ab	8.8
30% SRN (16-0-8) @ 1 lb N	6.6	7.4ab	8.3a	7.1b	7.8a	7.8a	7.4b	8.1a-c	8.4a	8.1a	8.3ab	8.6	8.8ab	8.4
50% SRN (19-0-0) @ 1 lb N	6.8	7.3ab	7.9a	7.1b	7.5a	8.0a	7.9ab	7.9bc	8.3a	8.5a	8.9a	8.9	9.0a	8.5
PCU (41-0-0) @ 1 lb N	6.6	6.4de	6.6b	5.6c	6.4b	7.1b	7.5b	7.1d	7.5b	8.3a	8.5ab	8.5	8.5b	8.1
PCU (41-0-0) @ 2 lbs N	7.1	7.0bc	7.9a	6.6b	7.4a	8.1a	8.3a	7.6cd	8.1a	8.6a	8.8ab	9.0	9.0a	8.9
BSD (6-2-0) @ 1 lb N	6.6	6.8dc	6.8b	5.8c	6.5b	6.6c	6.5c	6.3e	7.4b	8.0a	7.5c	7.6	7.5c	8.0
LSD	*ns*	*0.4*	*0.5*	*0.6*	*0.4*	*0.5*	*0.7*	*0.6*	*0.4*	*0.7*	*0.7*	-	*0.4*	-

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).
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 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 154. 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	14 Oct	29 Oct
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	4.3 d	4.3 e
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	6.5 c	6.5 d
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	6.5 c	6.5 d
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	8.0 a	8.0 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	8.3 a	8.8 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	7.3 b	7.5 bc
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	6.8 bc	7.0 cd
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	6.8 bc	7.8 cd
LSD	*1.1*	*0.8*	*1.3*	*1.0*	*0.9*	*1.2*	*1.4*	*1.5*	*ns*	*1.5*	*1.2*	*1.2*	*0.7*	*0.8*
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	6.0 d	6.0 c
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	8.5 ab	8.3 ab
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	8.0 bc	8.8 a
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	8.0 bc	8.5 ab
50% SRN (19-0-0) @ 1 lb N	7.0	7.8	8.3	8.8	9.0	9.0	7.8	8.5	8.0	7.8	8.5	8.5	8.0	8.5

	ab	a	b	a	a	a	bc	ab	a	bc	ab	a-c	bc	ab
PCU (41-0-0) @ 1 lb N	7.0	7.0	7.8	8.3	8.3	9.0	8.8	9.0	8.8	8.5	8.8	9.0	8.0	8.3
	ab	bc	b	a	bc	a	a	a	a	ab	ab	a	bc	ab
PCU (41-0-0) @ 2 lbs N	6.8	7.0	7.8	8.3	8.8	9.0	8.8	9.0	9.0	8.8	9.0	8.8	8.8	8.5
	b	bc	b	a	bc	a	a	a	a	a	a	ab	a	ab
BSD (6-2-0) @ 1 lb N	6.5	6.8	7.0	8.0	8.0	8.8	7.3	8.0	8.0	8.3	8.8	8.3	7.5	8.0
	b	c	c	a	c	a	c	b	a	ab	ab	bc	c	b
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*	*0.5*	*0.6*
Split-plot analysis *P*(F)														
Species	.0019	.0004	.0001	.0001	.0001	.0001	.0030	.0003	.0109	.0008	.0033	.0106	.0047	.0081
Treatment	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0175	.0001	.0001	.0001	.0001	.0001
Species*Treatment	.0002	.0002	.0008	.0012	.0002	.0001	.0006	.0180	.1050	.0135	.1753	.0233	.0001	.0001

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 and species are not significantly different according to Fisher's Least Significant Test (*P*=0.05).

Table 155. 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	14 Oct	29 Oct
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	4.3 c	4.3 e
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	6.5 b	6.3 d
Urea (46-0-0) @ 1 lb N	5.5 bc	5.5 cd	5.0 bc	5.0 b	6.5bc	5.8 ab	7.0 a	7.3 a	6.0	6.5 a	6.8 a	7.0 a	6.5 b	6.5 cd
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	7.5 a	7.8 ab
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	8.0 a	8.3 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	6.8 b	7.0 b-d
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	7.0 a	6.8 b	7.0 b-d
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	6.8 b	7.5 a-c
LSD	*0.7*	*0.7*	*1.2*	*1.0*	*0.8*	*1.1*	*0.9*	*0.8*	*ns*	*0.8*	*1.0*	*0.8*	*0.6*	*1.2*
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	5.3 d	5.0 d	5.0 c
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	7.8 bc	7.8 ab	8.3 ab
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	7.8 bc	7.3 bc	8.3 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	7.3 c	7.5 a-c	8.5 a
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	7.5 bc	7.5 a-c	8.3 ab

PCU (41-0-0) @ 1 lb N	6.5	6.5	7.8	8.0	7.5	8.3	8.8	9.0	8.3	8.5	8.5	8.0	7.5	7.8
	c	b	cd	ab	a	bc	a	a	a	a	ab	ab	a-c	ab
PCU (41-0-0) @ 2 lbs N	6.5	6.5	7.5	8.0	8.3	9.0	8.8	9.0	8.8	8.8	8.8	8.5	8.0	8.0
	c	b	de	ab	a	a	a	a	a	a	a	a	a	ab
BSD (6-2-0) @ 1 lb N	6.0	6.5	7.0	7.3	7.3	8.0	7.0	7.5	8.0	8.3	8.8	7.5	7.0	7.3
	d	b	e	b	b	c	d	b	a	a	a	bc	c	b
LSD	*0.5*	*0.5*	*0.5*	*0.9*	*0.7*	*0.5*	*0.7*	*0.8*	*1.5*	*0.8*	*0.8*	*0.7*	*0.7*	*1.0*
Split-plot analysis *P*(F)														
Species	.0021	.0001	.0001	.0001	.0050	.0001	.0338	.0087	.1379	.0018	.0100	.0332	.0312	.0279
Treatment	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0373	.0001	.0001	.0001	.0001	.0001
Species*Treatment	.0001	.0001	.0001	.0024	.0019	.0005	.0120	.0344	.1070	.0086	.0461	.0959	.0039	.0647

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 Test (*P*=0.05).

Table 156. 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	14 Oct	29 Oct
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	4.8 d	4.8 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	7.5 c	7.0 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	7.8 bc	7.3 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	8.5 ab	8.3 ab
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	9.0 a	9.0 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	8.3 a-c	8.0 bc
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	8.3 a-c	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	7.5 c	8.0 bc
LSD	*1.0*	*0.9*	*1.3*	*1.1*	*0.9*	*1.2*	*1.4*	*1.3*	*ns*	*1.8*	*1.4*	*1.2*	*0.9*	*0.9*
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	6.0 d	6.0 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	9.0 a	8.8 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	8.5 a-c	8.5 ab
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	8.3 bc	8.8 ab
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	8.5 a-c	9.0 a
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	8.8 ab	8.8 ab
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	9.0 a	9.0 a
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	8.0 c	8.3 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*	*0.6*	*0.6*
Split-plot analysis *P*(F)														
Species	.0163	.0055	.0001	.0015	.0001	.0001	.0018	.0003	.0184	.0001	.0027	.0088	.0175	.0028
Treatment	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0026	.0001	.0001	.0001	.0001	.0001
Species*Treatment	.0001	.0003	.0009	.3959	.0010	.0001	.0083	.0010	.0934	.0220	.1931	.0012	.0038	.0186

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).
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 157. 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 158. 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 159. 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 160. Effect of nitrogen source applications on shoot mass in 2008.

	Shoot mass (g)			
	St. Augustinegrass		Centipedegrass	
Treatment (lbs N 1,000 ft^{-2})	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
Pr>F	*ns*	*ns*	*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 161. Effect of nitrogen source applications on St. Augustinegrass shoot mass in 2009.

	Shoot mass (g)													
	St. Augustinegrass													
Treatment (lbs N 1,000 ft^{-2})	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	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
Am. Nitrate (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
LSD	*NS*	*NS*	*NS*	*1.91*	*1.82*	*1.94*	*2.55*	*2.31*	*1.85*	*1.69*	*0.57*	*2.08*	*1.63*	*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 162. Effect of nitrogen source applications on centipedegrass shoot mass in 2009.

	Shoot mass (g)													
	Centipedegrass													
Treatment (lbs N 1,000 ft^{-2})	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 c	11.80 d	6.41 e	3.95 f	3.68 e	2.38 e	5.94 e	2.19 d	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 a	36.80 bc	16.13 bc	18.37 ab	24.26 a	8.19 cd	23.40 bc	7.40 b	3.43
Urea (46-0-0) @ 1 lb N	13.51 b	4.90 ab	1.55	17.98	75.67 ab	61.04 a	37.67 a-c	13.84 c	15.11 c	21.51 ab	6.98 cd	18.73 cd	6.81 b	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 a	38.80 a-c	13.81 c	15.25 bc	21.16 b	8.40 b-d	20.30 bc	6.26 bc	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 a	48.50 ab	17.29 b	16.68 a-c	20.51 b	11.22 a-c	25.73 bc	9.48 b	2.83
PCU (41-0-0) @ 1 lb N	5.27 cd	1.58 d	1.25	9.87	29.29 cd	32.10 b	24.31 cd	15.59 bc	11.45 d	12.51 d	12.85 ab	28.03 b	9.05 b	2.43
PCU (41-0-0) @ 2 lbs N	7.01 cd	3.66 bc	7.43	28.37	53.69 bc	65.90 a	53.02 a	22.83 a	18.66 a	16.84 c	14.12 a	40.20 a	16.13 a	2.80
BSD (6-2-0) @ 1 lb N	4.80 d	2.19 dc	5.05	16.06	31.08 cd	30.24 bc	19.35 d	10.23 d	7.73 e	10.90 d	5.40 de	10.87 de	3.25 cd	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 163. Effect of nitrogen source applications on St. Augustinegrass shoot mass in 2010.

	Shoot mass (g)											
	St. Augustinegrass											
Treatment (lbs N 1,000 ft^{-2})	20 May	3 Jun	17 Jun	1 Jul	15 Jul	29 Jul	12 Aug	26 Aug	9 Sep	23 Sep	7 Oct	21 Oct
Untreated	0.03b	0.11b	0.36c	0.96c	1.72d	0.60c	0.16c	0.89d	0.37c	0.19	0.48	0.65ab
Am. Nitrate (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	0.66	0.62ab
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	0.60	0.57bc
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	0.65	0.79a
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	0.50	0.60b
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	0.43	0.72ab
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	0.54	0.63ab
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	0.39	0.41c
LSD	*0.15*	*0.42*	*2.05*	*2.89*	*2.00*	*4.17*	*1.31*	*6.00*	*1.77*	*NS*	*NS*	*0.18*

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 164. Effect of nitrogen source applications on centipedegrass shoot mass in 2010.

	Shoot mass (g)											
	Centipedegrass											
Treatment (lbs N 1,000 ft^{-2})	20 May	3 Jun	17 Jun	1 Jul	15 Jul	29 Jul	12 Aug	26 Aug	9 Sep	23 Sep	7 Oct	21 Oct
Untreated	1.43e	0.35d	5.42e	10.33e	17.66d	11.88d	2.41c	6.06d	5.38d	4.17c	1.76c	3.91
Am. Nitrate (34-0-0) @ 1 lb N	18.52a	7.09bc	45.56a	36.72cd	35.92c	24.27bc	9.57b	40.97ab	22.73bc	12.78b	3.27ab	9.98
Urea (46-0-0) @ 1 lb N	16.37ab	6.33bc	40.42ab	42.07bc	36.20c	23.62bc	10.71b	37.41b	24.31ab	13.72b	3.01b	4.83
30% SRN (16-0-8) @ 1 lb N	20.54a	7.66ab	41.31a	51.81a	38.56bc	26.62b	9.20b	39.45ab	19.36c	11.28b	3.98a	10.01
50% SRN (19-0-0) @ 1 lb N	18.10a	9.58a	45.79a	44.82b	40.25a-c	27.65b	11.24b	45.35a	26.32ab	14.78b	3.21b	7.89
PCU (41-0-0) @ 1 lb N	9.48cd	5.17c	34.79bc	33.71d	44.63ab	40.00a	16.55a	29.90c	27.72a	20.65a	3.25ab	11.65
PCU (41-0-0) @ 2 lbs N	11.86bc	6.69bc	34.21c	35.80d	45.55a	39.63a	19.09a	36.41b	27.94a	19.23a	3.46ab	3.83
BSD (6-2-0) @ 1 lb N	5.77de	2.26d	25.23d	33.11d	37.36c	19.91c	7.82b	29.92c	22.31bc	13.43b	3.23b	4.89
LSD	*4.61*	*1.93*	*5.90*	*5.38*	*6.59*	*5.58*	*3.42*	*5.62*	*4.80*	*3.54*	*0.75*	*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 165. Effect of nitrogen source applications on St. Augustinegrass shoot mass in 2011.

	Shoot mass (g)						
	St. Augustinegrass						
Treatment (lbs N 1,000 ft^{-2})	26 May	9 Jun	23 Jun	7 Jul	21 Jul	4 Aug	18Aug
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 166. Effect of nitrogen source applications on centipedegrass shoot mass in 2011.

	Shoot mass (g)						
	Centipedegrass						
Treatment (lbs N 1,000 ft^{-2})	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 167. 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 168. 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
LSD	*ns*	*ns*	*ns*	-	*ns*	-
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
LSD	*ns*	*ns*	*ns*	-	*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).
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 169. 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
LSD	*ns*	*ns*	-
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
LSD	*ns*	*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).
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 170. Effect of nitrogen source applications on turfgrass rooting in 2011.

	12 Apr 2011 % ash	
	St. Augustinegrass	Centipedegrass
Treatment (lbs N 1,000 ft^{-2})		
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 171. Effect of various nitrogen sources on total NO_3-N leached in 2008.

	Total N (kg ha^{-2})					
		Application 19 Aug 08				
		60 day	60 day	120 day Total		
	Pre*	T1	T2		Post	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
Pr>F	*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
Pr>F	*0.8371*	*0.0150*	*0.0037*	*0.0003*	*0.8535*	*0.0004*
Turf x Treatment Pr>F	*0.5415*	*0.2458*	*0.8053*	*0.4691*	*0.5446*	*0.3522*
R^2	*0.5099*	*0.6062*	*0.5462*	*0.6347*	*0.3521*	*0.6405*

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 172. Effect of various nitrogen sources on total NO_3-N leached in 2009.

	Total N (kg ha^{-1})								
		Application 15 Apr 09			Application 12 Aug 09				
	Pre*	60 day T1	60 day T2	120 day Total	60 day T3	60 day T4	120 day Total	Post	Total
Species									
St. Augustinegrass	0.254	0.283	0.214	0.487	0.353	1.459	1.811	3.346 a	5.645 a
Centipedegrass	0.122	0.228	0.218	0.446	0.323	0.385	0.709	0.703 b	1.858 b
Pr>F	*0.1220*	*0.1965*	*0.8779*	*0.3735*	*0.5728*	*0.1349*	*0.1486*	*0.0199*	*0.0387*
Treatment (lbs N 1,000 ft^{-2})									
Untreated	0.182	0.210	0.175	0.385	0.267	0.316	0.583	0.634	1.602
Am. Nitrate (34-0-0) @ 1 lb N	0.296	0.392	0.243	0.635	0.350	1.219	1.570	3.173	5.378
Urea (46-0-0) @ 1 lb N	0.130	0.267	0.242	0.509	0.394	1.819	2.213	2.611	5.334
30% SRN (16-0-8) @ 1 lb N	0.140	0.272	0.240	0.512	0.437	1.263	1.699	2.603	4.814
50% SRN (19-0-0) @ 1 lb N	0.183	0.254	0.206	0.459	0.353	1.191	1.544	2.325	4.328
PCU (41-0-0) @ 1 lb N	0.089	0.174	0.177	0.352	0.248	0.286	0.534	0.714	1.600
PCU (41-0-0) @ 2 lbs N	0.299	0.256	0.254	0.510	0.319	0.970	1.289	3.073	4.872
BSD (6-2-0) @ 1 lb N	0.175	0.207	0.189	0.370	0.334	0.314	0.649	1.067	2.086
Pr>F	*0.7806*	*0.1712*	*0.2862*	*0.0995*	*0.3450*	*0.2721*	*0.2594*	*0.0529*	*0.0741*
Species x Treatment Pr>F	*0.7205*	*0.3607*	*0.0161*	*0.1637*	*0.2532*	*0.4045*	*0.4839*	*0.1008*	*0.2393*
R^2	*0.3103*	*0.4145*	*0.4900*	*0.4131*	*0.3897*	*0.5175*	*0.5078*	*0.6353*	*0.5959*

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 173. Effect of various nitrogen sources on total NO_3-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
Pr>F	*0.0906*	*0.1394*
R^2	*0.3736*	*0.3409*

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 174. Nitrogen Source Study in 2010.

	Total N (kg ha^{-2})								
		Application 15 Apr 10			Application 9 Aug 10				
	Pre*	60 day T1	60 day T2	120 day Total	60 day T3	60 day T4	120 day Total	Post	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
Pr>F	*0.0199*	*0.0275*	*0.0285*	*0.0265*	*0.0103*	*0.0006*	*0.0025*	*0.0057*	*0.0096*
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 N	0.311	5.947	4.361	10.308	3.883	3.478	7.361	2.958	20.627
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
Pr>F	*0.0206*	*0.0303*	*0.1190*	*0.0302*	*0.5352*	*0.3498*	*0.3440*	*0.0291*	*0.0383*
Species x Treatment Pr>F	*0.0217*	*0.0353*	*0.1408*	*0.0365*	*0.5444*	*0.3610*	*0.3541*	*0.0301*	*0.0439*
R^2	*0.6860*	*0.6609*	*0.5434*	*0.6490*	*0.4183*	*0.4544*	*0.4714*	*0.6838*	*0.6489*

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 175. Nitrogen Source Study in 2010 by species when there was a significant interaction.

	Total N (kg ha^{-2})									
			Application 15 Apr 10							
Treatment (lbs N 1,000 ft^{-2})	Pre		60 day T1		120 day Total		Post		Total	
	St. Aug	Cent	St. Aug	Cent	St. Aug	Cent	St. Aug	Cent	St. Aug	Cent
Untreated	0.044	0.012	0.517	0.202	0.755	0.342	0.420	0.288	1.584	0.931
Am. Nitrate (34-0-0) @ 1 lb N	0.609	0.015	11.600	0.294	20.049	0.566	5.505	0.411	39.877	1.376
Urea (46-0-0) @ 1 lb N	0.455	0.012	14.259	0.341	22.881	0.623	5.432	0.461	46.238	1.507
30% SRN (16-0-8) @ 1 lb N	0.495	0.010	10.108	0.330	14.768	0.588	4.096	0.385	30.096	1.330
50% SRN (19-0-0) @ 1 lb N	0.244	0.010	4.256	0.282	6.657	0.498	1.284	0.556	12.922	1.420
PCU (41-0-0) @ 1 lb N	0.058	0.011	1.087	0.255	1.491	0.453	2.282	0.395	7.638	1.223
PCU (41-0-0) @ 2 lbs N	0.047	0.012	9.633	0.289	14.193	0.505	7.094	0.384	36.347	1.250
BSD (6-2-0) @ 1 lb N	0.090	0.012	1.673	0.216	2.472	0.383	3.422	0.375	10.583	1.134
Pr>F	*0.0742*	*0..6892*	*0.1115*	*0.3100*	*0.1021*	*0.2109*	*0.0758*	*0.6524*	*0.0930*	*0.4608*
R^2	*0.4121*	*0.1650*	*0.3582*	*0.2691*	*0.3648*	*0.3059*	*0.3862*	*0.1745*	*0.3717*	*0.2243*

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 176. Nitrogen Source Study in 2011.

	Total N (kg ha^{-2})					
		Application 12 Apr 11				
	Pre*	60 day T1	60 day T2	120 day Total	Post	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
Pr>F	*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 N	0.103	0.175	0.588	0.764	0.015	0.779
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
Pr>F	*0.0564*	*0.0609*	*0.0179*	*0.0210*	*0.1606*	*0.0218*
Species x Treatment Pr>F	*0.0497*	*0.0558*	*0.0052*	*0.0083*	*0.0096*	*0.0084*
R^2	*0.5503*	*0.6415*	*0.7050*	*0.6993*	*0.5173*	*0.6987*

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 177. Nitrogen Source Study in 2011 by species when there was a significant interaction.

	Total N (kg ha^{-2})											
			Application 12 Apr 11									
			60 day		60 day		120 day Total					
Treatment (lbs N 1,000 ft^{-2})	Pre*		T1		T2				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 a	0.117	0.014 a	0.890	0.336	1.008	0.350	0.029 a	0.012	1.037 b	0.362
Am. Nitrate (34-0-0) @ 1 lb N	0.200	0.007 bc	0.342	0.009 bc	0.810	0.366	1.153	0.375	0.011 c	0.019	1.163 b	0.394
Urea (46-0-0) @ 1 lb N	0.560	0.011 a-c	0.951	0.006 cd	1.900	0.359	2.851	0.365	0.074 ab	0.011	2.875 ab	0.376
30% SRN (16-0-8) @ 1 lb N	0.356	0.006 bc	0.441	0.007 b-d	1.862	0.336	2.302	0.343	0.012 bc	0.018	2.314 b	0.361
50% SRN (19-0-0) @ 1 lb N	0.109	0.015 a	0.040	0.008 bc	0.397	0.749	0.436	0.757	0.008 c	0.017	0.444 b	0.774
PCU (41-0-0) @ 1 lb N	0.334	0.006 bc	0.656	0.006 cd	1.866	0.378	2.521	0.384	0.010 c	0.015	2.531 b	0.399
PCU (41-0-0) @ 2 lbs N	1.201	0.004 c	1.410	0.003 d	4.197	0.328	5.607	0.331	0.009 c	0.010	5.616 a	0.341
BSD (6-2-0) @ 1 lb N	0.321	0.013 ab	0.415	0.011 ab	0.760	0.389	1.174	0.399	0.010 c	0.014	1.184 b	0.413
Pr>F	*0.1161*	*0.0071*	*0.1686*	*0.0034*	*0.0952*	*0.3987*	*0.1033*	*0.4018*	*0.0231*	*0.6032*	*0.1048*	*0.4144*
R^2	*0.3663*	*0.5218*	*0.3254*	*0.5544*	*0.3700*	*0.2417*	*0.3640*	*0.2408*	*0.4604*	*0.1871*	*0.3629*	*0.2372*

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 178. Effect of year, species and N-application rate on total nitrogen leached.

	Total N (kg ha^{-1})								
		1st N application			2nd N application				
	Pre	60 day T1	60 day T2	120 day total	60 day T3	60 day T4	120 day total	Post	Total
Year									
2008	8.697 a	10.863	5.037	15.900	-	-	-	0.810	16.710
2009	0.187 b	0.255	0.216	0.467	0.338	0.922	1.260	2.025	3.752
2010	0.136 b	3.459	1.993	5.452	2.189	2.526	4.715	2.049	12.216
2011	0.188 b	0.277	0.995	1.272	-	-	-	0.014	1.287
P(F)	*0.0001*	*0.0003*	*0.0001*	*0.0001*	*0.0145*	*0.0132*	*0.0096*	*0.0018*	*0.0001*
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
P(F)	*0.5348*	*0.0001*	*0.0070*	*0.0004*	*0.0104*	*0.0009*	*0.0020*	*0.0001*	*0.0001*
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
P(F)	*0.7977*	*0.0007*	*0.0008*	*0.0001*	*0.4982*	*0.1171*	*0.1712*	*0.0009*	*0.0001*
Year x Species	*0.9967*	*0.0019*	*0.1250*	*0.0099*	*0.0111*	*0.0092*	*0.0069*	*0.0060*	*0.0061*
Year x Treatment	*0.9797*	*0.0014*	*0.0001*	*0.0001*	*0.5639*	*0.7380*	*0.5766*	*0.1386*	*0.0007*
Species x Treatment	*0.5887*	*0.0121*	*0.3064*	*0.0134*	*0.5633*	*0.1481*	*0.2168*	*0.0012*	*0.0011*
Year x Species x Treatment	*0.5887*	*0.1452*	*0.7866*	*0.3146*	*0.5170*	*0.7055*	*0.5260*	*0.1551*	*0.1393*
R^2	*0.8000*	*0.7628*	*0.6126*	*0.7578*	*0.4576*	*0.4846*	*0.5053*	*0.6761*	*0.7114*

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).
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 179. Effect of year, species and N-application rate on % of applied nitrogen.

	% of applied N						
	1st N application			2nd N application			
	60 day T1	60 day T2	120 day total	60 day T3	60 day T4	120 day total	Total
Year							
2008	21.15	11.07	16.72	-	-	-	17.53
2009	0.52	0.44	0.49	0.66	2.07	1.38	2.07
2010	7.24	4.55	6.28	4.55	5.38	5.45	7.03
2011	0.52	1.73	1.38	-	-	-	1.40
P(F)	*0.0001*	*0.0001*	*0.0001*	*0.0183*	*0.0615*	*0.0097*	*0.0001*
Species							
St. Augustinegrass	10.43	7.05	9.37	4.73	6.82	6.26	10.66
Centipedegrass	4.28	1.84	3.07	0.48	0.63	0.57	3.36
P(F)	*0.0005*	*0.0114*	*0.0007*	*0.0133*	*0.0052*	*0.0021*	*0.0002*
Treatment (lbs N 1,000 ft^{-2})							
Untreated							
Am. Nitrate (34-0-0) @ 1 lb N	10.62	6.36	8.49	4.32	4.79	4.56	9.35
Urea (46-0-0) @ 1 lb N	7.51	4.03	5.77	4.57	7.05	5.81	6.53
30% SRN (16-0-8) @ 1 lb N	12.36	9.28	10.82	2.99	4.66	3.82	11.47
50% SRN (19-0-0) @ 1 lb N	6.96	4.20	5.58	1.90	2.40	2.15	6.24
PCU (41-0-0) @ 1 lb N	5.72	1.21	3.46	1.14	1.57	1.35	3.95
PCU (41-0-0) @ 2 lbs N	4.71	-	6.83	1.95	-	4.59	8.10
BSD (6-2-0) @ 1 lb N	3.64	1.59	2.58	1.37	1.87	1.62	3.42
P(F)	*0.0002*	*0.0003*	*0.0001*	*0.6327*	*0.2107*	*0.3802*	*0.0001*
Year x Species	*0.0083*	*0.1346*	*0.0171*	*0.0140*	*0.0431*	*0.0070*	*0.0188*
Year x Treatment	*0.0001*	*0.0001*	*0.0001*	*0.7047*	*0.8156*	*0.7433*	*0.0001*
Species x Treatment	*0.0137*	*0.3080*	*0.0184*	*0.6951*	*0.2460*	*0.4276*	*0.0066*
Year x Species x Treatment	*0.2404*	*0.5447*	*0.4027*	*0.6602*	*0.7903*	*0.7062*	*0.5601*
R^2	*0.7773*	*0.6654*	*0.7651*	*0.4594*	*0.5059*	*0.5044*	*0.7619*

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).

PROJECT 4
NITRATE-N LEACHING FROM 'FLORATAM' ST. AUGUSTINEGRASS AND 'ULTIMATEFLORA®' ZOYSIAGRASS DURING WINTER MONTHS – GAINESVILLE
FINAL REPORT

GAINESVILLE – Dr. Laurie Trenholm

EXECUTIVE SUMMARY

This research was undertaken to observe how NO_3–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 NO_3–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 NO_3–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 NO_3–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 NO_3–N loading.

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 NO_3–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 NO_3–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 ^{15}N-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 NO_3–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 NO_3–N loading from warm-season grasses during winter months. Brown et al. (1977) reported greatest NO_3–N losses in 'Tifdwarf' bermudagrass (*Cynodon dactylon* L. x *C. transvaalensis* Burtt-Davy) during winter months. Snyder et al. (1984) reported greater NO_3–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 NO_3–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. ⅛ lb. N monthly
3. ¼ lb. N monthly
4. ½ 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 180. 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 180. Climatology and average historical data for the periods during which the research was conducted from 2006 to 2009 in Citra, Fl.

Rainfall	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
Temperature	----------ºC----------			
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 NO_3–N mass flux in response to the interaction of grass × N rate (Table 181). 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 NO_3–N loading between control treatments and up to 12.2 kg N ha^{-1}.

In year 2, cumulative NO_3–N loads differed in response to main effects of grass and N rate (Table 181). 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 181). 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 181. Analysis of variance and means for NO_3–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	Cumulative Nitrate N Mass Flux		
		----------kg N ha^{-1}----------		
	------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.

Regression analysis showed a quadratic and linear response in St. Augustinegrass and zoysiagrass, respectively for year 1 (Fig. 36). Sod was not well established when treatments began in Nov and there was little opportunity for good root formation prior to the study period. Additionally, construction had recently ended on the plots and soil mineralization likely contributed to the nitrate losses. This mineralization likely also contributed to the higher losses in control and low N plots than those receiving up to 2.5 lbs N 1,0000 ft^{-2}, which had the lowest nitrate losses. Losses from zoysiagrass increased in a linear fashion as applied N increased.

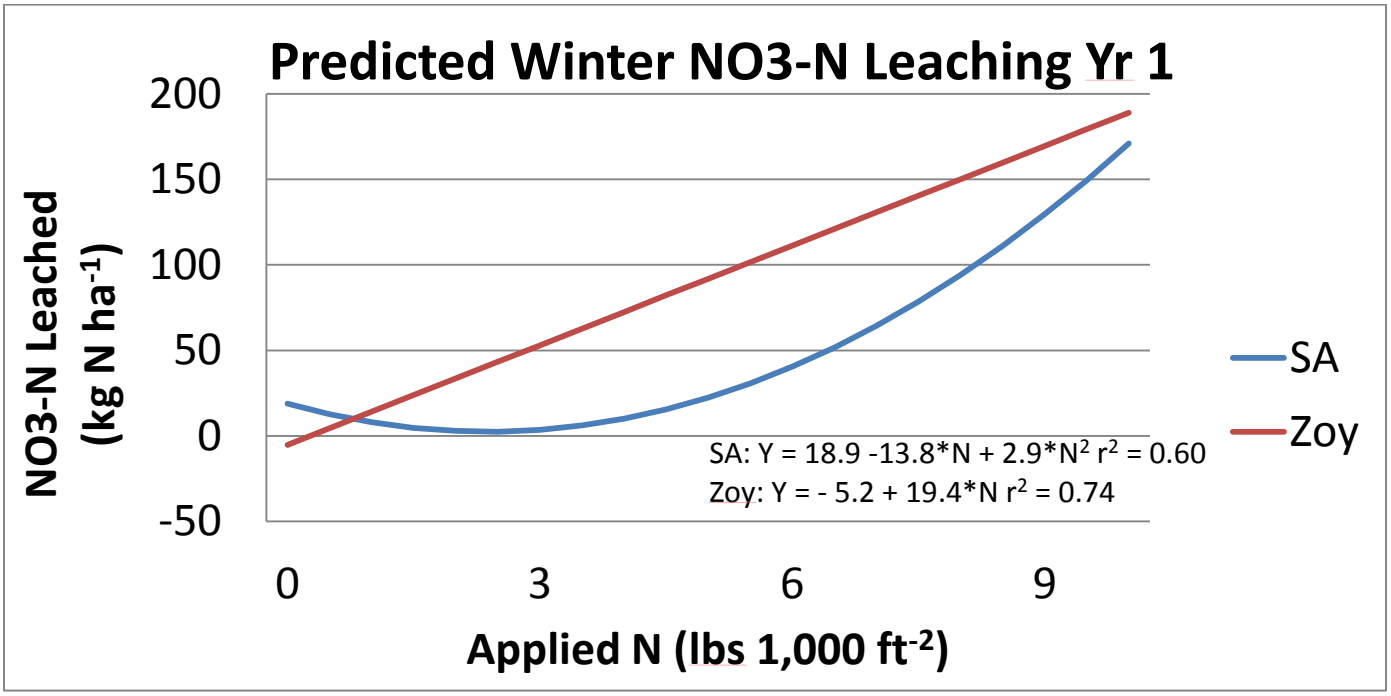

Figure 36.

In year 3, both grasses fit a quadratic model (Fig.37). Lowest predicted nitrate flux would occur at 2.5 and 2 lbs of applied N 1,000 ft^{-2} for St. Augustinegrass and zoysiagrass, respectively.

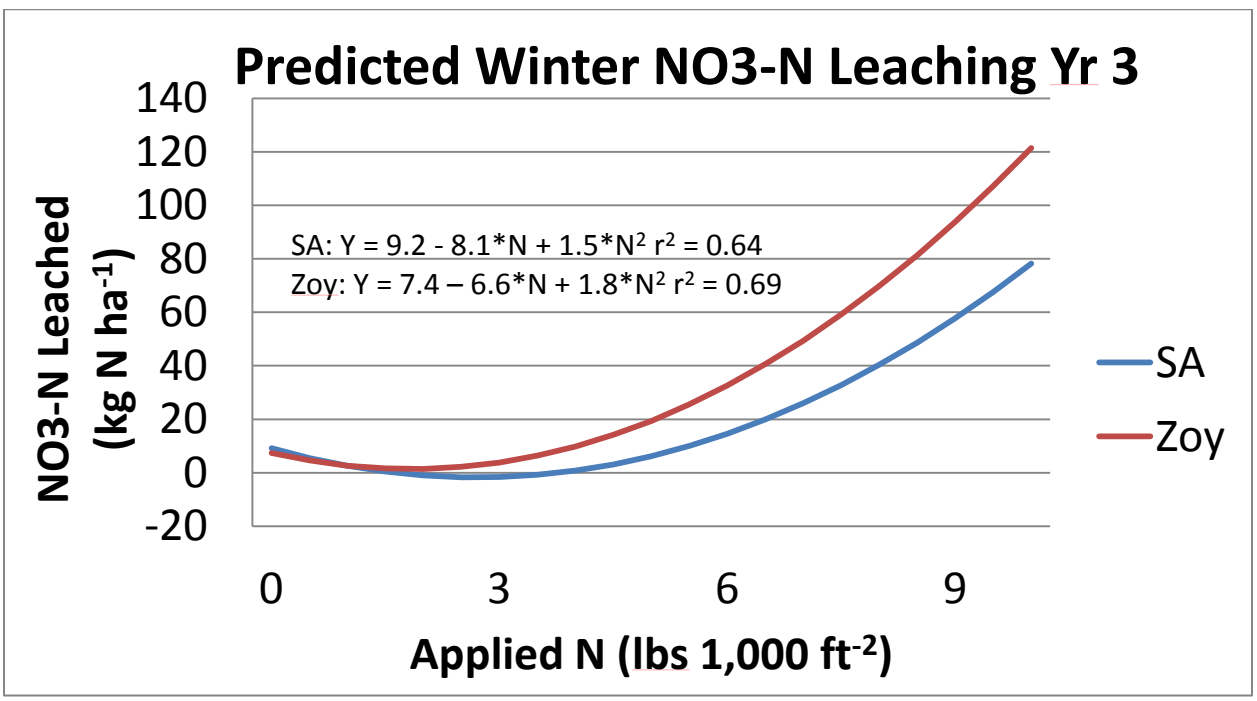

Figure 37.

The regression models do not imply that application of these rates of N would be appropriate management practices in north central Florida during the winter months.

Nitrate-N loads were also compared for the interaction of grass, N rate, and month of application. In years 1 and 3, there were significant 3 way interactions (Table 182). In year 2, there were differences due to grass and the interaction of N rate × month.

Table 182. Analysis of variance for NO_3–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 NO_3–N loading between months at the highest N rate (Table 183). 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 183. Nitrate-N mass flux in response to nitrogen rate and month in year 1 in St. Augustinegrass and zoysiagrass in Citra, FL.

	Nitrate N Mass Flux					
	----------kg N ha^{-1}----------					
	0	6.1	12.2	24.5	49.0	98.0
Month	St. Augustinegrass					
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
	Zoysiagrass					
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 184). Lowest NO_3–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 184. Nitrate-N mass flux in response to nitrogen rate and month in year 2 in St. Augustinegrass and zoysiagrass in Citra, FL.

	Nitrate N Mass Flux					
	----------kg N ha^{-1}----------					
Month	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 185). 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 185. Nitrate-N mass flux in response to nitrogen rate and month in year 3 in St. Augustinegrass and zoysiagrass in Citra, FL.

	Nitrate N Mass Flux					
	----------kg N ha^{-1}----------					
	0	6.1	12.2	24.5	49.0	98.0
Month	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 NO_3–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 NO_3–N leached from St. Augustinegrass than from other species investigated. Erickson et al. (2001) observed a cumulative annual NO_3–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 × N rate in year 1 in Dec, Jan and Mar (Table 186). 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 × 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 kg N ha^{-1}.

Table 186. 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	Turf quality					Turf color				
St. Augustinegrass	---kg N ha^{-1}--	Nov	Dec	Jan	Feb	Mar	Nov	Dec	Jan	Feb	Mar
	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
Zoysiagrass											
	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 ab	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	3.9 ab	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 bc	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	3.4 c	1.6 c	3.4 c	4.0	3.4 b	1.6 c	1.0 b	2.9 c
ANOVA											
Grass (G)…….		NS	**	**	*	*	***	**	**	**	NS
N Rate (N)……..		NS	***	***	***	***	*	***	***	***	***
G × 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 187). Quality scores for both grasses were below acceptable in all months. Color scores responded to the interaction of N × 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 kg N ha^{-1}or greater in Mar.

Table 187. 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	Turf quality				Turf color			
St. Augustinegrass	----kg N ha^{-1}----	Dec	Jan	Feb	Mar	Dec	Jan	Feb	Mar
	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
Zoysiagrass									
	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
ANOVA									
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 188). 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 188. 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.

	Monthly N Rate	Turf quality					Turf color				
St. Augustinegrass	--kg N ha^{-1}--	Nov	Dec	Jan	Feb	Mar	Nov	Dec	Jan	Feb	Mar
	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
Zoysiagrass											
	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
ANOVA											
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 kg N ha^{-1}) of N during winter months to St. Augustinegrass or zoysiagrass did not result in NO_3–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 NO_3–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 NO_3–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 NO_3–N mass loading.

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PROJECT 4
IMPACT OF FERTILIZER APPLICATIONS TO SEMI-DORMANT AND DORMANT LAWN GRASSES ON ENVIRONMENTAL QUALITY

Jay, FL – Dr. J. Bryan Unruh

MATERIALS AND METHODS

Experimental Site and Design

The study was conducted at the University of Florida's West Florida Research and Education Center, (30°46'3N, 87°08'W) on stands of Common Centipedegrass and Floratam St. Augustinegrass grown on native soil identified by the USGA survey as Fuquay loamy sand. The experiment consisted of 40-6m x 3m turfgrass split plots with 4 replications. Whole plots (Turfgrass variety) measured 15m x 12m. Sod was established the week of 25 Sep 2006. Treatments were applied approximately every 45 days, (2006-2007 Yr 1) 23 Oct, 06 Dec, 18 Jan, 05 Mar, (2007-2008 Yr 2) 31 Aug, 16 Oct, 30 Nov, 15 Jan, 29 Feb, (2008-2009 Yr 3) 28 Aug, 13 Oct, 1 Dec, 15 Jan, and 2 Mar. Each turf split plot regardless of variety received one of 5 N rates (0.000, 6.103, 12.206, 24.413, and 48.826 N kg $ha^{-1}yr^{-1}$) from soluble urea, applied as a spray with a volume of 1222 L per hectare with no other nutrients being applied. Leachate collection for volume (mL), NOx-N (mg/L), and Ortho-P (ug/L) analysis (Yr 1, Tx 1) was collected twice weekly began 05 October 2006 and ended 04 Dec 2006 for 17 sampling events, (Yr 1, Tx 2) began 11 Dec 2006 and ended 18 Jan 2007 for 13 sampling events (Yr 1, Tx 3) began 22 Jan 2007 and ended 04 Mar 2007 for 13 sampling events (Yr 1, Tx 4) began 07 Mar 2007 and ended 19 Apr 2007 for 13 sampling events. The 17,13,13, and 13 sampling events for 2006-2007 included 6 pre-treatment (pre first seasonal application of liquid urea) sampling events, and 0 post-treatment (>45days after last application of liquid urea) sampling events, (Yr 2, Tx 1) began 20 Aug 2007 and ended 15 Oct 2007 for 17 sampling events(Leachate collection for volume (mL), and NOx-N (mg/L) only (Ortho-P analysis was suspended 06 Aug 2007 due to it not being a treatment and to diminish a laboratory backlog), (Yr 2, Tx 2) began 19 Oct 2007 and ended 29 Nov 2007 for 13 sampling events, (Yr 2, Tx 3) began 03 Dec 2007 and ended 14 Jan 2007 for 13 sampling events, (Yr 2, Tx 4) began 17 Jan 2008 and ended 25 Feb 2008 for 9 sampling events (sampling events per treatment period of 45 days diminish from here forward because frequency changed from twice each week to weekly per DEP meeting 25 Jan 2008), (Yr 2, Tx 5) began 04 Mar 2008 and ended 15 Apr 2008 for 7 sampling events. The 17, 13, 13, and 9 sampling events for 2007-2008 included 4 pre-treatment, and 0 post-treatment events, (Yr 3, Tx 1) began 19 Aug 2008 and ended 07 Oct 2008 for 9 sampling events, (Yr 3, Tx 2) began 14 Oct 2008 and ended 24 Nov 2008 for 7 sampling events, (Yr 3, Tx 3) began 02 Dec 2008 and ended 13 January 2009 for 7 sampling events, (Yr 3, Tx 4) began 20 Jan 2009 and ended 24 Feb 2009 for 6 sampling events, (Yr 3, Tx 5) began 3 Mar 2009 and ended 09 Jun 2009 for 14 sampling events The 9, 7, 7, 6, and 14 sampling events for 2006 included 2 pre-treatment and 7 post-treatment sampling events. For turf establishment irrigation was supplied by 4 Rainbird 7005 rotary irrigation heads per plot in a 15m square layout with 4-90° arcs having a precipitation rate of 0.508mm per minute utilizing a programmable controller to deliver pulse irrigation of 4 minutes (2.032mm) 3x per day for days 1-7, followed by 6.35mm per day for days 8-14, followed by 80% of ET for St. Augustine and 60% of ET for

Centipede every third day adjusted when stress is noted. To avoid exceeding soil percolation rates 4 separate start times over 4.5 hours were utilized. Irrigation was not suspended for rain events. Additional precipitation (from rainfall events) and subsequent increases in leachate were quantified and reported as comparators to non rain event data. Plot preparation followed the installation of plot lysimeters utilizing light tillage, a box blade and drag mats with any settling at lysimeters corrected prior to placement of sod further utilizing a box blade and drag mats. Once plots were established they were maintained at a height of cut of 50.8mm for centipede and 76.2mm for St. Augustine using a rotary mower with clippings left in place.

Collection of Leachate

Using a Toro Dingo skid steer equipped with a 60.96cm power auger, soil was removed to a depth of 106.68cm taking care to keep horizons separated for reconstruction within lysimeters of high density polyethylene (HDPE), having an internal height of 86.36cm, cylinder wall height of 78.74cm, conical section height of 7.62cm, and I.D. of 55.88cm yielding a total volume of 199.333L, supported upon a hot dipped galvanized base having an internal diameter of 57.15cm and constructed such that it has a tank bearing surface ≅ 1935cm^2 and a soil bearing surface ≅ 2355. cm^2 with a total height of 25.4cm that raises the tank 10.16cm (initially designed to allow for the installation of a bulkhead fitting at the apex of the conical bottom, tapped to receive a 9.525mm MNPT x 9.525mm OD nylon elbow fitting which is connected via 9.525mm LDPE tubing via trench to central lysimeter leachate removal/sampling stations). However, with the expanded installation of these forty lysimeters the bottoms were left intact and the leachate was accessed directly with the 9.525mm LDPE tubing by entering through one of two 9.525mm holes bored through the side wall 10.16cm down from the top rim of the lysimeter and routed to the inside apex of the conical bottom, the other hole being for a vent line (to prevent pressure differentials from affecting leaching rates when lysimeters are being sampled) of 9.525cm LDPE to reach to the upper portion of the leach field just below the non-woven polyolefin was routed with the leachate collection line via trench to central lysimeter leachate removal/sampling stations, each servicing the ten lysimeters within a 15m x 12m plot. Bore holes were prepped by tamping and leveling soil with a 17kg, 858cm^2 hand tamping tool to a finished depth of 106.68cm allowing for 10.16cm of soil cover above the upper rim of the lysimeter. Lysimeters were prepared with a leaching bed of washed 1.905-4.445cm round river rock having a volume of 0.034m^3 covered with non-woven polyolefin cloth 60.96cm in diameter secured with an internal interference fitted hoop of 1.27cm HDPE tubing. Once lowered into the level and prepped bore holes original soil horizons were recreated in 15.24cm lifts within the lysimeter each being packed by dropping the tamping tool from a consistent height, allowing gravity rather than thrust to compact soil consistently. The area surrounding the lysimeter and undisturbed soil was treated in kind. Any settling at lysimeters was corrected prior to seedbed preparation utilizing a box blade and drag mats.

Leaching of NO_3-N + NO_2-N and Ortho-PO_4 was determined by removing all leachate for volume determination and acquiring a grab sample for NO_3-N + NO_2-N and Ortho-PO_4 (suspended 06 Aug 2007) analysis from each of the 40 lysimeters on a twice weekly basis until changed to weekly beginning 29 Jan 2008 per DEP meeting 25 Jan 2008. (Year 1, 23 Oct 2006 through 08 Feb 2007) Sampling was by applying a vacuum to a 2000ml filtering flask (leachate collection trap) preceded by an inline 60ml syringe tap that allowed connection directly to the 9.525mm LDPE leachate tube at the leachate removal/sampling station. The collected leachate was measured for volume utilizing 1000ml graduated cylinders and the samples were usually captured without contamination (appropriately coded if contamination was suspect) by cycling the syringes 3 times utilizing the initial flow of leachate or if volumes were not sufficient to triple rinse with leachate then the syringe was triple rinsed utilizing

distilled water prior to applying a vacuum to the collection apparatus. (Year 1, 12 Feb 2007 forward through Yr2 and Yr3) Sampling was by applying a vacuum to a secondary leachate collection trap equipped with a bottom drain, having a capacity greater than any one lysimeter leaching bed and connected via 9.525mm clear PVC tubing to a low volume primary trap constructed such that our 20ml sample vial was the trap. Thus, by triple rinsing the trap head with as little as 60ml of distilled water, connecting directly to the lysimeter leachate tube at the removal/sampling station and fitting our clean sample vial as the trap we were able to collect a contaminate free grab sample from any volume of leachate and by draining the secondary trap to a suspended load cell equipped weighing bucket, volume was inferred from mass, given 1g of pure H_2O at 4°C and 760mm Hg equals 1ml and leachate would vary insignificantly (<1%) at sampling temperatures and pressures. Upon DEP's request for quarterly sampling for Ortho-PO_4 beginning 17 Feb 2009 a new primary vacuum trap head was designed to accept the barrel of a separate sterile 60mL single use syringe equipped with a luer lock 45µm filter and syringe cap for a leachate trap. When removed from the vacuum head, the syringe was fitted with its plunger and assembled into a press to extract a filtered sample for Ortho-PO_4, a duplicate when needed and a NOx sample as well or a NOx sample, its duplicate and an Ortho-PO_4 sample as well. The syringe vacuum head was triple rinsed the same as the 20mL scintillation vial vacuum head.

Sample Analysis

Sample analysis was by colorimetric auto analyzer at the UF/IFAS Analytical Research Laboratory, Gainesville, FL utilizing EPA method 353.2 for NO_3-N + NO_2-N, and 365.1 for Ortho-PO_4. MDL's for NOx and Ortho-P were 0.05mg/L, and 2.5µg/L until 01 Dec 2008 when they changed to 0.148mg/L and 3.0µg/L. PQL's for NOx and Ortho-P were 0.5mg/L and 10µg/L and remained unchanged after 01 Dec 2008. Linear working ranges for NOx and Ortho-P were 0.50-30.00mg/L and 0.01-0.50mg/L. Laboratory estimates of uncertainty for NOx and Ortho-P have an estimated bias of +0.95 and +1.46 and an estimated precision of ±3.61% and ±3.16%. Note: Precision estimates only apply to laboratory instrumentation and do not include any error associated with sample handling or collection variances and were determined by measuring the dispersion of values obtained from a known certified reference standard using typically 20-30 data points. With this, both bias (average % yield – 100) and precision (standard deviation of % yield) were determined (UF/IFAS Analytical Research Laboratory).

Measures of Turfgrass Quality, Dry Clipping Mass, and Dry Root Mass

Turfgrass visual quality, color, and density assessments were conducted 31 Oct 2006 through 14 Jun 2007 (Year 1), 07 Sep 2007 through 06 May 2008 (Year 2), and 17 Sep 2007 through 25 Jun 2008 (Year 3) on two week intervals or less, unless dormant or changes were insignificant (which accounts for assessment periods greater than 2 weeks), utilizing NTEP turfgrass evaluation guidelines. Scales are 1-9 with a quality rating of 9 being best and 1 being poorest, color rating of 9 being dark green and 1 light green, and density rating of 9 being maximum density. Any rating 6 or greater is considered generally acceptable. Ratings are generally in whole numbers. Winter injury and %weeds were assessed on (Year 1) 28 Mar 2007, 06 Apr 2007, 18 Apr 2007, (Year 2) 02 Dec 2007, 29Feb 2008, 14 Mar 2008, 07 Apr 2008, 06 May2008 16 (Year 3) Feb 2009, and 17 Apr 2009.

Turfgrass clipping samples were not collected (Year 1) due to late sod installation (week of 25 Sep 2006) and dormancy. Turfgrass clippings were collected (Year 2) at 5,12,19,26,34, and 41 days post Tx1 (05 Sep 2007) and 68 days post Tx5 (07 May 2008), (Year 3) at 27, 42 days post Tx1 (28 Aug 2008) (long sampling interval was due to irrigation well being down from 21 Aug 2008 to 22 Sept 2008 and drought conditions resulting in very little growth), 66, 79, 93, 105, and 114 post Tx5 (02 Mar 2009) Clippings represented approximately 7 days *shoot*

growth with a collection interval of approximately 7 days(Year 2 post Tx1), and 10-14 days (Year 3 post Tx5) of shoot growth from a 3.25m^2 areas within each 3m x 6m plot using a rotary mower set at a mowing height of 50.8mm for centipede and 76.2mm for St. Augustine with a modified grass catching system utilizing a 30.48cm by 40.64cm cloth bag in lieu of the manufacturers grass catching system. Samples were dried using forced hot air averaging 50°C for 48 to 72 hours prior to measuring masses.

Following each season of dormancy 5 root samples were collected using a pedal style soil sampler measuring 20mm dia. x 100mm long, one from each quadrant and one from the center of each plot. Soil, and debris separation from roots was accomplished by washing with water in a sieve accompanied by mechanical pressure and agitation. Separated roots were then air dried followed by oven drying at 50°C for 48-72 hours prior to measuring masses. These masses were corrected for retained mineral materials by ashing the samples and subtracting the mass of the remaining debris minus the ash. Note: Due to poor data controls the actual dates of sampling and year 1 data cannot be confirmed, thus the omission of actual sampling dates and year 1 data.

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 189) 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 191). The 24.0 kg ha^{-1} N application rate also increased shoot growth over the untreated on 7 May 2008 (Table 191). 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 190). 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 192).

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 193 and 194). 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 193). 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 (Table1957).

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 197). Acceptable turf quality was achieved with rates above 12.0 kg ha^{-1} (Table 196). Centipedegrass density during the winter months was not affected by nitrogen rate (Table 198).

Combined Analysis: During the fall months, centipedegrass exhibited better turf quality than St. Augustinegrass (Table 199) which is likely attributed to turf color (Table 200). 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 200). St. Augustinegrass maintains better color during the winter months (Table 200). Across all nitrogen rates, centipedegrass had better turf quality during active growing conditions (Table 200). Turf density is was comparable between the two species and increasing nitrogen application rate produced greater turf density (Table 201)

2007-08

St. Augustinegrass: Through September, plots receiving any level of nutrition had acceptable turf quality (Table 202). From October 2007 through spring 2008, acceptable turf quality was evident only in turf receiving ≥ 24.0 kg ha^{-1} (Table 202). N rates ≥ 24.0 kg ha^{-1} retained color longer into the fall and promoted faster spring green-up (Table 203). Turf density was also best on plots receiving ≥ 24.0 kg ha^{-1} (Table 204).

Centipedegrass: Centipedegrass followed similar trends as St. Augustinegrass (Table 205). Untreated centipedegrass had acceptable turf quality throughout 2007 indicating that residual nutrition (from sod production practices) was still sufficient (Table 205). 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 206). Turf density was acceptable at all levels of applied nitrogen (Table 207).

Combined Analysis: During the fall months, centipedegrass exhibited better turf quality than St. Augustinegrass (Table 208) which is likely attributed to turf color (Table 209). Turf density is was comparable between the two species and increasing nitrogen application rate produced greater turf density (Table 210).

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 211). 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 212). 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 213). 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 191).
Centipedegrass: Centipedegrass followed similar trends as St. Augustinegrass (Table 214). Acceptable turf quality was achieved with N rates above 12.5 kg ha^{-1} (Table 214). Nitrogen rates ≥ 12.5 kg ha^{-1} promoted a more rapid spring green-up (Table 215) and centipedegrass density during the winter months was not affected by N rate (Table 216).

Combined Analysis – Turf Type: Centipedegrass turf exhibited higher quality, turf color and density compared to St. Augustinegrass turf during the fall months (Table 217, 218, and 219). Centipedegrass exhibited better turf quality than St. Augustinegrass (Table 217) which is likely attributed to turf color (Table 218). 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 218). In general, increasing N application rate improved turf quality, color and density (Table 217, 218, and 219).

<u>Nitrate Leaching</u>

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 220). 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 220). 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 221).

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 222). 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 222). Expressed as a percent of applied, differences between the two species were never significant during 2007-08 (Table 223) However, difference due to N rate were present on each treatment cycle except for T5 (4 Mar – 15 Apr) (Table 223).

2008-09

In 2008-09 there were no differences between St. Augustinegrass and centipedegrass in the amount of NO_3-N leached or the % of applied N (Tables 224 and 225). No significant differences in NO_3-N leaching between N application rates were detected until sampling periods T5 and T6 (March 2009 through June 2009 (Tables 224). 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 224). Leaching events consistently follow major rain events (Figure 38) and lead to the total NO_3-N leaching being highest with the 49 kg ha^{-1} (Table 224). 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 225). During the T5 and T6 periods and total accumulated % nitrogen applied was highest at the 49 kg ha^{-1} which corresponds to the total NO_3-N leaching (Tables 224 and 225).

Combined Analysis – Years: Leaching was highest during 2006 and is likely attributed to nutrient import from the sod production farm (Table 226). Over the three years, centipedegrass leached more NO_3-N than St. Augustinegrass during the T3 and T4 time periods (Table 226; Figure 39). 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 NO_3-N leaching (Table 226; Figure 40). The % of applied nitrogen was highest in 2006 (Table 227) 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 227).

Table 189. Effect of turf type and N-application rate on St. Augustinegrass shoot growth in 2007-08.

	Mass (g)						
Rate	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}	0.360 b	0.142 b	0.265 b	0.403 b	0.516	0.352 b	6.726 c
6.0 kg ha^{-1}	0.350 b	0.235 b	0.218 b	0.302 b	0.385	0.276 b	6.949 c
12.5 kg ha^{-1}	0.696 b	0.332 b	0.424 b	0.329 b	0.473	0.262 b	7.554 c
24.0 kg ha^{-1}	0.906 b	0.607 b	0.567 b	0.562 b	0.533	0.441 ab	24.751 b
49.0 kg ha^{-1}	3.005 a	2.655 a	1.359 a	1.433 a	0.893	0.701 a	55.918 a
LSD	*0.851*	*0.688*	*0.505*	*0.452*	*ns*	*0.278*	*13.831*

Means followed by the same letter(s) in a column are not significantly different according to Fisher's Protected LSD (*P=0.05*).

Table 190. Effect of turf type and N-application rate on Centipedegrass shoot growth in 2007-08.

	Mass (g)						
Rate	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	13.709 c	10.892 bc	8.963 c	10.101 b	7.292 bc	11.042 c
6.0 kg ha^{-1}	27.434	11.564 c	9.742 c	8.301 c	8.823 b	6.500 c	9.807 c
12.5 kg ha^{-1}	19.688	14.525 bc	11.351 bc	10.069 c	10.621 b	7.765 bc	15.590 c
24.0 kg ha^{-1}	19.203	18.878 b	14.981 b	13.648 b	11.624 b	8.876 b	29.863 b
49.0 kg ha^{-1}	23.910	29.995 a	29.031 a	18.762 a	20.915 a	13.948 a	81.333 a
LSD	*ns*	*5.156*	*4.758*	*2.772*	*3.588*	*2.316*	*9.851*

Means followed by the same letter(s) in a column are not significantly different according to Fisher's Protected LSD (*P=0.05*).

Table 191. Effect of turf type and N-application rate on St. Augustinegrass shoot growth in year 3 (2008-09).

	Mass (g)							
N Rate	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}	6.726 c	1.588	0.558	0.963	0.057 b	0.148 b	0.276	2.037
6.0 kg ha^{-1}	6.949 c	1.089	0.421	0.776	0.036 b	0.162 b	0.304	1.508
12.5 kg ha^{-1}	7.554 c	1.376	0.401	0.775	0.056 b	0.119 b	0.255	2.675
24.0 kg ha^{-1}	24.751 b	1.052	0.591	0.848	0.038 b	0.143 b	0.390	1.558
49.0 kg ha^{-1}	55.918 a	1.399	1.059	2.132	0.161 a	0.376 a	0.589	3.129
P(F)	****	*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 192. Effect of turf type and N-application rate on centipedegrass shoot growth in year 3 (2008-09).

	Mass (g)							
N Rate	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 193. N fertilization effects on St. Augustine turf quality in 2006-07.

	Nitrogen application date													
	23 October			6 December			18 Jan	5 March		21 April				
N rate	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 194. N fertilization effects on St. Augustine turf color in 2006-07.

	Nitrogen application date													
	23 October			6 December			18 Jan	5 March		21 April				
N rate	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 195. N fertilization effects on St. Augustine turf density in 2006-07.

	Nitrogen application date													
	23 October			6 December			18 Jan	5 March		21 April				
N rate	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 196. N fertilization effects on Centipede turf quality in 2006-07.

	Nitrogen application date													
	23 October			6 December			18 Jan	5 March		21 April				
N rate	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 197. N fertilization effects on Centipede turf color in 2006-07.

	Nitrogen application date													
	23 October			6 December			18 Jan	5 March		21 April				
N rate	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 198. N fertilization effects on Centipede turf density in 2006-07.

	Nitrogen application date													
	23 October			6 December			18 Jan	5 March		21 April				
N rate	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 199. 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 200. 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 201. 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 202. N fertilization effects on St. Augustine turf quality in 2007-08.

	Nitrogen application date								
	31 August					30 November		29 February	
N rate	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 203. N fertilization effects on St. Augustine turf color in 2007-08.

	Nitrogen application date								
	31 August					30 November		29 February	
N rate	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 204. N fertilization effects on St. Augustine turf density in 2007-08.

	Nitrogen application date								
	31 August					30 November		29 February	
N rate	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 205. N fertilization effects on Centipede turf quality in 2007-08.

	Nitrogen application date								
	31 August					30 November		29 February	
N rate	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 206. N fertilization effects on Centipede turf color in 2007-08.

	Nitrogen application date								
	31 August					30 November		29 February	
N rate	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 207. N fertilization effects on Centipede turf density in 2007-08.

	Nitrogen application date								
	31 August					30 November		29 February	
N rate	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
LSD.....	*ns*	*ns*	*0.3*	*0.5*	*0.7*	*ns*	*0.9*	*0.8*	*ns*

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 208. 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 209. 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 210. N fertilization effects on turf density 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	7.4	7.4	7.4	6.6	7.0 b	6.8	7.0	7.0	6.4
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 211. N fertilization effects on St. Augustine turf quality in 2008-09.

	Nitrogen application date						
	28 August 2008		15 January 2009	2 March 2009	17 April 2009		
N rate	20 DAA	43 DAA	32 DAA	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 212. N fertilization effects on St. Augustine turf color in 2008-09.

	Nitrogen application date						
	28 August 2008		15 January 2009	2 March 2009	17 April 2009		
N rate	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 cd	1.0	5.0 b	5.6	4.9 bc	4.8 c
12.5 kg ha^{-1}	6.8 bc	6.4 bc	1.0	5.4 ab	5.9	5.1 bc	5.5 b
24 kg ha^{-1}	7.3 ab	6.6 b	1.0	6.5 a	6.3	5.6 b	5.0 bc
49 kg ha^{-1}	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 213. N fertilization effects on St. Augustine turf density in 2008-09.

	Nitrogen application date						
	28 August 2008		15 January 2009	2 March 2009	17 April 2009		
N rate	20 DAA	43 DAA	32 DAA	46 DAA	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 cd	5.8 b	5.0	5.5	4.3	4.5 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 214. N fertilization effects on centipede turf quality in 2008-09.

	Nitrogen application date						
	28 August 2008		15 January 2009	2 March 2009	17 April 2009		
N rate	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 215. N fertilization effects on centipede turf color in 2008-09.

	Nitrogen application date						
	28 August 2008		15 January 2009	2 March 2009	17 April 2009		
N rate	20 DAA	43 DAA	32 DAA	46 DAA	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 216. N fertilization effects on centipede turf density in 2008-09.

	Nitrogen application date						
	28 August 2008		15 January 2009	2 March 2009	17 April 2009		
N rate	20 DAA	43 DAA	32 DAA	46 DAA	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 217. 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 a-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 218. 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 219. 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 bc	4.8 bc
12.5 kg ha^{-1}	6.6	7.1 c	5.6 b	6.1 ab	6.2 b	5.6 ab	5.5 ab
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 bc	6.3 ab	5.6 ab	5.6 ab
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 220. Effect of turf type and N-application rate on total nitrogen leached in 2006-07.

	Total N (kg/ha)					
	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
P(F).....	*0.6441*	*0.7494*	*0.2251*	*0.0642*	*0.0010*	*0.9139*
Rate						
0.0 kg/ha	25.885	11.295	5.751	1.796	0.686 ab	45.411
6.0 kg/ha	32.760	13.903	7.993	1.495	0.424 b	56.576
12.5 kg/ha	22.838	11.260	5.203	1.647	0.679 ab	41.627
24 kg/ha	24.224	15.478	6.763	1.381	0.407 b	48.253
49 kg/ha	27.216	15.272	7.602	2.536	0.928 a	53.554
P(F).....	*0.7917*	*0.6554*	*0.6168*	*0.2996*	*0.0175*	*0.6653*
Turf x Rate.....	*0.4514*	*0.6138*	*0.9992*	*0.9832*	*0.0683*	*0.5020*
R^2	*0.6564*	*0.3675*	*0.3319*	*0.5093*	*0.8250*	*0.5983*

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).

Table 221. 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
P(F).....	*0.4275*	*0.6656*	*0.3593*	*0.0580*	*0.0090*	*0.5730*
Rate						
0.0 kg/ha	-	-	-	-	-	-
6.0 kg/ha	546.00 a	231.71 a	133.22 a	24.92 a	7.07 a	396.93 a
12.5 kg/ha	182.70 b	90.08 b	41.62 b	13.17 b	5.44 a	150.31 b
24 kg/ha	100.93 b	64.49 b	28.18 b	5.75 b	1.69 b	100.12 b
49 kg/ha	55.54 b	31.17 b	15.52 b	5.18 b	1.89 b	53.75 b
P(F).....	*0.0158*	*0.0001*	*0.0006*	*0.0007*	*0.0053*	*0.0001*
Turf x Rate.....	*0.3919*	*0.8290*	*0.8552*	*0.2532*	*0.2025*	*0.9939*
R^2	*0.6175*	*0.7812*	*0.6597*	*0.7284*	*0.7584*	*0.7852*

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).

Table 222. Effect of turf type and N-application rate on total nitrogen leached in 2007-08.

	Total N (kg/ha)						
	Pre	T1	T2	T3	T4	T5	Total Post
Turf type							
St. Augustine.....	0.040	0.118	0.178 b	0.205	0.234	0.126 b	0.902 b
Centipede.....	0.049	0.190	0.257 a	0.297	0.913	0.504 a	2.364 a
P(F).....	*0.5824*	*0.0774*	*0.0315*	*0.2187*	*0.0264*	*0.0330*	*0.0432*
Rate							
0.0 kg/ha	0.051	0.129	0.188	0.257	0.516	0.272	1.771
6.0 kg/ha	0.045	0.158	0.243	0.234	0.338	0.163	1.180
12.5 kg/ha	0.051	0.168	0.234	0.267	0.458	0.362	1.540
24 kg/ha	0.027	0.170	0.186	0.236	0.509	0.161	1.290
49 kg/ha	0.050	0.138	0.228	0.261	1.046	0.615	2.383
P(F).....	*0.4739*	*0.8634*	*0.5976*	*0.9040*	*0.0584*	*0.1876*	*0.1599*
Turf x Rate.....	*0.2609*	*0.5033*	*0.7043*	*0.6376*	*0.0458*	*0.1596*	*0.1346*
R^2	*0.4579*	*0.3182*	*0.3178*	*0.6870*	*0.7021*	*0.5487*	*0.6989*

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).

Table 223. Effect of turf type and N-application rate on total nitrogen leached in 2007-08.

	% nitrogen applied						
	Pre	T1	T2	T3	T4	T5	Total Post
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
P(F).....	*0.8434*	*0.1713*	*0.1426*	*0.3926*	*0.0614*	*0.1281*	*0.1021*
Rate							
0.0 kg/ha	-	-	-	-	-	-	-
6.0 kg/ha	0.74 a	2.63 a	4.05 a	3.90 a	5.64 a	2.72	18.93 a
12.5 kg/ha	0.41 ab	1.34 b	1.87 b	2.14 b	3.66 ab	2.90	11.91 ab
24 kg/ha	0.11 b	0.71 b	0.77 b	0.98 c	2.12 b	0.67	5.26 b
49 kg/ha	0.09 b	0.28 b	0.47 b	0.53 c	2.13 b	1.26	4.67 b
P(F).....	*0.0022*	*0.0039*	*0.0004*	*0.0001*	*0.0251*	*0.3358*	*0.0015*
Turf x Rate.....	*0.4768*	*0.4519*	*0.3618*	*0.9837*	*0.9785*	*0.6955*	*0.9144*
R^2	*0.6299*	*0.6199*	*0.7019*	*0.7953*	*0.6937*	*0.4467*	*0.7132*

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).

Table 224. Effect of turf type and N-application rate on total NO_3-N leached in 2008-09.

	Total N (kg/ha)							
	Pre	T1	T2	T3	T4	T5	T6	Total Post
Turf type								
St. Augustine.....	0.087	0.094	0.155	0.058	0.346	2.600	1.479	5.577
Centipede.....	0.112	0.077	0.171	0.065	0.391	2.829	1.039	5.202
P(F).....	*0.0714*	*0.4027*	*0.7846*	*0.8722*	*0.8575*	*0.8665*	*0.5580*	*0.8869*
Rate								
0.0 kg/ha	0.115	0.101	0.190	0.039	0.229	0.616 b	0.213 b	1.881 b
6.0 kg/ha	0.094	0.080	0.111	0.036	0.206	0.443 b	0.268 b	1.487 b
12.5 kg/ha	0.108	0.062	0.139	0.035	0.252	0.737 b	0.500 b	2.132 b
24 kg/ha	0.080	0.093	0.133	0.055	0.359	0.880 b	0.312 b	2.293 b
49 kg/ha	0.101	0.093	0.241	0.145	0.796	10.895 a	5.004 a	19.152 a
P(F).....	*0.9133*	*0.7833*	*0.2141*	*0.1632*	*0.0948*	*0.0001*	*0.0001*	*0.0001*
Turf x Rate.....	*0.6881*	*0.8903*	*0.1979*	*0.8643*	*0.9469*	*0.9797*	*0.9618*	*0.9839*
R^2	*0.1911*	*0.2638*	*0.5306*	*0.4507*	*0.5207*	*0.7477*	*0.6672*	*0.7016*

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). . Means followed by the same letter(s) in a column are not significantly different according to Fisher's Protected LSD (*P=0.05*)

Table 225. Effect of turf type and N-application rate on % of applied nitrogen in 2008-09.

	% nitrogen applied							
	Pre	T1	T2	T3	T4	T5	T6	Total Post
Turf type								
St. Augustine.....	0.66	0.63	0.95	0.36	2.09	9.73	6.02	22.87
Centipede.....	0.82	0.57	1.06	0.36	2.19	9.86	3.97	20.59
P(F).....	*0.3544*	*0.6968*	*0.7073*	*0.9640*	*0.9389*	*0.9791*	*0.4665*	*0.8153*
Rate								
0.0 kg/ha	-	-	-	-	-	-	-	-
6.0 kg/ha	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	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	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	0.21 b	0.19 b	0.49 b	0.30	1.63	2.23 a	10.21 a	38.88 a
P(F).....	*0.0075*	*0.0229*	*0.0065*	*0.1270*	*0.1555*	*0.0041*	*0.0262*	*0.0315*
Turf x Rate.....	*0.9503*	*0.9322*	*0.6320*	*0.7576*	*0.4864*	*0.6040*	*0.6976*	*0.6949*
R^2	*0.5168*	*0.4458*	*0.5836*	*0.6038*	*0.6405*	*0.6390*	*0.5910*	*0.5748*

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).

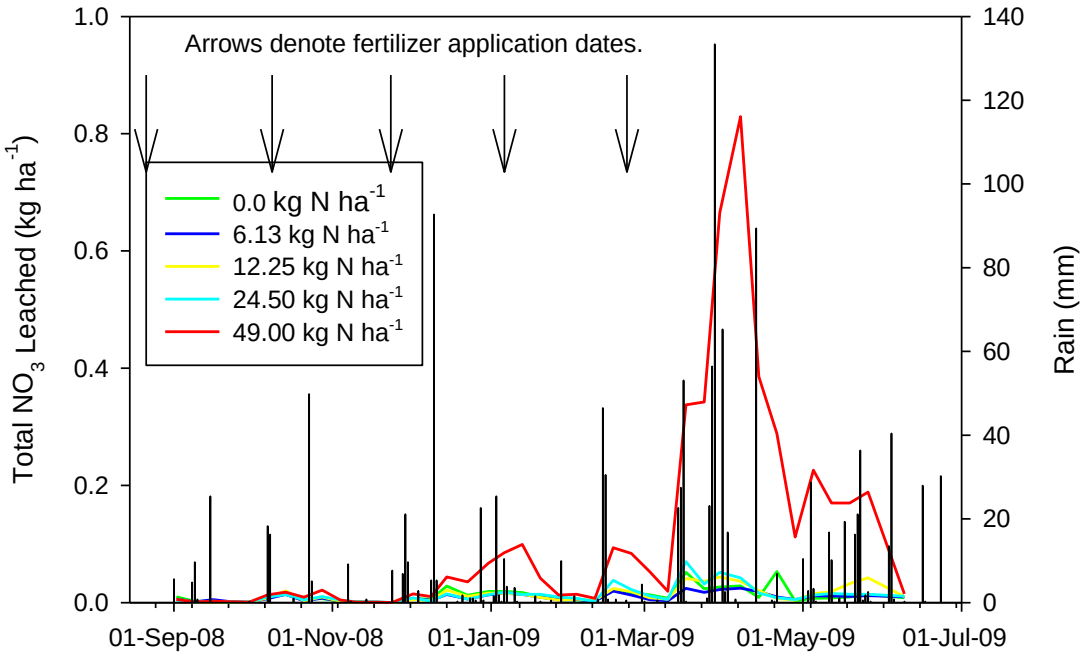


Figure 38. Fall fertility 2008 total NO3 leached from different nitrogen rates and the corresponding rainfall that occurred.

Table 226. Effect of year, turf type and N-application rate on total nitrogen leached.

	Total N (kg/ha)						
	Pre	T1	T2	T3	T4	T5	Total Post
Year							
2006.....	26.584 a	.	13.442 a	6.663 a	1.771 a	0.625 b	22.500 a
2007.....	0.045 b	0.153 a	0.217 b	0.251 b	0.573 b	0.315 b	1.579 b
2008.....	0.100 b	0.086 b	0.163 b	0.062 b	0.369 b	2.714 a	5.261 b
P(F).....	*0.0001*	*0.0217*	*0.0001*	*0.0001*	*0.0001*	*0.0005*	*0.0001*
Turf type							
St. Augustine	9.991	0.106	4.434	1.994 b	0.606 b	0.972	8.822
Centipede	7.960	0.132	4.857	2.657 a	1.203 a	1.464	10.738
P(F).....	*0.7286*	*0.1340*	*0.6663*	*0.0155*	*0.0255*	*0.3705*	*0.1512*
Rate							
0.0 kg/ha.....	8.683	0.114	4.052	2.016	0.847 b	0.525 b	7.671 b
6.0 kg/ha.....	10.966	0.119	4.752	2.754	0.680 b	0.344 b	8.782 b
12.5 kg/ha	7.666	0.115	3.878	1.835	0.786 b	0.593 b	7.434 b
24 kg/ha.....	8.110	0.132	5.266	2.352	0.750 b	0.483 b	9.120 b
49 kg/ha.....	9.517	0.115	5.247	2.669	1.459 a	4.146 a	15.893 a
P(F).....	*0.7929*	*0.9675*	*0.6476*	*0.6024*	*0.0043*	*0.0001*	*0.0007*
Year x Turf.....	*0.8796*	*0.0235*	*0.8599*	*0.0117*	*0.2235*	*0.8725*	*0.2608*
Year x Rate.....	*0.9046*	*0.6996*	*0.7643*	*0.7187*	*0.9637*	*0.0001*	*0.0195*
Turf x Rate	*0.4394*	*0.4561*	*0.6176*	*0.9994*	*0.9205*	*0.8943*	*0.8705*
Year x Turf x Rate.....	*0.4799*	*0.7211*	*0.7037*	*1.0000*	*0.7869*	*0.9994*	*0.9796*
R^2.....	*0.8251*	*0.3868*	*0.8039*	*0.7681*	*0.6994*	*0.7758*	*0.7785*

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). Means followed by the same letter(s) in a column are not significantly different according to Fisher's Protected LSD (*P=0.05*).

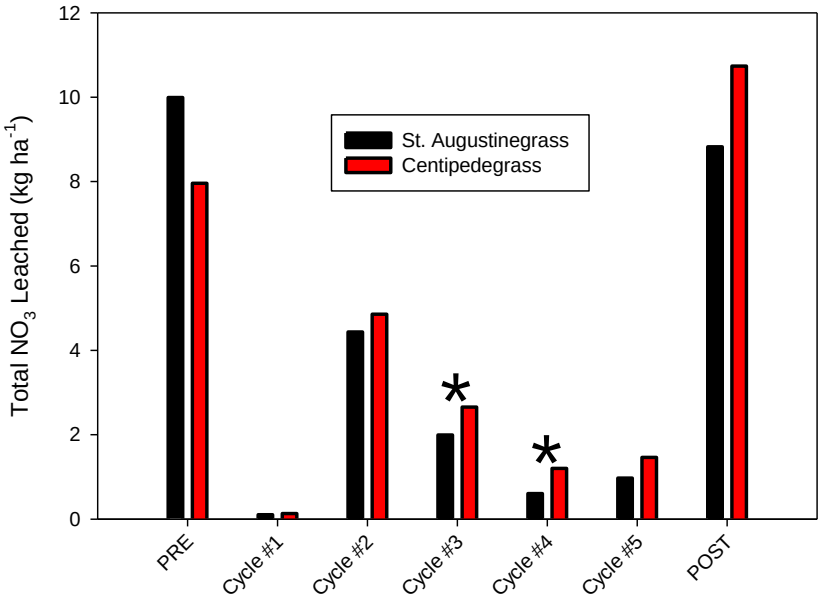


Figure 39. Comparison of NO_3-N leaching losses from five nitrogen rates applied to either St. Augustinegrass or centipedegrass over three winter seasons (2006 – 2009). Cycles are six weeks in duration with Cycle #1 starting around 01 September each year. The "*" indicates significance (P>0.05) according to Duncan's Multiple Range Test (P=0.05).

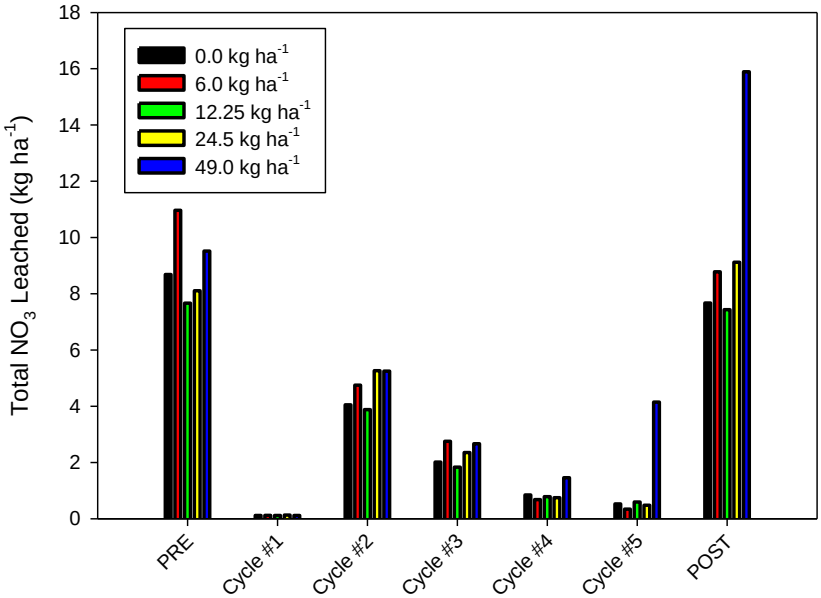


Figure 40. Comparison of leaching losses from five nitrogen rates applied to St. Augustinegrass and centipedegrass over three winter seasons (2006 – 2009). Cycles are six weeks in duration with Cycle #1 starting around 01 September each year.

Table 227. Effect of year, turf type and N-application rate on total nitrogen leached.

	Total N (kg/ha)						
	Pre	T1	T2	T3	T4	T5	Total Post
Year							
2006	221.30 a	-	104.36 a	54.64 a	12.26 a	4.02 c	175.28 a
2007	0.34 b	1.24 a	1.79 b	1.89 b	3.39 b	1.89 c	10.19 b
2008		0.60 b	1.00 b	0.35 b	2.14 b	9.80 a	21.73 b
P(F)	*0.0007*	*0.0352*	*0.0001*	*0.0001*	*0.0012*	*0.0001*	*0.0001*
Turf type							
St. Augustine	94.26	0.79	37.34	16.16	3.98 b	4.03	65.07
Centipede	53.99	1.05	34.10	21.75	7.88 a	6.44	73.06
P(F)	*0.5013*	*0.1462*	*0.6753*	*0.2618*	*0.0051*	*0.2930*	*0.5282*
Rate							
0.0 kg/ha	-	-	-	-	-	-	-
6.0 kg/ha	182.77 a	1.98 a	79.21 a	45.91 a	11.33 a	5.73 ab	146.36 a
12.5 kg/ha	61.33 b	0.92 b	31.02 b	14.68 b	6.28 b	4.74 bc	59.47 b
24 kg/ha	33.79 b	0.55 b	21.94 b	9.80 b	3.12 c	2.01 c	38.00 b
49 kg/ha	18.61 b	0.24 b	10.71 b	5.45 b	2.98 c	8.46 a	32.43 b
P(F)	*0.0065*	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0052*	*0.0001*
Year x Turf	*0.6264*	*0.0899*	*0.7862*	*0.3139*	*0.0285*	*0.6207*	*0.7693*
Year x Rate	*0.0009*	*0.2925*	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0001*
Turf x Rate	*0.3765*	*0.3977*	*0.8535*	*0.8547*	*0.2220*	*0.7283*	*0.9794*
Year x Turf x Rate	*0.3990*	*0.7574*	*0.9280*	*0.9546*	*0.2794*	*0.5329*	*0.9998*
R^2	*0.6942*	*0.6160*	*0.8793*	*0.7687*	*0.7968*	*0.7036*	*0.8693*

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).

PROJECT 5
PHOSPHORUS RESPONSE AND ORTHOPHOSPHATE LEACHING IN FLORATAM ST. AUGUSTINEGRASS AND EMPIRE ZOYSIAGRASS

GAINESVILLE – Dr. Jerry Sartain

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.

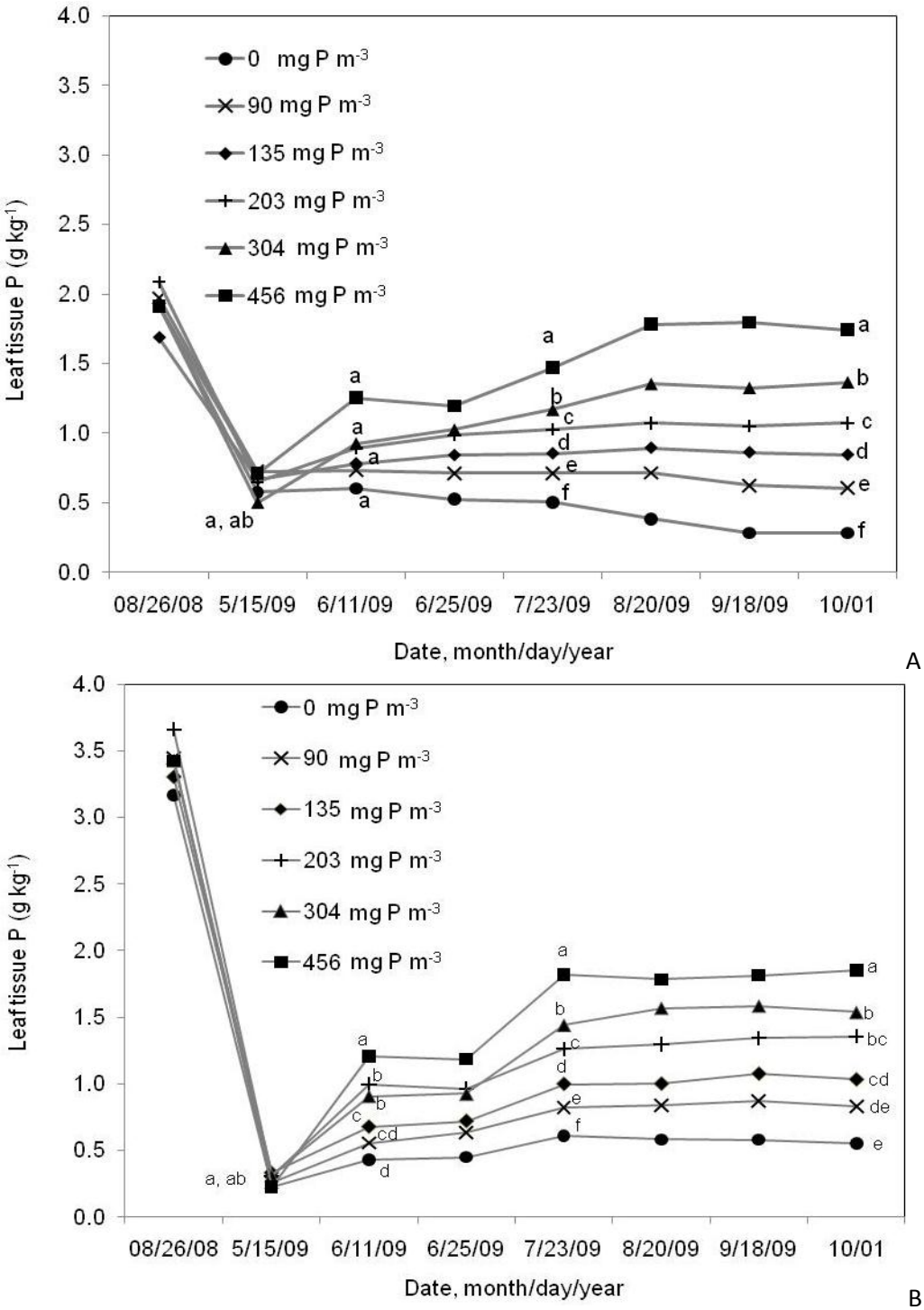
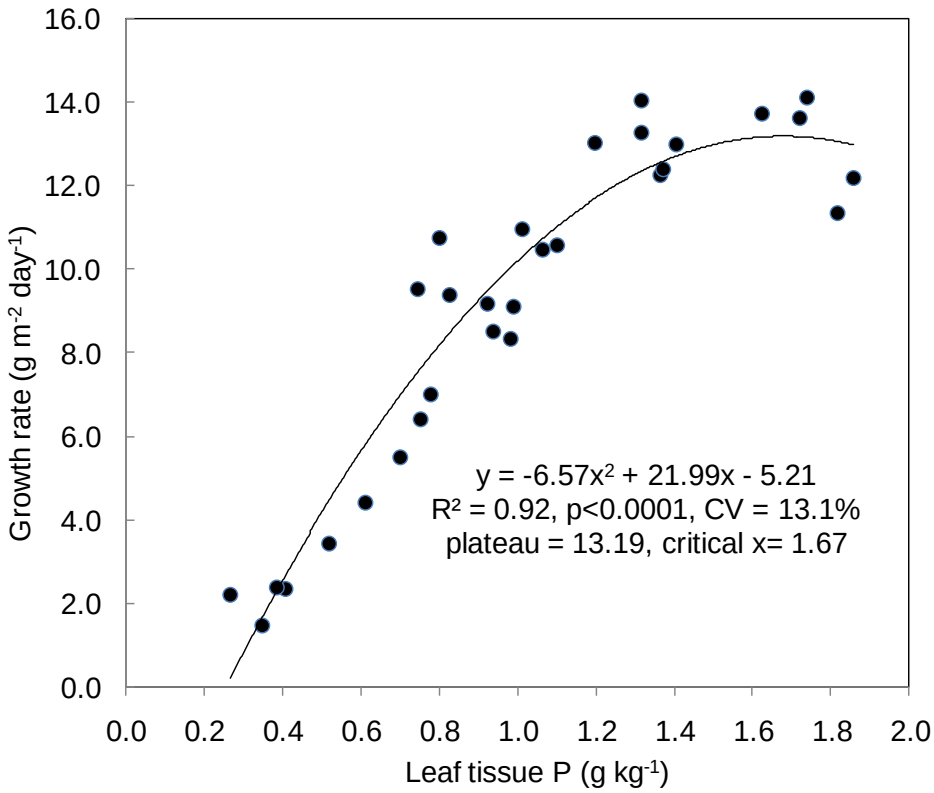
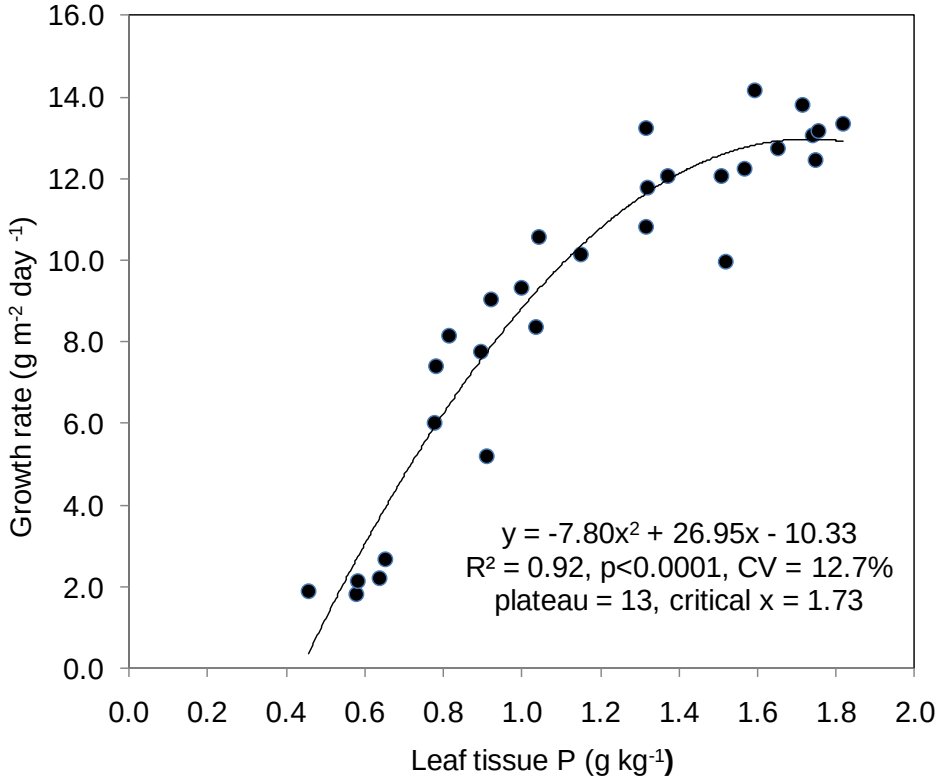


Figure 41. Phosphorus concentration in leaf tissue over time as influenced by phosphorus supply rate. A) Empire zoysiagrass and B) Floratam St. Augustinegrass. Symbols labeled with the same letter within a sampling date are not significantly different at p = 0.05 by single degree of freedom contrast analysis.



A



B

Figure 42. Aboveground tissue growth rate relative to leaf tissue P concentration. A) Empire zoysiagrass and B) Floratam St. Augustinegrass.

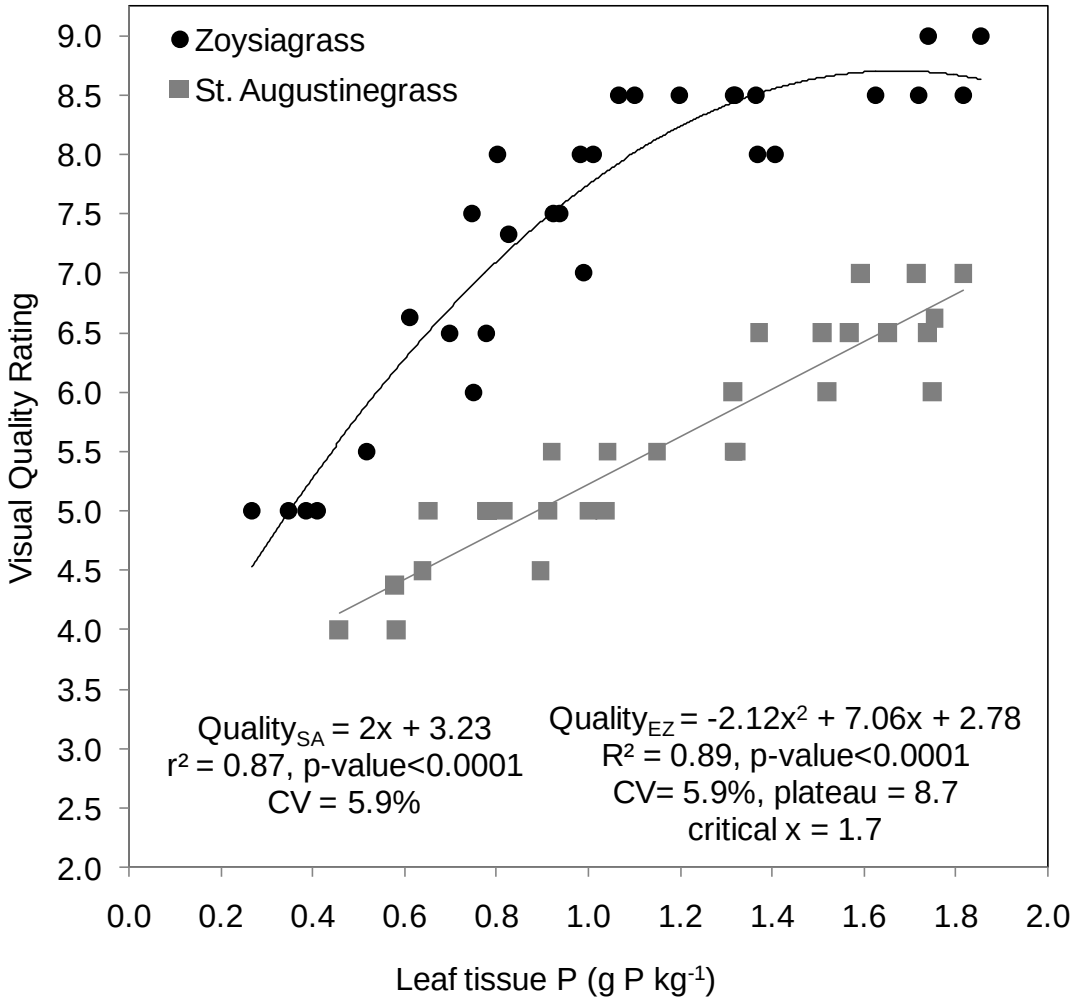


Figure 43. Empire zoysiagrass (EZ) and Floratam St. Augustinegrass (SA) visual quality rating relative to leaf tissue P concentration.

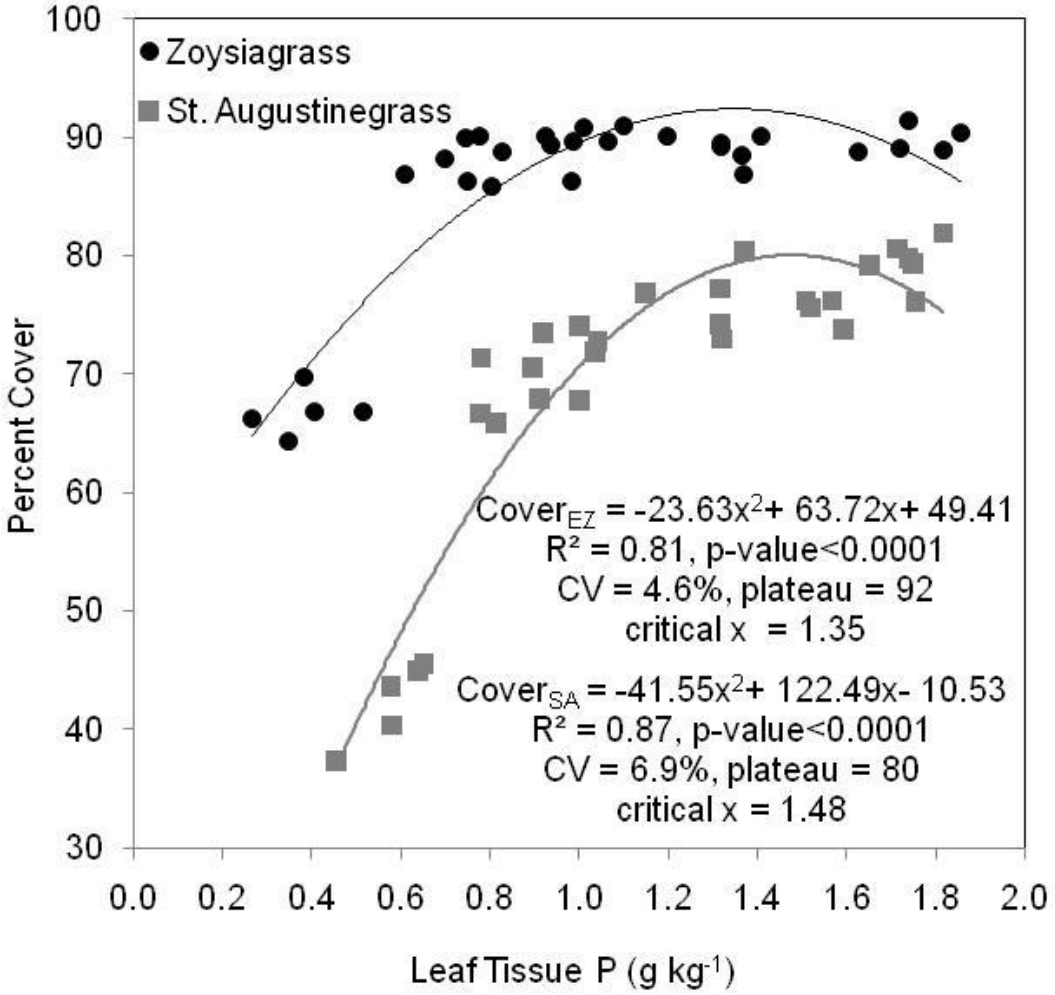


Figure 44. Empire zoysiagrass (EZ) and Floratam St. Augustinegrass (SA) percent cover relative to leaf tissue P concentration.

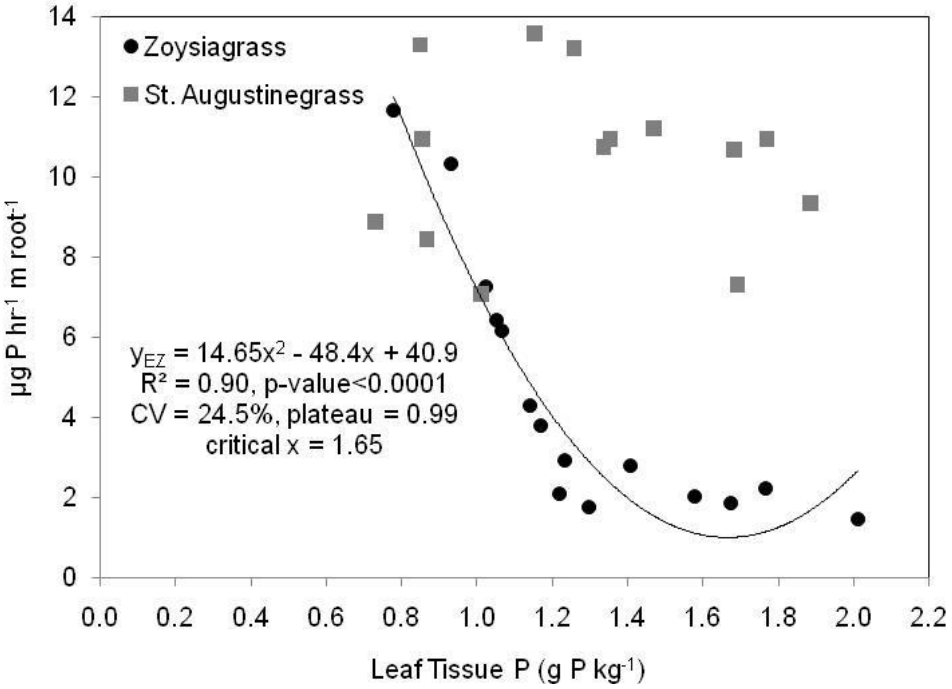


Figure 45. Phosphorus depletion rate from the nutrient solution by Empire zoysiagrass (EZ) and Floratam St. Augustinegrass (SA) as related to phosphorus concentration in leaf tissue.

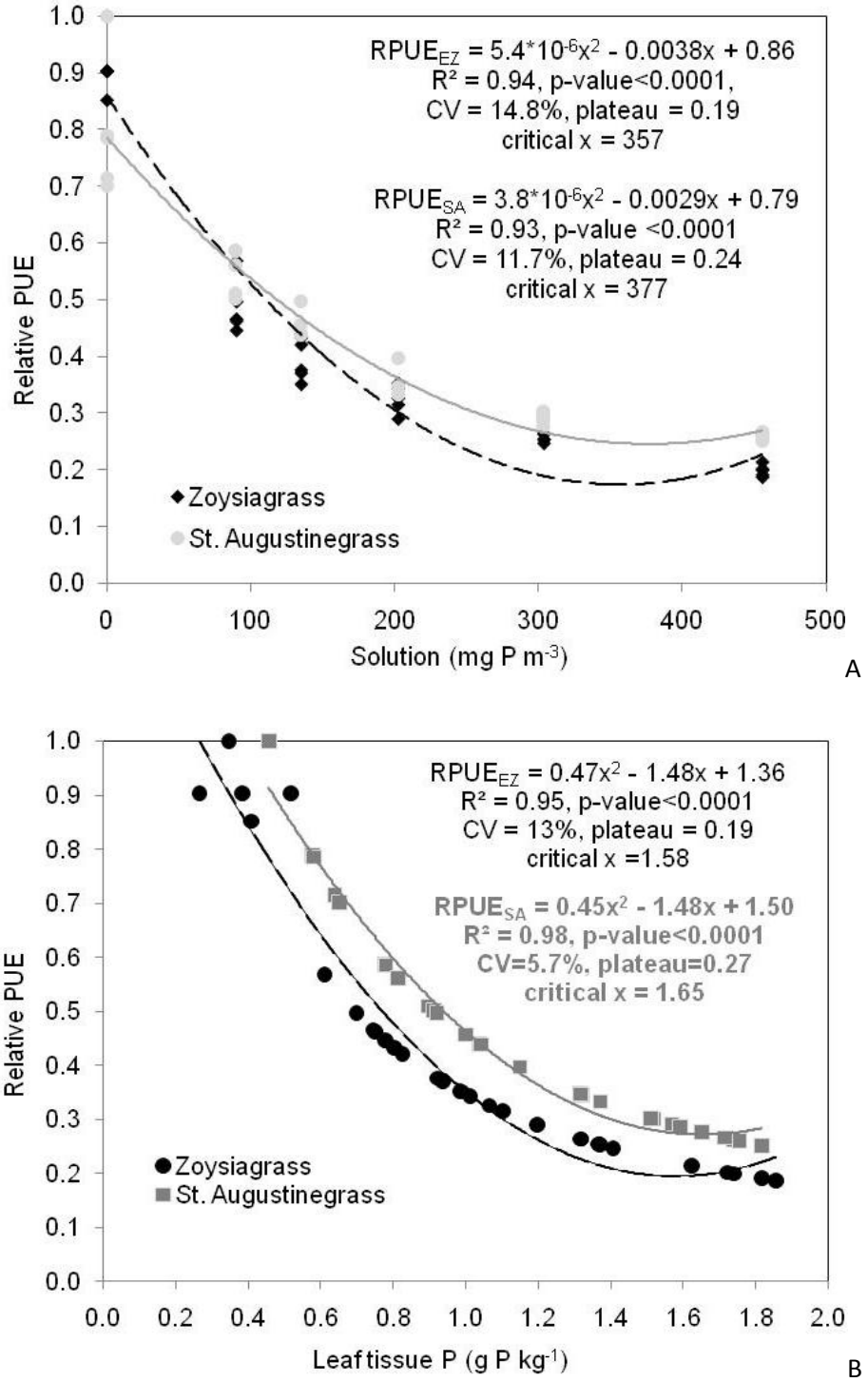


Figure 46. Relative P use efficiency (RPUE) of Empire zoysiagrass (EZ) and Floratam St. Augustinegrass (SA). A) RPUE in relation phosphorus concentration in solution and B) RPUE as influenced by leaf tissue P concentration.

Table 228. 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 229. 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	Floratam 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 230. 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	Floratam 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.

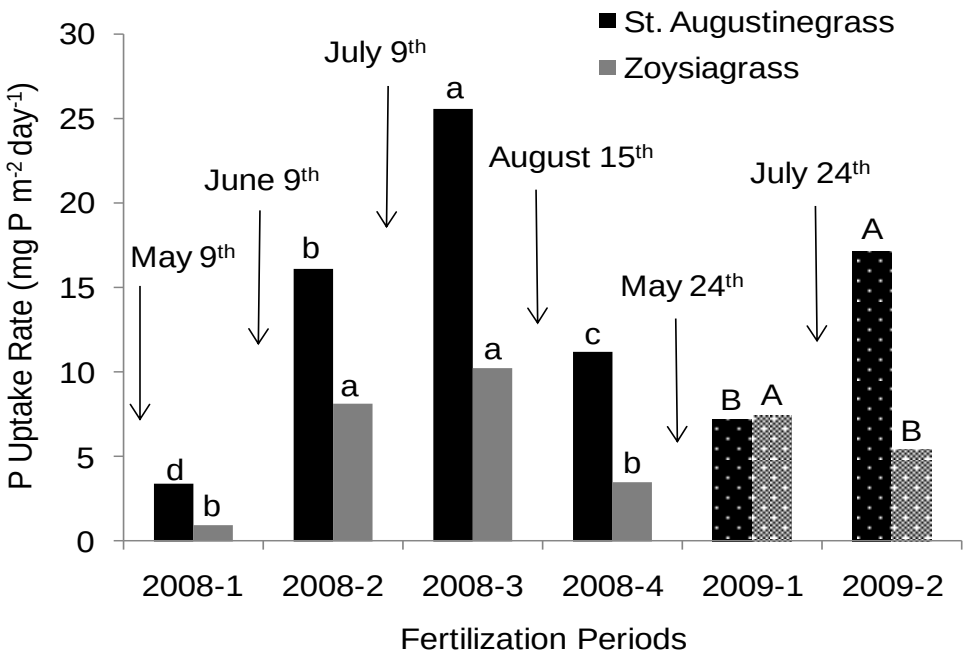


Figure 47. Phosphorus uptake rate in Empire zoysiagrass and Floratam St. Augustinegrass during each fertilization period. A fertilization period starts when a fertilizer application is conducted and ends when the following fertilization takes place. The date when each fertilizer application was carried 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.

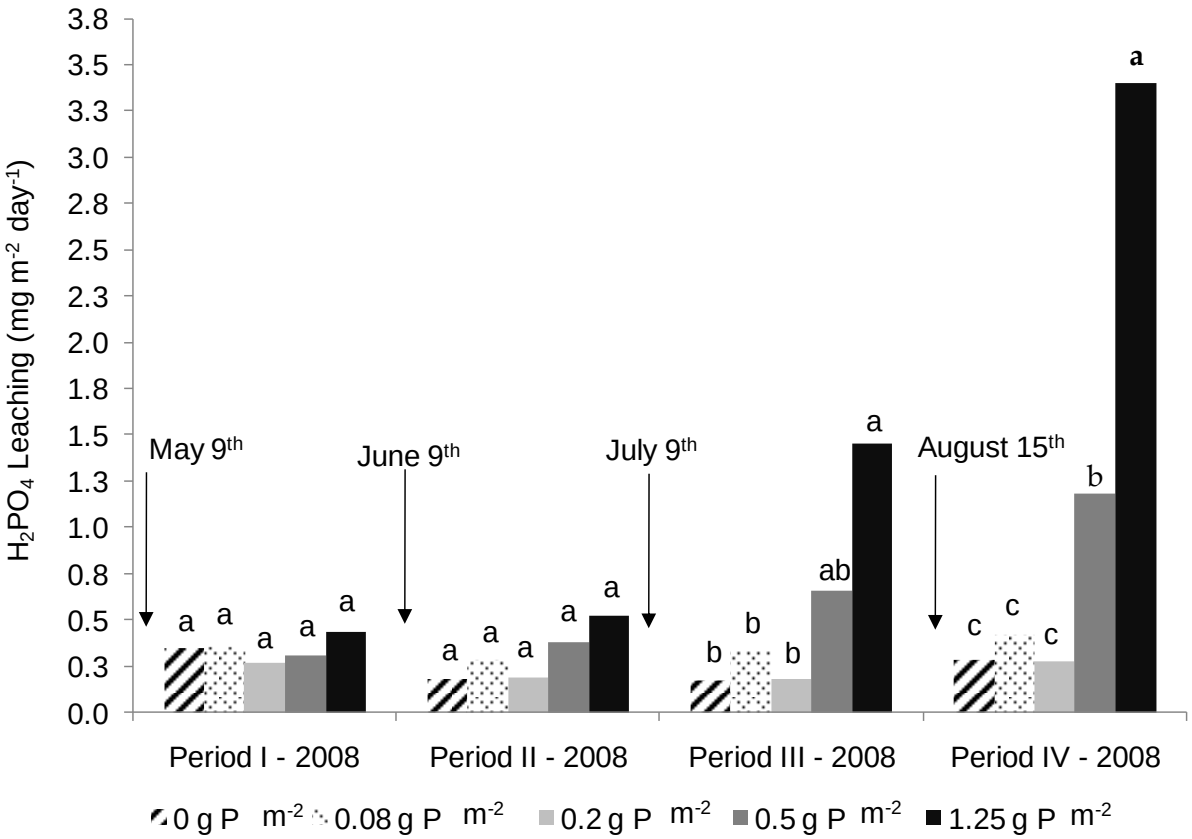


Figure 48. Orthophosphate leaching rate in Empire zoysiagrass as influenced by phosphorus application rate within each fertilizer application period during the first growing season (2008). The date when each fertilizer application was carried out is indicated next to an arrow. Columns with the same letter within an application period are not significantly different at p=0.05 according to single degree of freedom contrast analysis.

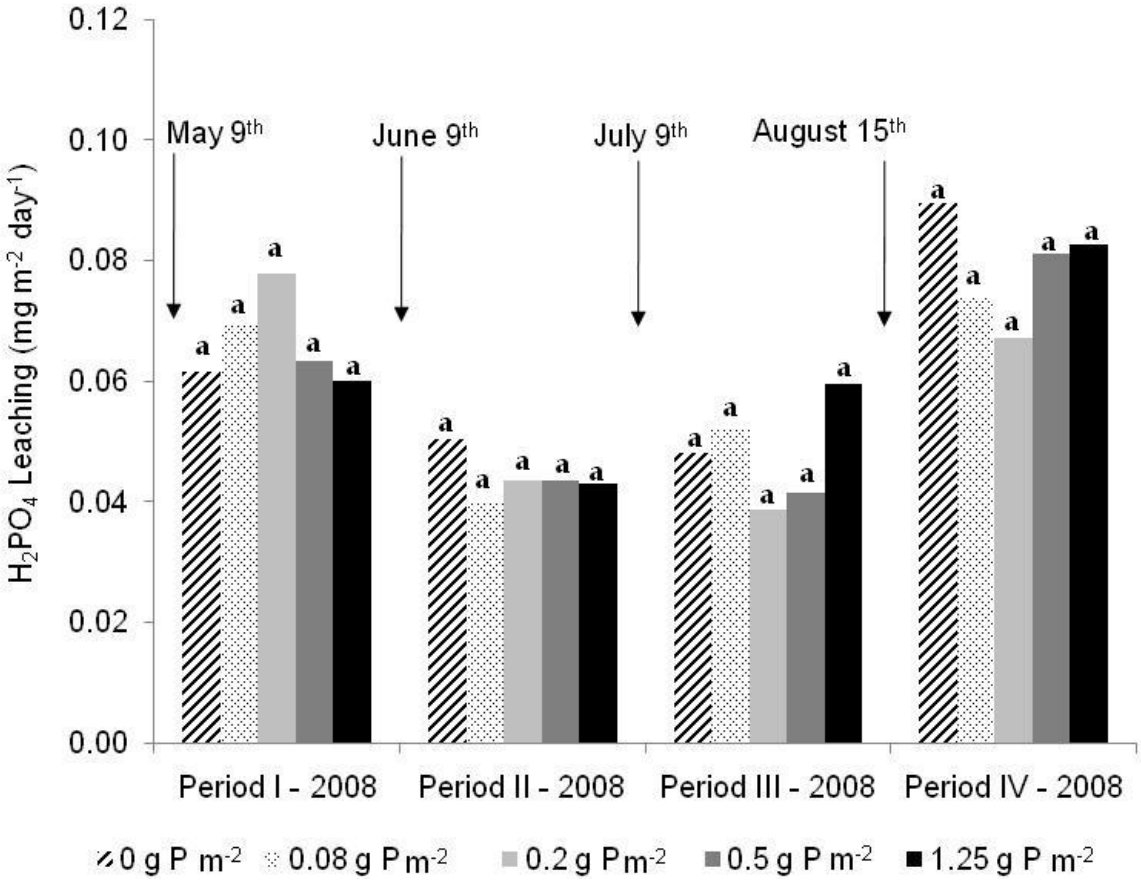


Figure 49. Orthophosphate leaching rate in Floratam St. Augustinegrass as influenced by phosphorus application rate within each fertilizer application period during the first growing season (2008). The date when each fertilizer application was carried out is indicated next to an arrow. Columns with the same letter within an application period are not significantly different at p=0.05 according to single degree of freedom contrast analysis.

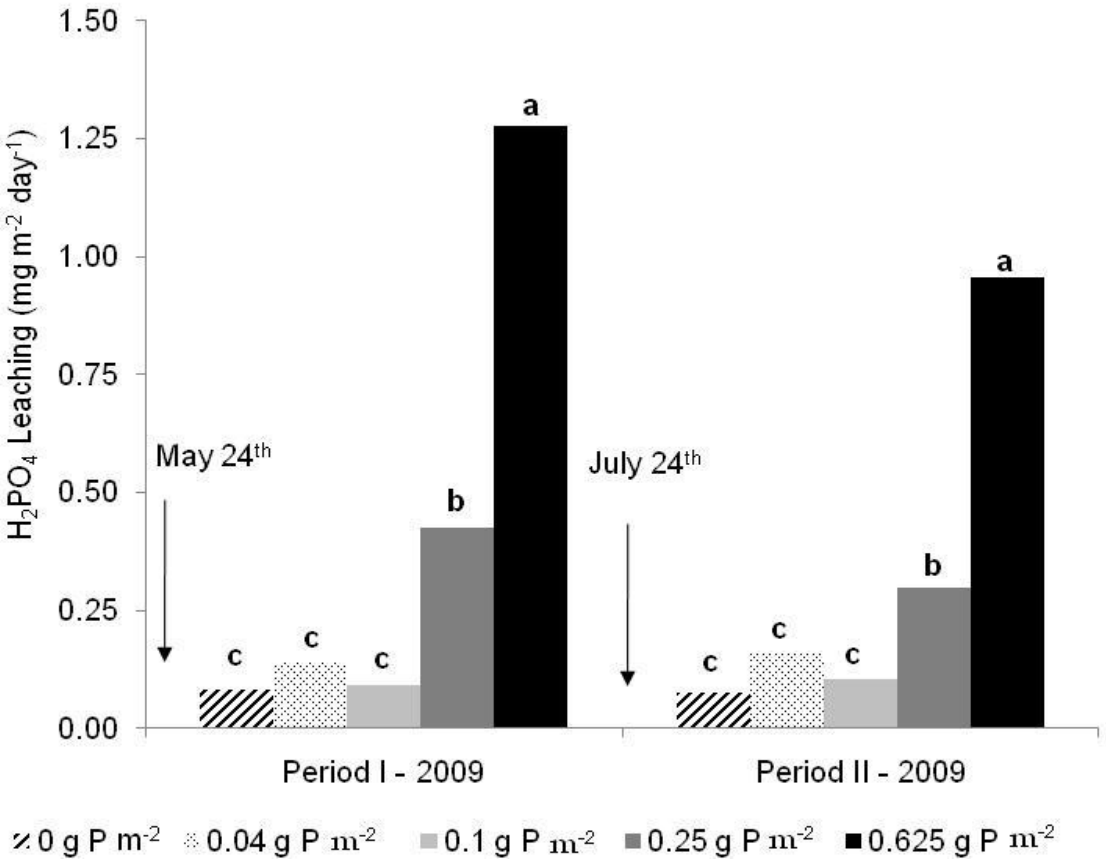


Figure 50. Orthophosphate leaching rate in Empire zoysiagrass as influenced by phosphorus application rate within each fertilizer application period during the second growing season (2009). The date when each fertilizer application was carried out is indicated next to an arrow. Columns with the same letter within an application period are not significantly different at p=0.05 according to single degree of freedom contrast analysis.

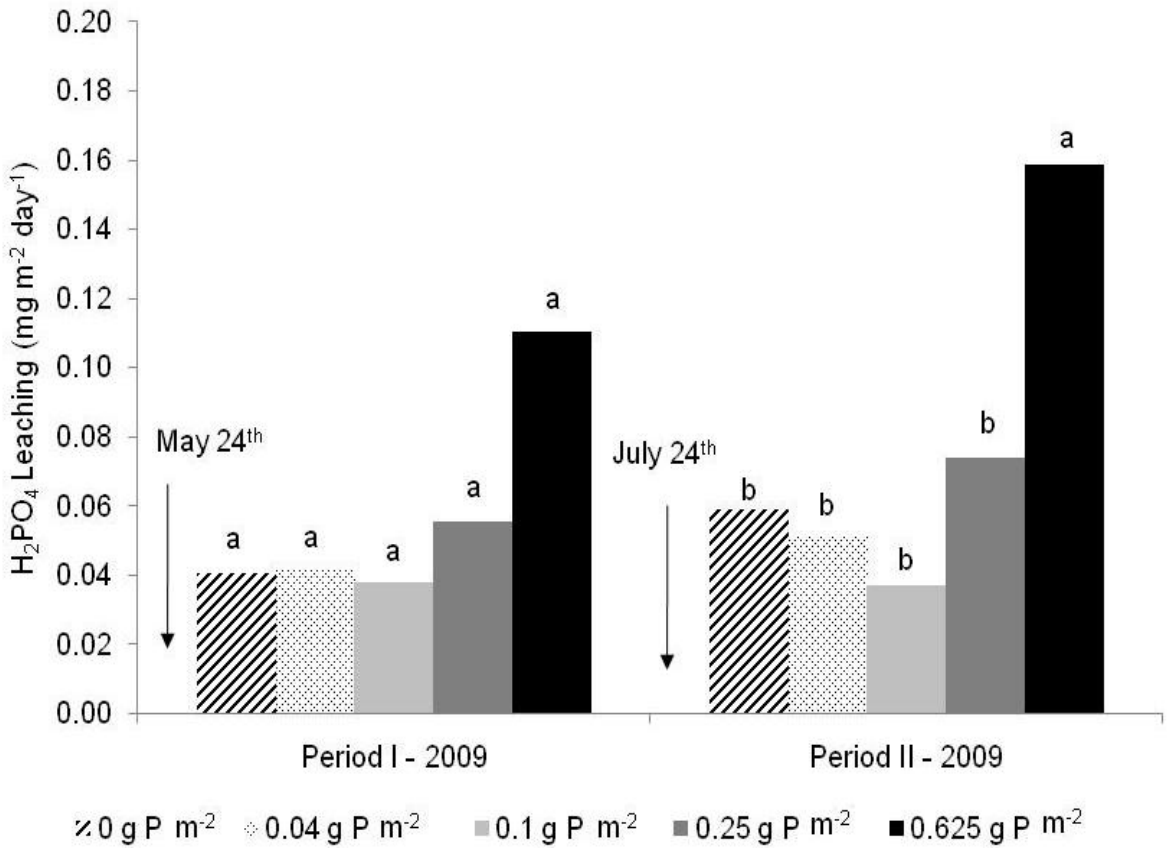


Figure 51. Orthophosphate leaching rate in Floratam St. Augustinegrass as influenced by phosphorus application rate within each fertilizer application period during the second growing season (2009). The date when each fertilizer application was carried out is indicated next to an arrow. Columns with the same letter within an application period are not significantly different at p=0.05 according to single degree of freedom contrast analysis.

Table 231. Percent cumulative phosphorus leached from fertilizer application between May 2008 and June 2010 in Floratam St. Augustinegrass.

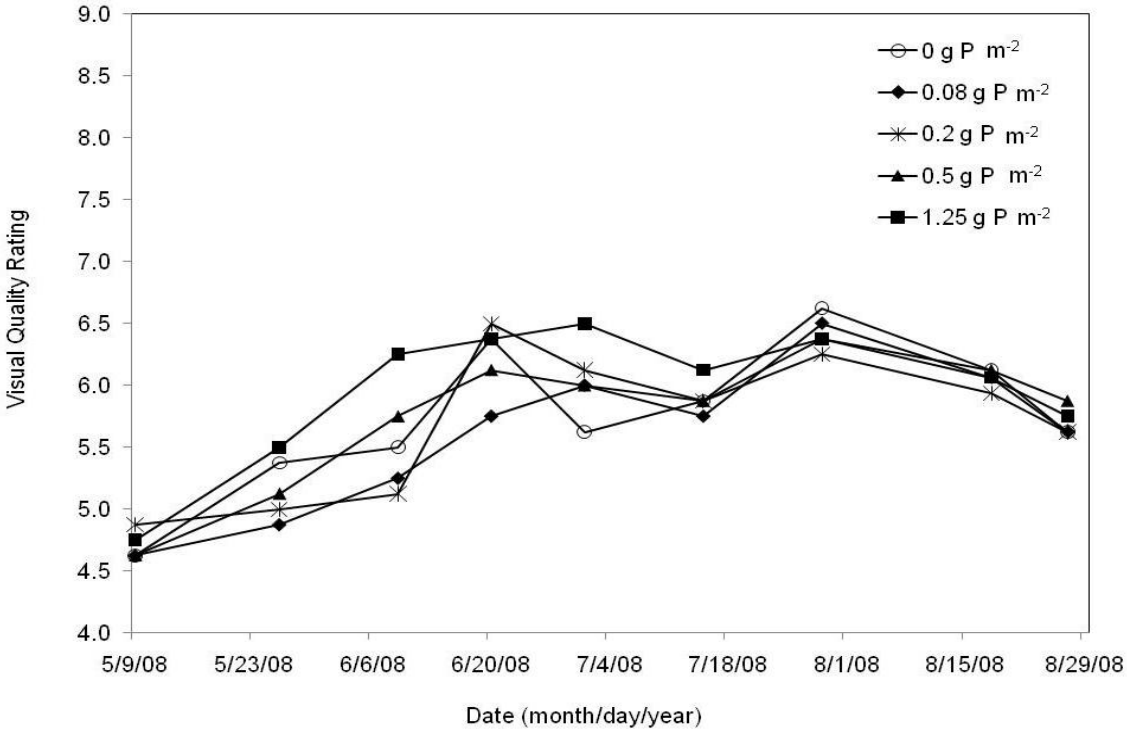
Fertilizer Application Period	Phosphorus Application Rate (g m^{-2})				
	0(0)	0.08(0.04)	0.2(0.1)	0.5(0.25)	1.25(0.625)*
2008-1	0.00	0.48	0.22	0.03	-0.01
2008-2	0.00	0.05	0.06	0.00	-0.01
2008-3	0.00	0.09	-0.02	-0.02	0.00
2008-4	0.00	-0.02	-0.06	-0.02	0.00
2009-1	0.00	0.04	-0.04	0.02	0.08
2009-2	0.00	-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.

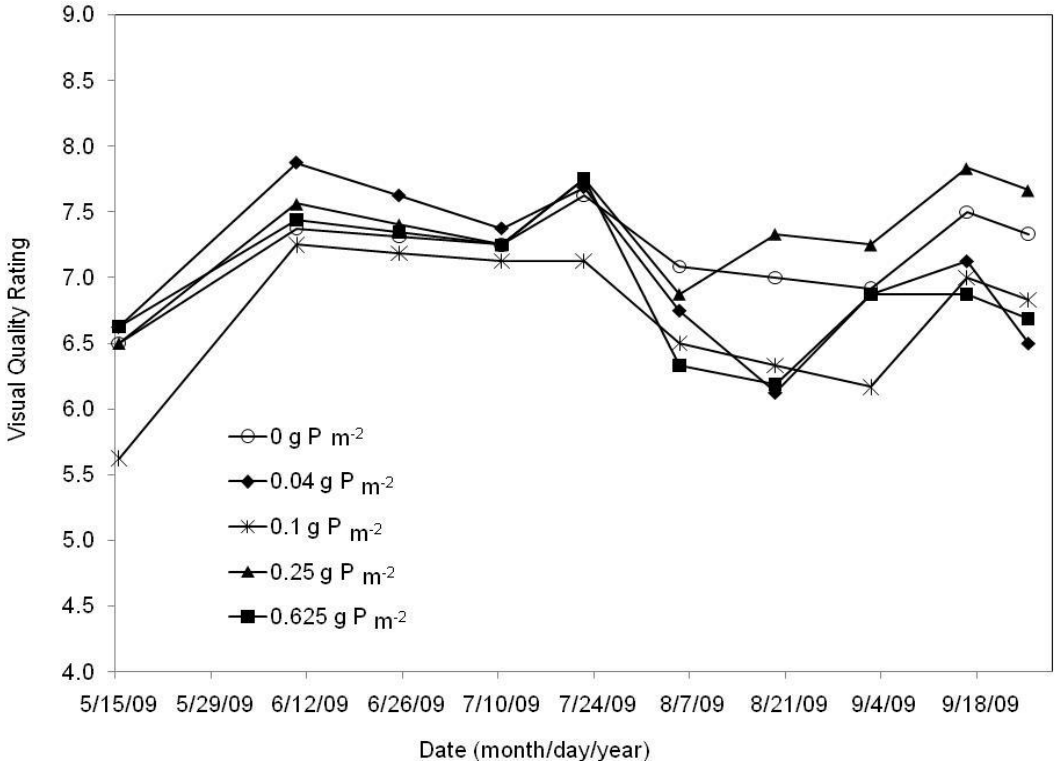
Table 232. Percent cumulative phosphorus leached from fertilizer application between May 2008 and June 2010 in Empire Zoysiagrass.

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.

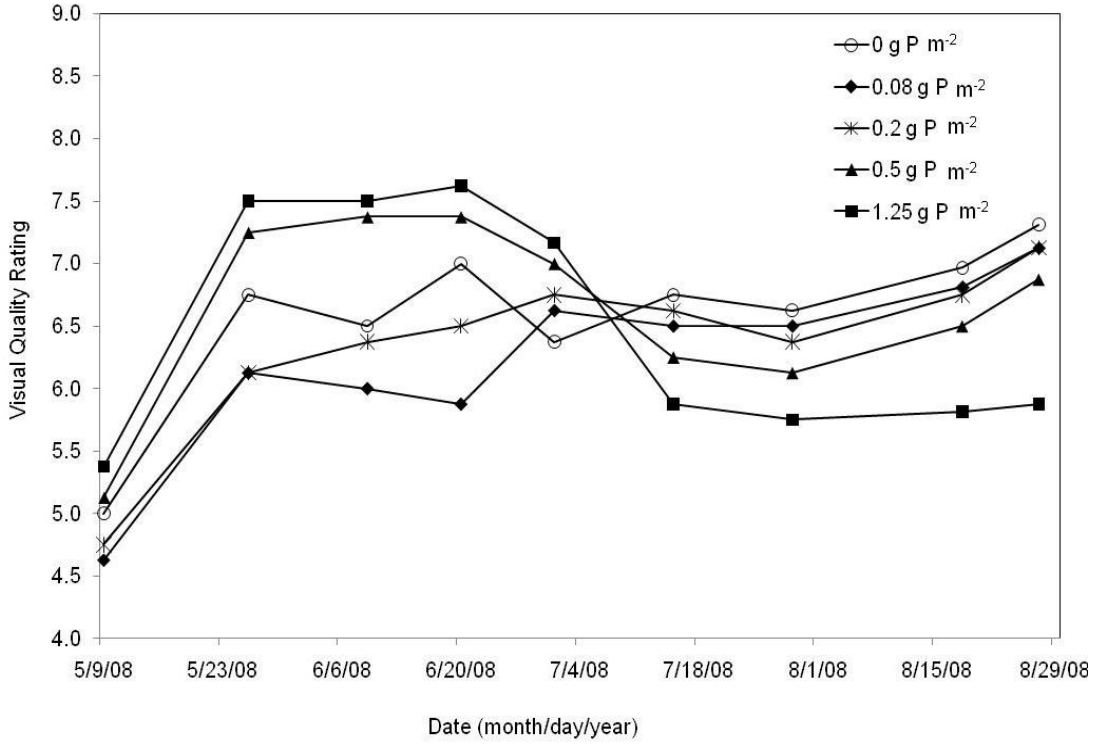


A

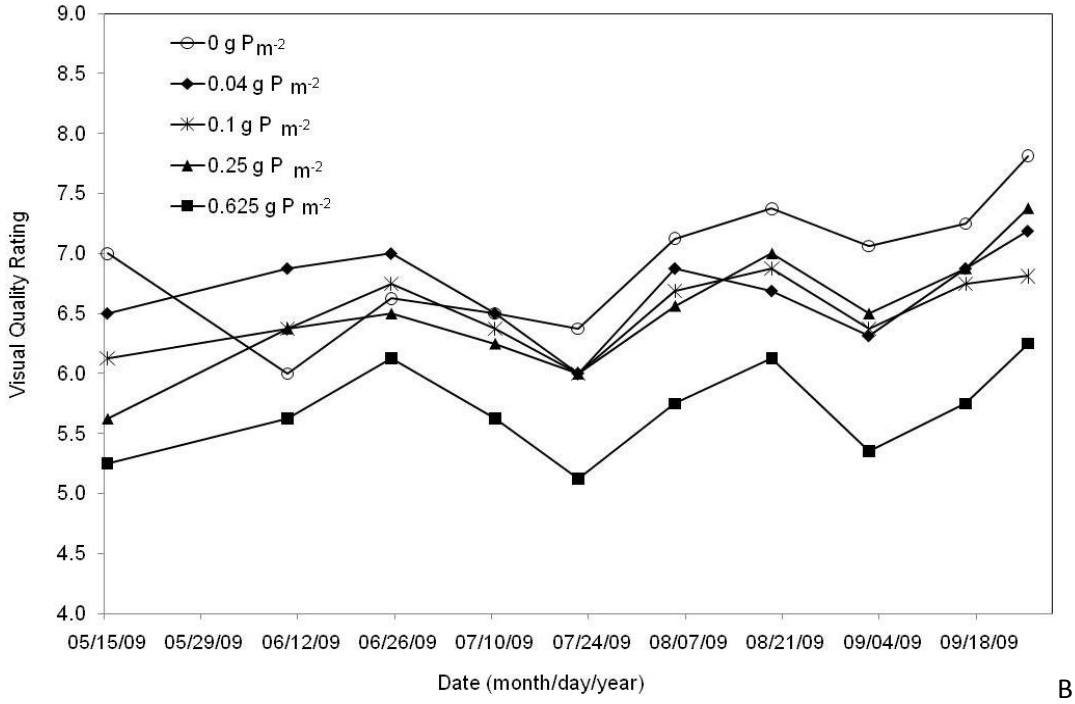


B

Figure 52. 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 53. 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 233. 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).

	Floratam St. Augustinegrass				Empire Zoysiagrass			
Application Rate	Mehlich 1 extractable	Leaf P concentration	Leaf growth rate	Visual quality rating	Mehlich 1 extractable	Leaf P concentration	Leaf growth rate	Visual quality rating
	mg P kg^{-1}	g P kg^{-1}	g m^{-2} day^{-1}		mg P kg^{-1}	g P kg^{-1}	g m^{-2} day^{-1}	
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 234. 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).

	Floratam St. Augustinegrass				Empire Zoysiagrass			
Application Rate	Mehlich 1 extractable	Leaf P concentration	Leaf growth rate	Visual quality rating	Mehlich 1 extractable	Leaf P concentration	Leaf growth rate	Visual quality rating
	mg P kg^{-1}	g P kg^{-1}	g m^{-2} day^{-1}		mg P kg^{-1}	g P kg^{-1}	g m^{-2} day^{-1}	
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 235. Floratam St. Augustinegrass leaf growth rate (g DM m^{-2} day^{-1}) per fertilizer application period during each evaluation year as influenced by phosphorus application rate.

Application Period	0(0)	0.08(0.04)	0.2(0.1)	0.5(0.25)	1.25(0.625)*	p-value**
			g P m^{-2}			
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

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Table 236. Empire Zoysiagrass leaf growth rate (g DM m^{-2} day^{-1}) per fertilizer application period during each evaluation year as influenced by phosphorus application rate.

Application Period	0(0)	0.08(0.04)	0.2(0.1)	0.5(0.25)	1.25(0.625)*	p-value**
			g P m^{-2}			
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 237. 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 238. 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.

PROJECT 5
THE EFFECT OF SOIL-TEST PHOSPHORUS ON TURFGRASS QUALITY, GROWTH AND P LEACHING

GAINESVILLE – Dr. Jerry Sartain

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 239) 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 243).

Table 239. 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-PO_4 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 'Floratam' 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-PO_4 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 240-242). 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 240 and 241).

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 242). 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 243).

Leaching of P was significantly affected by soil-test P throughout the reporting period with more leaching from higher soil-test P treatments (Table 244). Although the greatest amount of leaching occurred initially, significant differences were observed through 2009 (Table 244). 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 245).

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 246).

In the greenhouse trials, the very low soil-test P treatment generally had significantly lower turf quality ratings and clipping growth (Tables 247, 248, 250 & 251). Increasing the soil-test above medium did not increase ratings or growth (Tables 247, 248, 250 & 251). 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 249 and 252). 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 249 and 252).

Table 240a. 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 240b. 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.

Table 241a. 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 241b. 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 242a. 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 242b. 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 243. 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 244a. 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 244b. 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 244c. 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 244d. 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 244e. 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 244f. 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 245. 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 246a. 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 246b. 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 246c. 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 246d. 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 246e. 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 246f. 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.

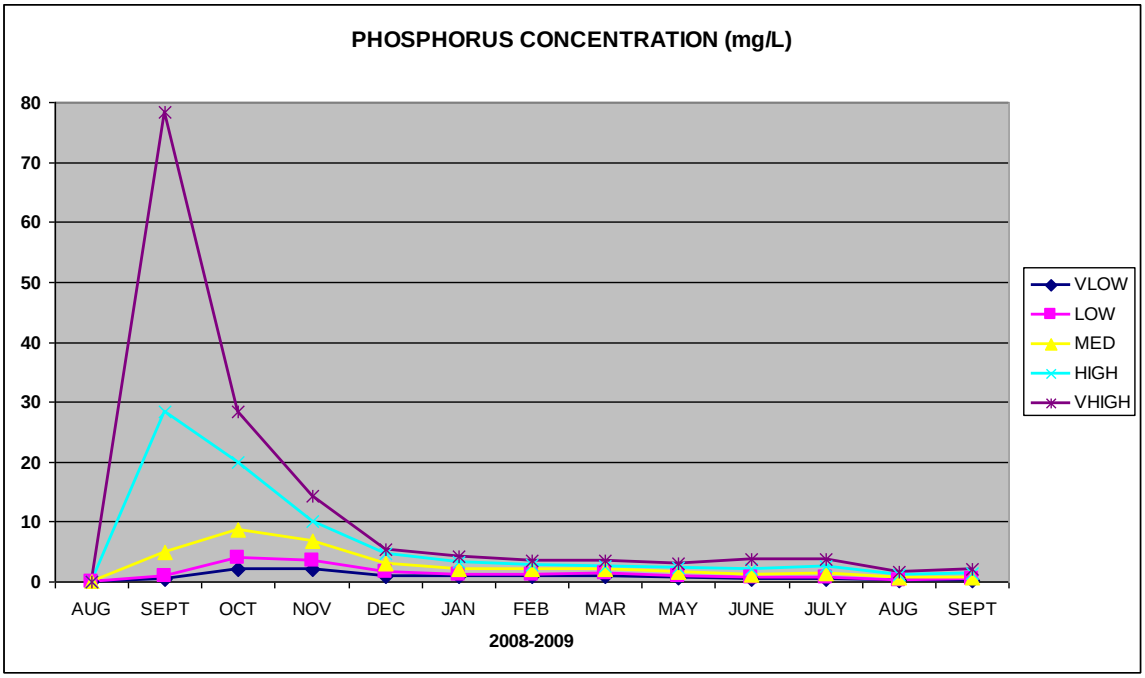

Figure 54. Daily P concentrations from August 2008 – Sept. 2009 for P Availability Field Test at the Fort Lauderdale Research and Education Center.

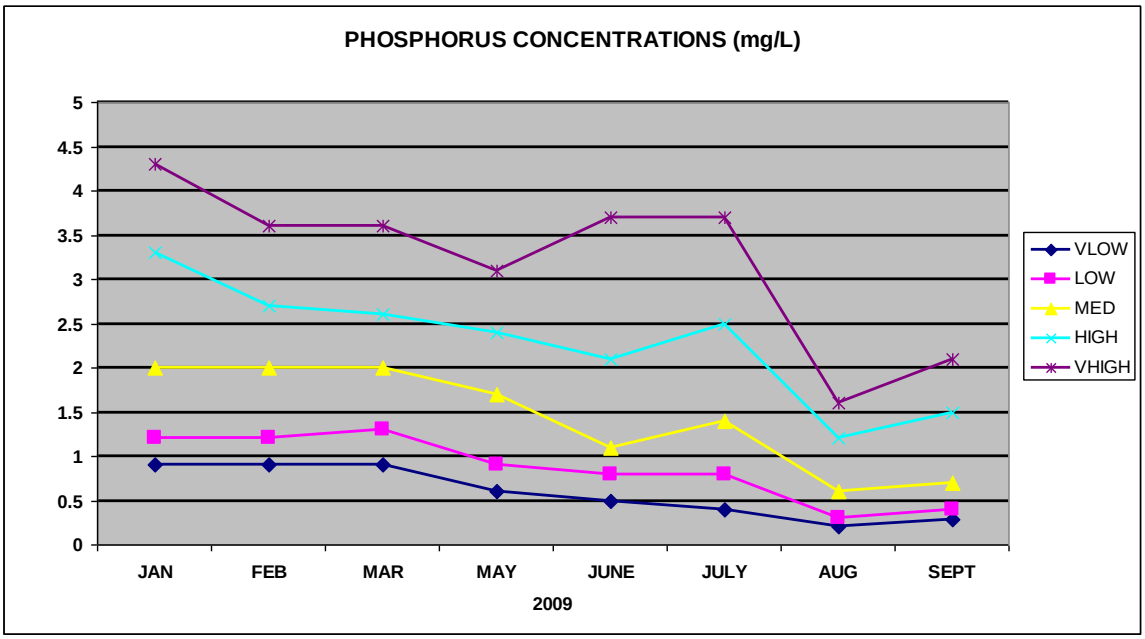

Figure 55. Daily P concentrations from January 2009 – Sept. 2009 for P Availability Field Test at the Fort Lauderdale Research and Education Center.

RESULTS - GREENHOUSE TRIALS

Greenhouse Trial 1

Table 247. 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 248. 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 249. 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 250. 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 251. 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 252. 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.

Table 253. Climatology: September 2008—December 2009.

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

PROJECT 6
INFLUENCE OF SLOW RELEASE NITROGEN SOURCE ON NO^-_3-N LEACHING WHEN APPLIED TO CENTIPEDEGRASS

JAY, FL – Dr. J. Bryan Unruh

Experimental Site and Design

The study was conducted at the University of Florida's West Florida Research and Education Center, (30°46'3N, 87°08'W) on Common Centipedegrass grown on native soil identified by the USGA survey as Fuquay loamy sand. The experiment consisted of 24-4m x 3m turfgrass plots in a randomized complete block with 4 replications. Existing centipede sod was established the week of 25 Sep 2006. Treatments periods were for 120 days, (2008 Yr 1) 19 Aug, (2009 Yr 2) 15 Apr, 13 Aug, (2010 Yr 3) 15 Apr, 09 Aug, and 12 Apr 2011. Each split plot received one of 6 SRN sources 39-0-0 SCU-Agrium, 43-0-0 XCU-Agrium, 40-0-0 Nutralene-Agrium, 46-0-0 Duration CR-Type V-Agrium, 15-2-15 Florikan, or 9-0-0 Corn Gluten Meal at a 98 kg ha^{-1} rate. Leachate collection for volume (mL), and NOx-N (mg/L) analysis (Yr 1) was collected weekly began 05 Aug 2008 and ended 15 Dec 2008 for 20 sampling events, which included 2 pre-treatment events prior to the 18 treatment sampling events. Sampling for volume and NOx-N was suspended after the 120 day trial period until 17 Feb 2009 when requested by DEP (Mike Thomas) to resume weekly sampling for volume (mL), NOx-N (mg/L) and quarterly sampling for Ortho-PO_4 analysis. This resulted in Yr 1 post-treatment data weekly from 17 Feb 2009 through 30 Mar 2009 totaling 7 sampling events post treatment and the first quarterly sampling for Ortho-P on 17 Feb 2009. (Yr 2, Run 1) began 06 Apr 2009 and ended 11 Aug 2009 for 19 sampling events, which included 2 pre, 17 treatment, and 0 post sampling events. Second quarter sampling for Ortho-P was 09 Jun 2009. (Yr 2, Run 2) began 18 Aug 2009 and ended 30 Mar 2010 for 33 sampling events, which included 0 pre, 17 treatment and 16 post sampling events. Third and fourth quarter 2009 and first quarter 2010 sampling for Ortho-P was within this period on 22 Sep 2009, 07 Dec 2009, and 09 Mar 2010. (Yr 3, Run 1) began 06 Apr 2010 and ended 03 Aug 2010 for 18 sampling events, which included 2 pre, 16 treatment, and 0 post sampling events. Second quarter sampling for Ortho-P was 01 Jun 2010. (Yr 3, Run 2) began 10 Aug 2010 and ended 29 Mar 2011 for 34 sampling events, which included 0 pre, 18 treatment and 16 post sampling events. Third and fourth quarter 2010 and first quarter 2011 sampling for Ortho-P was within this period on 07 Sep 2010, 07 Dec 2010, and 08 Mar 2011. (Yr 4) began 05 Apr 2011 and ended 30 Aug 2011 for 22 sampling events, which included 2 pre, 17 treatment, and 3 post sampling events. Second quarter sampling for Ortho-P was 07 Jun 2011. Irrigation was supplied by 6 Toro Super 800 rotary irrigation heads in a rectilinear layout with 4-90° and 2-180° arcs having a precipitation rate of 0.762mm per minute utilizing a programmable controller, programmed for day intervals of 3 to 4 days (interval was changed to 3 days if there were symptoms of wilt when high ET's resulted in rapid depletion of soil moisture in the root zone, otherwise a 4 day interval was utilized), delivered with 4 starts between 0200 and 0630 (to minimize wind effects and evaporation losses while diminishing surface run off by not exceeding soil percolation rates) with run times being adjusted to previous weeks ET when wilting (insufficient irrigation) or excessive leachate (excessive irrigation) was observed.

Additional precipitation (from rainfall events) and subsequent increases in leachate were quantified and reported as comparators to non rain event data. No irrigation was available from 21 Aug 2008 to 22 Sep 2008 due to irrigation well be off line. Plots were maintained at a height of cut of 50.8mm using a rotary mower with clippings left in place.

Collection of Leachate

Using a Toro Dingo skid steer equipped with a 60.96cm power auger, soil was removed to a depth of 106.68cm taking care to keep horizons separated for reconstruction within lysimeters of high density polyethylene (HDPE), having an internal height of 86.36cm, cylinder wall height of 78.74cm, conical section height of 7.62cm, and I.D. of 55.88cm yielding a total volume of 199.333L, supported upon a hot dipped galvanized base having an internal diameter of 57.15cm and constructed such that it has a tank bearing surface ≅ 1935cm^2 and a soil bearing surface ≅ 2355cm^2 with a total height of 25.4cm that raises the tank 10.16cm allowing for the installation of a bulkhead fitting tapped to receive a 9.525mm MNPT x 9.525mm OD nylon elbow fitting which is connected via 9.525mm low density polyethylene tubing via trench to a central lysimeter leachate removal/sampling station. Bore holes were prepped by tamping and leveling soil with a 17kg, 858cm^2 hand tamping tool to a finished depth of 106.68cm allowing for 10.16cm of soil cover above the upper rim of the lysimeter. Lysimeters were prepared with a leaching bed of washed 1.905-4.445cm round river rock having a volume of 0.034m^3 covered with non-woven polyolefin cloth 60.96cm in diameter secured with an internal interference fitted hoop of 1.27cm HDPE tubing. A vent line (to prevent pressure differentials from affecting leaching rates when lysimeters are being sampled) of 9.525cm LDPE by sufficient length to reach from the upper portion of the leach field just below the non-woven polyolefin to several inches above finished grass height is temporarily held to the rim of the lysimeter until soil horizons have been reestablished in the lysimeter. Once lowered into the level and prepped bore holes original soil horizons were recreated in 15.24cm lifts within the lysimeter, each being packed by dropping the tamping tool from a consistent height, allowing gravity rather than thrust to compact soil consistently. The area surrounding the lysimeter and undisturbed soil was treated in kind. Any settling at lysimeters was corrected prior to seedbed preparation utilizing a box blade and drag mats.

Leaching of NO_3-N + NO_2-N and Ortho-PO_4 was determined by removing all leachate for volume determination and acquiring a grab sample weekly for NO_3-N + NO_2-N analysis and quarterly (beginning 17 Feb) for Ortho-PO_4 analysis from each of the 24 plots lysimeters. Sampling was by applying a vacuum to a secondary leachate collection trap equipped with a bottom drain, having a capacity greater than any one lysimeter leaching bed and connected via 9.525mm clear PVC tubing to a low volume primary trap constructed such that our 20ml sample vial was the trap. Thus, by triple rinsing the trap head with as little as 60ml of distilled water, connecting directly to the lysimeter leachate tube at the removal/sampling station and fitting our clean sample vial as the trap we were able to collect a contaminate free grab sample from any volume of leachate and by draining the secondary trap to a suspended load cell equipped weighing bucket, volume was inferred from mass, given 1g of pure H_2O at 4°C and 760mm Hg equals 1ml and leachate would vary insignificantly (<1%) at sampling temperatures and pressures. Upon DEP's request for quarterly sampling for Ortho-PO_4 beginning 17 Feb 2009 a new primary vacuum trap head was designed to accept the barrel of a separate sterile 60mL single use syringe equipped with a luer lock 45µm filter and syringe cap for a leachate trap. When removed from

the vacuum head, the syringe was fitted with its plunger and assembled into a press to extract a filtered sample for Ortho-PO_4, a duplicate when needed and a NOx sample as well or a NOx sample, its duplicate and an Ortho-PO_4 sample as well. The syringe vacuum head was triple rinsed the same as the 20mL scintillation vial vacuum head.

Sample Analysis

Sample analysis was by colorimetric auto analyzer at the UF/IFAS Analytical Research Laboratory, Gainesville, FL utilizing EPA method 353.2 for NO_3-N + NO_2-N, and 365.1 for Ortho-PO_4. MDL's for NOx and Ortho-P were 0.05mg/L, and 2.5µg/L until 01 Dec 2008 when they changed to 0.148mg/L and 3.0µg/L. PQL's for NOx and Ortho-P were 0.5mg/L and 10µg/L and remained unchanged after 01 Dec 2008. Linear working ranges for NOx and Ortho-P were 0.50-30.00mg/L and 0.01-0.50mg/L. Laboratory estimates of uncertainty for NOx and Ortho-P have an estimated bias of +0.95 and +1.46 and an estimated precision of ±3.61% and ±3.16%. Note: Precision estimates only apply to laboratory instrumentation and do not include any error associated with sample handling or collection variances and were determined by measuring the dispersion of values obtained from a known certified reference standard using typically 20-30 data points. With this, both bias (average % yield – 100) and precision (standard deviation of % yield) were determined (UF/IFAS Analytical Research Laboratory).

Measures of Turfgrass Quality, Dry Clipping Mass, and Dry Root Mass

Turfgrass visual quality, color, and density assessments were conducted, 28 Aug 2008 through 10 Oct 2008 (Yr 1), 17 Apr 2009 through 07 May 2009 (Yr 2 Run 1), 24 Aug 2009 through 13 Nov 2009 (Yr 2 Run 2), 29 Apr 2010 through 06 Aug 2010 (Yr 3 Run 1), 19 Aug 2010 through 29 Oct 2009 (Yr 3 Run 2), 02 May 2011 through 25 Aug 2011 (Yr 4) on two week intervals or less, unless dormant or changes were insignificant (which accounts for assessment periods greater than 2 weeks), utilizing NTEP turfgrass evaluation guidelines. Scales are 1-9 with a quality rating of 9 being best and 1 being poorest, color rating of 9 being dark green and 1 light green, and density rating of 9 being maximum density. Any rating 6 or greater is considered generally acceptable. Ratings are generally in whole numbers. Winter injury and %weeds were assessed on (Yr 1-2) 17 Apr 2009, (Year 2-3) 19 Mar 2010, 13 Apr 2010, (Year 3-4) 17 Mar 2011.

Turfgrass clippings were collected (Yr 1) at 20, and 51 days post-treatment (long sampling interval was due to irrigation well being down from 21 Aug 2008 to 22 Sept 2008 and drought conditions resulting in very little growth), (19 Aug 2008), (Yr 2 Run 1) at 22,35,49,61,70,84,99, and 112 days post-treatment (15 Apr 2009), (Yr 2 Run 2) at 7,21,35,49,62, and 77 days post-treatment (12 Aug 2009), (Yr 3 Run 1) at 35,49,63,77,91, and 105 days post-treatment (15 Apr 2010), (Yr 3 Run 2) at 3,17,31,45,59, and 73 days post-treatment (09 Aug 2010), (Yr 4) at 44,58,72,86,100,114, and 128 days post-treatment (12 Apr 2011) Clippings represented approximately 7 days shoot growth with an attempt to sample every 2 weeks from a 2.17m^2 areas within each 4m x 3m plot using a rotary mower set at a mowing height of 50.8mm with a modified grass catching system utilizing a 30.48cm by 40.64cm cloth bag in lieu of the manufacturers grass catching system. Samples were dried using forced hot air averaging 50°C for 48 to 72 hours prior to measuring masses.

Following each 120 day treatment period in years 2, 3, and 4, 5 root samples were collected using a pedal style soil sampler measuring 20mm dia. x 100mm long, one from each quadrant and one from the center of each plot. Soil, and debris separation from roots was accomplished by washing with water in a sieve accompanied by mechanical pressure and agitation. Separated roots were then air dried followed by oven drying at 50°C for 48-72 hours prior to measuring masses. These masses were corrected for retained mineral materials by ashing the samples and subtracting the mass of the remaining debris minus the ash.

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 254) or turf density (Table 256) but surges in color were observed (Table 255). 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 254). 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 256).

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 257). 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 258). 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 259).

2010 – Differences in turf quality were observed on 4 or 14 rating dates; three of which were early in the growing season (Table 260). Consistent with previous years, the PCU – 120 Day product was slow to promote improved turf quality (Table 260), turf color (Table 261), and turf density (Table 262). 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 those plots treated with this SRN source (Figure 56). 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 261) and turf density (Table 263).

Figure 56. 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.

2011 – The consequence of providing a cumulative rate of 196 kg N Kg^{-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 263) and turf density (Table 265) 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 264).

Shoot Mass

2008 – Initial shoot mass collections in 2008 showed no statistical differences among treatments (Table 266). 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 267). PCU – 120 Day produced the least quantity of clippings for the first 61 days following application following by an increase in clipping production (Table 267).

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 (Table 269 and 270).

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 271).

Root Growth

No differences in rooting due to SRN fertilizer sources were observed at any time throughout the duration of the study (Tables 272 – 274).

Nitrate Leaching

2008 – No differences in NO^{-}_{3}-N leaching occurred between the six SRN sources (Table 275). 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 to do significant rain events that occurred on 14 Oct, 28 Oct, and 1 Dec.

2009 – No differences in NO^{-}_{3}-N leaching due to N source were observed in 2009 (Table 276). 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 277). 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 ha^{-1}, respectively), during treatment cycle 4. XCU, methylene urea, and PCU + SCU leached the least (0.17, 0.56, and 0.70 kg N ha^{-1} respectively). The majority of the leached NO^{-}_{3}-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 ha^{-1} (PCU + SCU) to 32.9 kg N ha^{-1} (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 NO^{-}_{3}-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}) (Table 278). 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 kg N ha^{-1} (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 254. Effect of nitrogen source on turf quality in 2008.

		Rating Date	
Treatment @ 2.0 lbs N 1000 ft^{-2}	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
Pr>F	*ns*	*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 255. Effect of nitrogen source on turf color in 2008.

	Rating Date		
Treatment @ 2.0 lbs N 1000 ft^{-2}	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
Pr>F	*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 256. Effect of nitrogen source on turf density in 2008.

	Rating Date		
Treatment @ 2.0 lbs N 1000 ft^{-2}	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
Pr>F	*ns*	*ns*	*ns*

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 257. Effect of nitrogen source applications on turf quality in 2009.

	Rating Date													
Treatment @ 2.0 lbs N 1000 ft^{-2}	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	7.9ab	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	8.1a	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	7.8ab	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	6.9c	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	7.6ab	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	7.3bc	8.1	6.5	7.5	8.0	7.8	8.3	8.3	8.3	9.0	8.3	7.8	7.8
Pr>F	*ns*	*0.7*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*

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 258. Effect of nitrogen source applications on turf color in 2009.

	Rating Date													
Treatment @ 2.0 lbs N 1000 ft^{-2}	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
Pr>F	*ns*	*0.6*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*0.5*	*ns*	*ns*	*ns*	*ns*	*ns*

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 259. Effect of nitrogen source applications on turf density in 2009.

	Rating Date													
Treatment @ 2.0 lbs N 1000 ft^{-2}	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
Pr>F.....	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*

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 260. Effect of nitrogen source applications on turf quality in 2010.

	Rating Date													
Treatment @ 2.0 lbs N 1000 ft^{-2}	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)	6.5 ab	7.3	8.0 a	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)	6.3 ab	7.0	8.0 a	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)	6.8 a	7.5	7.3 b	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)	6.3 ab	8.3	6.5 c	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)	6.0 b	7.0	8.0 a	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)	6.0 b	7.0	8.0 a	9.0 a	9.0	8.0	8.8	8.8	9.0	5.0 d	7.5	7.3	7.5	8.3
Pr>F	*0.6*	*ns*	*0.4*	*0.6*	*ns*	*n s*	*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 261. Effect of nitrogen source applications on turf color in 2010.

	Rating Date													
Treatment @ 2.0 lbs N 1000 ft^{-2}	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)	7.3a	8.0a	7.8ab	9.0a	9.0	8.0	8.5	8.5	9.0a	7.8ab	7.5	7.0	7.0	7.8ab
XCU (43-0-0)	7.0a	7.5a	8.3a	9.0a	9.0	8.0	9.0	8.0	8.8a	7.0bc	7.8	7.0	7.0	7.8ab
Methylene Urea (40-0-0)	6.8a	7.5a	7.3bc	8.3b	9.0	7.8	8.5	8.8	9.0a	7.8ab	7.8	7.0	6.8	7.3bc
PCU - 120 Day (43-0-0)	6.0b	6.3b	6.8c	8.3b	9.0	8.0	9.0	8.5	8.0b	8.0a	8.0	6.8	6.8	7.0c
Florikan (15-2-15)	7.3a	8.0a	8.0ab	8.8a	9.0	8.0	8.5	8.0	8.8a	6.5c	7.0	7.0	7.0	8.3a
Corn Gluten Meal (9-0-0)	6.0b	7.3a	8.5ab	9.0a	9.0	8.0	9.0	8.8	9.0a	8.0a	8.0	7.3	7.5	8.0a
Pr>F	*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 262. Effect of nitrogen source applications on turf density in 2010.

	Rating Date													
Treatment @ 2.0 lbs N 1000 ft^{-2}	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	8.5a	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	8.0ab	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	7.5b	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	6.5c	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	8.5a	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	8.5a	6.8	9.0	8.3	8.5	8.5	8.8	8.5 ab	8.0 bc	7.8	8.3	8.8
Pr>F	*ns*	*ns*	*0.8*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*0.7*	*0.8*	*ns*	*ns*	*ns*

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 263. Effect of nitrogen source applications on turf quality in 2011.

	Rating Date								
Treatment @ 2.0 lbs N 1000 ft^{-2}	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
Pr>F	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*

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 264. Effect of nitrogen source applications on turf color in 2011.

	Rating Date								
Treatment @ 2.0 lbs N 1000 ft^{-2}	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
Pr>F	*0.9*	*ns*	*0.6*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*

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 265. Effect of nitrogen source applications on turf density in 2011.

	Rating Date								
Treatment @ 2.0 lbs N 1000 ft^{-2}	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
Pr>F	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*

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 266. Effect of nitrogen source applications on centipedegrass shoot mass in 2008.

	Shoot mass (g)	
Treatment @ 2.0 lbs N 1000 ft^{-2}	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
LSD	*ns*	*ns*

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 267. Effect of nitrogen source applications on centipedegrass shoot mass in 2009.

	Shoot mass (g)							
Treatment @ 2.0 lbs N 1000 ft^{-2}	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	12.09 bc	16.14 b	27.64	23.99	14.73
XCU (43-0-0)	4.59	3.76 ab	6.29 a	16.04 ab	18.71 ab	22.56	26.12	13.01
Methylene Urea (40-0-0)	4.79	3.03 bc	3.97 b	10.71 bc	13.55 b	20.87	24.91	12.18
PCU - 120 Day (43-0-0)	2.17	1.06 d	1.57 c	6.42 c	16.95 b	27.19	27.24	14.62
Florikan (15-2-15)	3.76	4.47 a	5.51 ab	15.21 ab	16.84 b	19.18	24.25	13.28
Corn Gluten Meal (9-0-0)	2.83	1.86 cd	4.99 ab	20.02 a	24.34 a	25.72	26.61	11.56
LSD	*ns*	*1.29*	*1.93*	*7.56*	*6.37*	*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 Protected LSD (*P*=0.05).

Table 268. Effect of nitrogen source applications on centipedegrass shoot mass in 2009.

	Shoot mass (g)					
Treatment @ 2.0 lbs N 1000 ft^{-2}	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
LSD	*2.07*	*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 Protected LSD (*P*=0.05).

Table 269. Effect of nitrogen source applications on centipedegrass shoot mass in 2010.

	Shoot mass (g)

Treatment @ 2.0 lbs N 1000 ft^{-2}	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 270. Effect of nitrogen source applications on centipedegrass shoot mass in 2010.

	Shoot mass (g)					
Treatment @ 2.0 lbs N 1000 ft^{-2}	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 271. Effect of nitrogen source applications on centipedegrass shoot mass in 2011.

	Shoot mass (g)						
Treatment @ 2.0 lbs N 1000 ft^{-2}	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 272. Effect of nitrogen source applications on turfgrass rooting in 2009.

	13 August 2009			9 October 2009		
Treatment @ 2.0 lbs N 1000 ft^{-2}	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 273. Effect of nitrogen source applications on turfgrass rooting in 2010.

	11 August 2010			8 October 2010		
Treatment @ 2.0 lbs N 1000 ft^{-2}	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 274. Effect of nitrogen source applications on turfgrass rooting in 2011.

	9 June 2011		
Treatment @ 2.0 lbs N 1000 ft^{-2}	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 275. Effect of various nitrogen sources on total NO_3-N leached in 2008.

	Total N (kg ha^{-2})					
		Application 19 Aug 08				
		60 day	60 day	120 day		
Treatment @ 2.0 lbs N 1000 ft^{-2}	Pre*	T1	T2	Total	Post	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
Pr<F.....	*0.5160*	*0.8086*	*0.3612*	*0.3744*	*0.5290*	*0.4943*
R^2	*0.3405*	*0.1559*	*0.3954*	*0.3887*	*0.3648*	*0.3767*

*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 276. Effect of various nitrogen sources on total NO_3-N leached in 2009.

	Total N (kg ha^{-2})								
		Application 15 Apr 09			Application 12 Aug 09				
Treatment @ 2.0 lbs N 1000 ft^{-2}	Pre*	60 day T1	60 day T2	120 day Total	60 day T3	60 day T4	120 day Total	Post	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
Pr<F	*0.5172*	*0.4562*	*0.5196*	*0.4551*	*0.1489*	*0.3486*	*0.3356*	*0.0949*	*0.1480*
R^2	*0.3655*	*0.2959*	*0.5260*	*0.3286*	*0.4318*	*0.3130*	*0.3214*	*0.4874*	*0.4351*

*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 277. Effect of various nitrogen sources on total NO_3-N leached in 2010.

	Total N (kg ha^{-2})								
		Application 15 Apr 10			Application 9 Aug 10				
Treatment @ 2.0 lbs N 1000 ft^{-2}	Pre*	60 day T1	60 day T2	120 day Total	60 day T3	60 day T4	120 day Total	Post	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*
Pr<F	*0.1700*	*0.4746*	*0.4008*	*0.4262*	*0.8852*	*0.0130*	*0.0172*	*0.0058*	*0.0054*
R^2	*0.4909*	*0.3068*	*0.2869*	*0.2937*	*0.1973*	*0.6058*	*0.5892*	*0.6420*	*0.6428*

*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 278. Effect of various nitrogen sources on total NO_3-N leached in 2011.

	Total N (kg ha^{-2})					
		Application 12 Apr 11				
Treatment @ 2.0 lbs N 1000 ft^{-2}	Pre*	60 day T1	60 day T2	120 day Total	Post	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	6.51 c
LSD.....	*1.15*	*3.89*	*28.18*	*31.40*	*ns*	*31.59*
Pr<F.....	*0.0427*	*0.0028*	*0.0214*	*0.0152*	*0.3931*	*0.0155*
R^2	*0.5606*	*0.6893*	*0.5643*	*0.5867*	*0.3129*	*0.5855*

*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).