Journal of Plant Nutrition
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/lpla20

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Accepted author version posted online: 05 Jul 2013.

To cite this article: L. E. Trenholm , J. B. Unruh & J. B. Sartain (2013) NITRATE LEACHING AND TURF QUALITY IN NEWLY SODDED ST. AUGUSTINEGRASS, Journal of Plant Nutrition, 36:12, 1935-1943, DOI: 10.1080/01904167.2013.819893

To link to this article: http://dx.doi.org/10.1080/01904167.2013.819893

Journal of Plant Nutrition, 36:1935–1943, 2013

ISSN: 0190-4167 print / 1532-4087 online
DOI: 10.1080/01904167.2013.819893

NITRATE LEACHING AND TURF QUALITY IN NEWLY SODDED ST. AUGUSTINEGRASS

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□ *There are increasing concerns about the fate of fertilizers applied to lawn grasses. The objectives of this research were to evaluate nitrate leaching and turf response to nitrogen (N) treatment and irrigation in newly sodded St. Augustinegrass. The research was conducted in Citra, FL in 2006 and 2007. Nitrogen was applied at three rates day of sodding and again at 30 days after planting. Analysis of variance indicated there were no differences in nitrate-N (NO_3–N) leached due to N treatment or timing. During the establishment period, NO_3–N loading was greater than reported for established turf and could possibly present a source of nitrate contamination. Turf quality and color were above or just below an acceptable score at all N rates. Due to the potential for high amounts of NO_3–N leaching in new sod, it is not recommended to apply N fertilizer to St. Augustinegrass in the first 30–60 days after planting.*

Keywords: turfgrass, Floratam, fertilizer

INTRODUCTION

There are concerns regarding the fate of nitrogen (N) fertilizers applied to home lawns and other urban turf areas. In some locations, these concerns have prompted ordinances, restrictions, or regulations designed to reduce potential nutrient leaching from lawn care activities. Numerous research reports over the last several years have documented that many factors influence the degree of nitrate leaching from turf areas, including N application rate, N source, irrigation management, root architecture, and soil type.

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

Received 12 July 2011; accepted 4 October 2011.
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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 (NO_3) 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 yr 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 is 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 N leaching (4.1 kg ha^{-1} annually) from sodded 'Floratam' St. Augustinegrass than from a mixed-species landscape (48.3 kg 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. Augustinegrass 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.

Given that Florida currently has increasing regulations at both state and local levels regarding fate of nutrients applied to lawn grasses and due to a lack of information on NO_3–N leaching and turf quality during establishment of St. Augustinegrass, the objectives of this research were to determine the influence of total N application rate and irrigation regime on NO_3–N leaching and turfgrass quality in newly sodded Floratam St. Augustinegrass.

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.

Plots measured 4.0 m × 4.0 m. High-density polyethylene (HDPE) drainage lysimeters were installed in the center of each plot, with the top approximately 10 cm below the soil surface. Lysimeters measured 57 cm diam. and 88 cm in height with a volume of 168 L. Lysimeters were assembled by placing 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 bases of the units were filled with washed egg rock (1.9 – 6.4 cm) for a volume of 38 L. 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. Plot areas were cleared of existing vegetation until Floratam St. Augustinegrass was sodded on 2 May 2006. The grass was removed from the plot area in April 2007 and glyphosate [N-(phosphonomethyl) glycine] was used as needed to keep plots clear of vegetation until sod was replanted on 22 May 2007.

Nitrogen treatments are listed in Table 1 and were hand applied as soluble urea (46-0-0) granules. All plots received N treatments on the same day that sod was planted and half of the plots received a second treatment 30 days later. Nitrogen treatments were irrigated with 0.6 cm water. Inclusion of control plots would have been inconsistent with our objective of determining NO_3–N leaching due to N application; therefore, control plots receiving no N were not included in this experiment.

Irrigation treatments began on the next day and are described in Table 2. Irrigation was applied as either a graduated irrigation regime (IR 1) for the first 21 days, or at the rate of 1.3 cm daily for the first 21 days (IR 2). From 22 days through the end of the study, all plots were irrigated at 1.3 cm twice weekly. When rainfall amounts exceeded irrigation treatments, irrigation was withheld until the next scheduled application.

TABLE 1 Nitrogen treatments applied to Floratam St. Augustinegrass in a 60-day study in Citra, FL over two consecutive years

Nitrogen Treatment	Number of Fertilizations†	$g \cdot m^{-2}$	
		Nitrogen Rate	Total N Applied
1	1	2.5	2.5
2	1	5.0	5.0
3	1	10.0	10.0
4	2	2.5	5.0
5	2	5.0	10.0
6	2	10.0	20.0

†1 = Treatment applied same day as planting.
2 = Treatment applied same day as planting and 30 days after planting (DAP).

Turf was mowed weekly at a height of 8.9 cm with clippings returned. No pesticides were applied during the study periods.

Leachate samples were collected twice weekly for eight weeks, beginning the day after the first N application. Samples were collected by applying a vacuum to the collection tubing and withdrawing percolate from the reservoir of the lysimeter until empty. To ensure that a perched water table did not exist, lysimeters were evacuated more than twice weekly if heavy rain events (>2.5 cm) occurred. The large surface area of the lysimeters enhanced percolation through the soil profile, so preferential flow within lysimeters was minimized. 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 while in the field and then frozen at 0°C until NO_3–N analysis was completed. Nitrate concentration was measured using an AutoAnalyzer 3 continuous segmented flow analyzer (Seal Analytical, Mequon, WI) at the UF Analytical Research Laboratory in Gainesville. Nitrate leaching data are presented as total cumulative NO_3–N leached over the study period and percent of applied N leached. Any

TABLE 2 Irrigation treatments applied to Floratam St. Augustinegrass in a 60-day study in Citra, FL over two consecutive years

	Irrigation regime 1		Irrigation regime 2	
	Frequency	Weekly amount cm	Frequency	Weekly amount 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

TABLE 3 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 nitrate leached %	Average turf quality	Average turf color
		2006		
N treatment (NT)	NS	NS	**	**
Irrigation regime (IR)	NS	NS	NS	NS
NT × IR	NS	NS	NS	NS
		2007		
NT	NS	NS	***	***
IR	NS	NS	NS	NS
NT × IR	NS	NS	*	NS

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

concentrations that were lower than the minimum detection limit (MDL) of 0.05 mg·L^{-1} were corrected to the MDL value.

Turf visual quality (TQ) and color (TC) scores were taken weekly throughout the study period and were based on a scale from 1 to 9 where 1 = dead, brown turf and 9 = optimal, lush green turf. A score of 6 was considered to be the minimum acceptable score for a lawn.

Experimental design was a nested design, with N treatments nested and randomized within irrigation treatments. There were three replications. Proc ANOVA and Proc GLM (SAS Institute, Cary, NC, USA) 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, data 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 AND DISCUSSION

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 3). However, single degree of freedom contrasts in 2006 indicated that nitrogen rate affected cumulative NO_3–N leaching (Table 4). Contrasts differed significantly between treatments 1 and treatments 2 and 3, with higher leaching occurring at the higher N application rates. There was no difference between treatment 1 and 4 and between treatment 2 and 5, indicating no differences in leaching due to one application at day of planting or applications at both day of planting and 30 DAP at these

TABLE 4 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

	2006		2007	
Nitrogen Treatment (NT)	Total Nitrate Leached ($g \cdot m^{-2}$)	Nitrate Leached (% applied N)	Total Nitrate Leached ($g \cdot m^{-2}$)	Nitrate Leached (% 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	**	**	NS	NS
NT1 vs. NT3	**	NS	NS	*
NT1 vs. NT4	NS	NS	NS	NS
NT1 vs. NT5	**	NS	NS	NS
NT1 vs. NT6	***	NS	*	**
NT2 vs. NT4	NS	**	NS	NS
NT2 vs. NT5	NS	*	NS	NS
NT3 vs. NT5	NS	NS	NS	NS
NT3 vs. NT6	*	NS	NS	NS

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

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 3). Single degree of freedom contrasts in 2006 showed differences between treatments 1 and 2 and treatment 2 vs. 5 (Table 4). In 2007, percentage leached varied between the lowest and highest rates of applied N when applied at time of planting. Highest percentages were lost from lowest rates of applied N. It is not unusual that percentages of N lost increase at lower N rates, as even low levels of 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.

Previous reports on other species likewise indicate high rates of NO_3–N leaching from newly planted turf. Easton and Petrovic (2004) found NO_3–N leaching of up to 18.6 $g \cdot m^{-2}$ in the first year of a trial on a mixture of newly seeded Kentucky bluegrass and perennial ryegrass. In the second year of the study, highest NO_3–N levels were 2.2 g·m^{-2}. Lower levels of NO_3–N leaching (8–12% of applied N) were reported from newly planted bermudagrass (Shaddox and Sartain, 2001). Nitrate N losses from Kentucky bluegrass were reported to be 14.6 and 2.3 mg·L^{-1}, respectively, for years 1 and 2 of a study (Geron et al., 1993). In a sod production cycle of 22 months, 3.3 to 16.7 g·m^{-2} was reported leached from bermudagrass (Barton et al., 2006). The authors attributed leaching losses to irrigation rather than N treatment.

While the lack of statistical differences in these results may imply that N may be applied at either time of planting or 30 DAP at the lower rates, the NO_3–N leaching values reported here are considerably greater than amounts reported to have leached from established St. Augustinegrass. Although the objectives of the current study were not to compare newly sodded St. Augustinegrass NO_3–N leaching with established grass leaching, it is important to note the increased leaching that occurs during sod establishment when root systems are minimal and that this may increase the potential for nutrient movement. For example, Trenholm et al. (2012) reported cumulative annual NO_3–N leaching in ranges of 0.1 to 0.6 g·m^{-2} or 0.3 to 1.3% of the N applied, on an annual basis in established St. Augustinegrass. Other research on established grasses also shows low amounts of NO_3–N leached, including Kentucky bluegrass (Frank et al., 2006), a mixture of Kentucky bluegrass, perennial ryegrass, and creeping red fescue (*Festuca rubra* ssp. *rubra*) (Guillard and Kopp, 2004), and St. Augustinegrass (Erickson et al., 2008).

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. 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.

Turf Visual Ratings

Turf visual quality and color ratings differed in 2006 only in response to N treatment (Table 3). Both TQ and TC were highest with treatment 6 and lowest with treatment 2 (Table 5). Color scores were always above a minimally acceptable score and TQ was above acceptable from N treatment 1, 4, 5, and 6. In 2007, all scores were above acceptable, with highest scores from treatment 6 and lowest from treatment 1. Turf visual responses to nitrogen are often reported in established turf, so it is probable that the slight, although significant, responses reported here are most likely due to

TABLE 5 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

	2006		2007	
Nitrogen Treatment	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 $P = 0.05$.

residual pre-harvest fertilization, which may imply that nitrogen fertilization was not needed during the time period of this study.

CONCLUSIONS

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, contrast analysis indicates differences between some individual treatments. When these differences existed, the highest rate of applied N differed from the lower rates. 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. Although fertilizer timing did not appear to influence leaching as much as rate, the reductions reported in NO_3–N leached between the first and second N applications should be considered in a nutrient management plan to reduce nutrient leaching. Results of this research indicate that N fertilization should be withheld for a minimum of 30 to until 60 days after sodding St. Augustinegrass to reduce potential NO_3–N leaching.

ACKNOWLEDGMENTS

We thank the Florida Dep. of Environmental Protection for funding this research.

REFERENCES

Barton, L., G. G. Y. Wan, and T. D. Colmer. 2006. Turfgrass (*Cynodon dactylon* L.) sod production on sandy soils:II. Effects of irrigation and fertilizer regimes on N leaching. *Plant and Soil* 284: 147–164.

Bowman, D. C., C. T. Cherney, and T. W. Rufty, Jr. 2002. Fate and transport of nitrogen applied to six warm-season turfgrasses. *Crop Science* 42: 833–841.

Bowman, D. C., D. A. Devitt, M. C. Engelke, and T. W. Rufty, Jr. 1998. Root architecture affects nitrate leaching from bentgrass turf. *Crop Science* 38: 1633–1639.

Easton, Z. M., and A. M. Petrovic. 2004. Fertilizer source effect on ground and surface water quality in drainage from turfgrass. *Journal of Environmental Quality* 33:645–655.

Erickson, J. E., J. L. Cisar, G. H. Snyder, D. M. Park, and K. E. Williams. 2008. Does a mixed-species landscape reduce inorganic-nitrogen leaching compared to a conventional St. Augustinegrass lawn? *Crop Science* 48: 1586–1594.

Erickson, J. E., J. L Cisar, J. C. Volin, and G. H. Snyder. 2001. Comparing nitrogen runoff and leaching and between newly established St. Augustine grass turf and an alternative residential landscape. *Crop Science* 41: 1889–1895.

Frank, K. W., K. M O'Reilly, J. R. Crum, and R. N. Calhoun. 2006. The fate of nitrogen applied to a mature Kentucky bluegrass turf. *Crop Science* 46: 209–215.

Geron, C. A., T. K. Danneberger, S. J. Traina, T. J. Logan, and J. R. Street. 1993. The effects of establishment methods and fertilization practices on nitrate leaching from turfgrass. *Journal of Environmental Quality* 22: 119–125.

Guillard, K., and K. L. Kopp. 2004 Nitrogen fertilizer form and associated nitrate leaching from cool-season lawn turf. *Journal of Environmental Quality* 33: 1822–1827.

Morton, T. G., A. J. Gold, and W. M. Sullivan. 1988. Influence of overwatering and fertilization on nitrogen losses from home lawns. *Journal of Environmental Quality* 17: 124–130.

Shaddox, T. W., and J. B. Sartain. (2001). Fate of nitrogen during grow-in of a golf course fairway under different nitrogen management practices. *Soil and Crop Science Society Florida Proceedings* 60: 59–63.

Trenholm, L. E., J. B. Unruh, and J. B. Sartain. 2012. Nitrate leaching and turf quality in established 'Floratam' St. Augustinegrass and 'Empire' Zoysiagrass. *Journal of Environmental Quality* 41: 793–799.