Comparing Nitrogen Runoff and Leaching between Newly Established St. Augustinegrass Turf and an Alternative Residential Landscape

J. E. Erickson,* J. L. Cisar, J. C. Volin, and G. H. Snyder

ABSTRACT

Turfgrass landscapes have the potential for loss of applied N through both runoff and leaching. Lower maintenance alternative vegetation used in mixed-species landscapes may reduce N leaching and runoff, which is important for reducing N pollution of surface and ground waters. However, few studies have examined this paradigm. Therefore, we constructed a field-scale facility to compare fertilizer N runoff and leaching between St. Augustinegrass [*Stenotaphrum secundatum* (Walt.) Kuntze] and a mixed-species landscape. Four replications of each landscape were randomly assigned to 50-m^2 plots. A medium-fine sand (75-cm depth) was used as the root zone mix. A blended granular fertilizer was applied at a rate of 300 and 150 kg N ha^{-1} yr^{-1} on the turfgrass and mixed-species, respectively. Throughout the first year following installation of the landscapes, fertilizer N loss in surface runoff was insignificant. In contrast, N leaching losses were significantly greater on the mixed-species landscape during three fertilizer cycles, resulting in 48.3 kg N ha^{-1} compared with 4.1 kg N ha^{-1} for the St. Augustinegrass annually. The results from the newly established landscapes presented here indicated that St. Augustinegrass was more efficient at using applied N and minimizing N leaching compared with the alternative landscape. Furthermore, the study identified areas of concern with respect to N management practices on alternative landscapes. These results hold implications for future landscape models and management of resources in a residential setting.

Anthropogenic alterations in the N cycle have been quite severe with numerous consequences (Aber et al., 1995; Vitousek et al., 1997). As a result, various research projects have focused on the ecology of human-altered N cycling in terrestrial and aquatic ecosystems. Much of the literature indicated an overall decline in both plant and animal species diversity and accelerated eutrophication (Howarth, 1988; National Research Council Committee on Wastewater Management for Coastal Areas. Water Science and Technology Board, 1993). In addition to ecological consequences, greater losses of NO_3^-–N to ground water increase the likelihood of exceeding the NO_3^-–N drinking water standard of 10 mg L^{-1} set by the EPA for human safety. While sources of anthropogenic N pollution are diverse, large human population concentrations have unquestionably impacted water resources through N pollution (Cole et al., 1993; Vitousek et al., 1997). For example, increasing NO_3^-–N concentrations and fluxes in water resources have been correlated with human population densities in various watersheds (Peierls et al., 1991; Vitousek et al., 1997). However, the underlying sources of elevated N in watersheds remain unclear. One possibility includes fertilizer N runoff and leaching from residential and commercial landscapes, where routinely fertilized turfgrass is a major landscape component (Kelling and Peterson, 1975; Petrovic, 1990). As residential land use increases, the potential for N loss to water resources becomes even greater. Therefore, a better understanding of N pollution from residential landscapes is needed. In Florida, where urban populations are rapidly expanding, efforts to assess N leaching and runoff from urban landscapes are underway (Erickson et al., 1999).

St. Augustinegrass is the predominant vegetation used in Florida residential landscapes. It is a moderate fertility warm-season turfgrass that receives 150 to 300 kg N ha^{-1} yr^{-1} when appropriately fertilized (Cisar et al., 1991). No quantitative N leaching and runoff data specifically from St. Augustinegrass in Florida are available, although a number of investigators have demonstrated conditions favorable for N runoff and leaching from turfgrass land use (Kelling and Peterson, 1975; Petrovic, 1990; Snyder et al., 1984). For example, the potential for N leaching from turfgrass may be substantial on coarse-textured soils (Reike and Ellis, 1974). In addition, excessive irrigation may lead to N leaching (Snyder et al., 1984). However, very little N leaching or runoff has generally been observed from judiciously managed turfgrass (Gross et al., 1990; Miltner et al., 1996; Morton et al., 1988; Snyder et al., 1980; Star and DeRoo, 1981). Thus, the literature demonstrates the potential for N pollution from various turfgrass landscapes, but the magnitude of N pollution has been highly variable and context specific.

A University of Florida Extension initiative, entitled The Florida Yards and Neighborhoods (FYN) Program, began in the 1990s in response to numerous residential landscape concerns, including N pollution (Best, 1994). The program advocates the use of alternative landscape materials requiring less water and fertilizer inputs that might conceivably reduce N pollution from urban areas. However, while landscapes utilizing the principles of the FYN Program are intended to enhance the environment by reducing harmful N pollution (Garner et al., 1996), no data are available to quantify N leaching and runoff from FYN alternative landscapes. Analogous to the objectives of the FYN Program, other authors have proposed the use of alternative plant materials in residential landscapes to minimize environmental impacts, especially in arid climates where water conservation is

J.E. Erickson, Forest Ecology and Management, Univ. of Wisconsin, 1630 Linden Dr., Madison, WI 53706; J.L. Cisar, Environmental Horticulture, Fort Lauderdale Research and Education Center, 3205 College Ave, Fort Lauderdale, FL 33314; J.C. Volin, Environmental Sciences, Florida Atlantic University, 2912 College Ave., Davie, FL 33314; and G.H. Snyder, Soil and Water Science, Everglades Research and Education Center, P.O. Box 8003, Belle Glade, FL 33430. Journal Series no. R-08216 of the Florida Agricultural Experiment Station. Received 15 Dec. 2000. *Corresponding author (jeerick1@students.wisc.edu).

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Abbreviations: ET, Evapotranspiration; FYN, Florida Yards and Neighborhoods.

Table 1. The alternative landscape included a variety of ornamental species chosen by the Florida Yards and Neighborhoods Program with consideration for N requirement, drought tolerance, wildlife habitat, and aesthetic appeal. Categories of vegetation type include ground cover (GC), ornamental grass (G), shrub (S), and tree (T). Size indicates pot size at planting.

Scientific name	Common name	Veg. type	Florida native	No. plot^{-1}	Size
					L
Lirope muscari (Dcne.) Bailey 'evergreen giant'	Liriope	GC	N	25	3.8
Lantana montevedenis (K. Spreng) Briq.	Trailing lantana	GC	N	3	3.8
Tripsacum floridana L. 'dwarf'	Dwarf fakahatchee grass	G	Y	3	11.4
Zamia pumila L.	Coontie	S	Y	15	7.6
Ilex vomitoria Ait. 'schellings dwarf'	Yaupon holly	S	Y	7	11.4
Hamelia patens Jacq. 'compacta'	Firebush	S	Y	5	11.4
Galphimia glauca Cav.	Thyrallis	S	N	4	11.4
Myrcianthes fragrans (Sw.) McVaugh	Simpson's stopper	S/T	Y	3	11.4
Podocarpus macrophyllus (Thunb.) Sweet	Podocarpus	S/T	Y	3	11.4
Myrica cerifera (L.) Small	Wax myrtle	T	N	1	26.5
Tabebuia heterophylla (DC.) Britt.	Pink trumpet-free	T	N	1	26.5
Acoelorrhaphe wrightii (Griseb. & H. Wendl.) H. Wendl. ex Becc.	Everglades palm	T	Y	1	26.5

a major concern (Hipp et al., 1993; Sacamano and Jones, 1975). In fact, a study considering alternative landscapes on silty clay in Texas observed more runoff from a high maintenance landscape, which was attributed to antecedent soil moisture. However, the results were somewhat inconclusive with respect to N pollution since N leaching was not measured (Hipp et al., 1993). Overall, very little is known about N pollution from alternative landscapes.

Due to the lack of data regarding N pollution from residential landscapes, there is considerable interest in quantifying the magnitude of N runoff and leaching from these contrasting residential landscape types. Therefore, we constructed a field-scale facility to monitor N pollution from contrasting residential landscapes at the lawn scale level for three approximately 4-mo fertilizer cycles (Erickson et al., 1999). The objective of this study was to compare N leaching and runoff between a St. Augustinegrass monoculture and a mixed-species landscape designed by the FYN Program. In pursuing this objective, we tested the null hypothesis that no difference in N leaching and runoff would be observed between the two contrasting landscape systems.

MATERIALS AND METHODS

A facility containing eight 9.5 by 5.0 m research plots was constructed at the University of Florida's Fort Lauderdale Research and Education Center to collect both surface runoff and subsurface percolate from two contrasting landscape treatments. One treatment consisted of a 'Floratam' St. Augustinegrass monoculture and the other treatment was an arrangement of ornamental ground covers, shrubs, and trees designed by Mr. Allen Garner of the FYN program. The St. Augustinegrass was installed as a sod and maintained at a height of 7.5 cm. The clippings were removed for the first 6 mo of the study and mulched in situ for the final 6 mo. The mixed-species landscape consisted of 12 ornamental species and contained no turfgrass (Table 1). Over 50% of the species used were considered native to Florida. All species were commercially available and purchased at a local nursery. The plants were installed from pots with the soil and intact root systems. Following the protocol of the FYN program, eucalyptus mulch (The Bushel Stop, Pompano Beach, FL) was uniformly applied at a depth of 7.5 cm on the mixed-species landscape to minimize soil water evaporation and weed growth.

Construction of the facility commenced in the fall of 1998. A crushed limestone foundation layer provided a 10% slope. A 6-mm polyvinyl plastic sheet placed on the bottom and sides of the eight plot cells provided hydrological isolation for each plot. Subsequently, a root zone mix was placed on the plastic at a depth of 0.75 m. The mix was a mined sand (Boynton Sand and Gravel, Palm Beach County, Florida) chosen for its lack of N-containing organic matter. The use of this root zone mix avoided the potentially confounding influence of N losses derived from organic matter as a result of increased N mineralization associated with soil disturbance during establishment (Geron et al., 1993). Furthermore, the root zone mix was a medium-fine sand with a relatively high infiltration rate, similar to many residential sandy soils in Florida. The soil pH measured at the end of the study averaged 7.0 across all plots.

In each of the eight plots we installed a rectangular perimeter irrigation system comprised of six inward-facing spray nozzles. The rate of irrigation was uniform across all plots (Erickson et al., 1999). After about 5 mo, the irrigation on the ornamental plots was converted to a microjet irrigation system, which delivered water directly to the plants. An irrigation time clock controlled each plot as a separate zone. An automatic rain shutoff switch was connected to the time clock to avoid irrigation following sufficient rainfall. Irrigation volume applied to each treatment was recorded based on a flow meter installed in the irrigation system. Soil percolate was measured initially by random manual measurements on each plot and subsequently by tipping bucket flow gauges (Unidata America-Model 6406H, Lake Oswego, OR) that continuously monitored percolate volume. A data logger (CR10X, Campbell Scientific, Logan, UT) recorded the percolate volume. Rainfall was recorded continually and averaged monthly. Both rainfall and irrigation were randomly tested for inorganic N (NO_3^-–N and NH_4^+–N). Estimates of evapotranspiration (ET) were calculated using a moisture budget system based on the following formula: ET = irrigation + rainfall − percolate (Snyder et al., 1980).

For each of the approximately 4-mo cycles, fertilizer N was applied at a rate of 50 kg N ha^{-1} per application to both treatments. However, the fertilizer was applied twice per cycle to the St. Augustinegrass (300 kg N ha^{-1} yr^{-1}) and only once per cycle to the mixed-species (150 kg N ha^{-1} yr^{-1}). Thus, each cycle was determined by the fertilization dates on the mixed-species landscape. The fertilization programs used in the study were moderate for both landscapes and common for subtropical conditions in south Florida (Cisar et al., 1991; Yeager and Gilman, 1991). A blended 26-3-11 (N-P_2O_5-K_2O) granular fertilizer (LESCO Inc., Sebring, FL) was chosen for both treatments, except for the last cycle when a 12-2-14 (N-P_2O_5-K_2O) mix was used on the mixed-species landscape to supply more K and micronutrients to the ornamental species.

According to the Florida label on the fertilizer bag, N sources in the fertilizer were urea (58%), S-coated urea (37.5%), and ammonium phosphate (4.5%). The granular material was hand distributed and watered in with approximately 5.0 mm of irrigation at each application.

Planting of both treatments occurred on 18 Dec. 1998. The first fertilizer cycle and data collection commenced in February 1999. Nitrogen leaching and runoff data were collected continually for all three cycles over a 12-mo period following the onset of fertilization. A gutter system at the base of each plot was designed to collect any surface water runoff during storm events. Initially, percolate flow measurements and samples were taken at least once daily from a slotted drainage pipe placed across the lower edge of each plot, which drained the percolate for the entire plot. Beginning in July, ISCO (model 2900) Autosamplers (ISCO, Inc., Lincoln, NE) were installed to collect daily composite percolate samples. The automated samplers were programmed to draw a fresh 50-mL percolate sample from the tipping bucket every 6 h to an internal sample container. Thus, a daily (24 h) 200-mL composite sample was collected and used for subsequent N analyses. Both runoff and percolate water samples were immediately acidified with sulfuric acid upon collection and refrigerated at 4°C until analysis. The samples were analyzed for inorganic N (NH_4^+–N and NO_3^-–N) using colorimetric autoanalyzers (OI Analytical, College Station, TX; U.S. EPA Methods 350.1 and 353.2). All analyses were performed at the University of Florida Analytical Research Laboratory (ARL) in Gainesville, FL.

The experimental design for this study was a completely randomized design with a single factor, landscape type. The design included two treatments and four replications per treatment. Inorganic N loadings (quantity leached) in runoff and percolate were calculated from each replication. For runoff samples, the concentration of nutrient was multiplied by volume of the runoff event. In the percolate samples, a daily nutrient load was determined by multiplying the concentration of each nutrient found in the daily composite percolate sample by the volume of percolate measured for the respective 24-h period. Statistically significant treatment effects on inorganic N loading in runoff and percolate for each approximately 4-mo fertilizer cycle were identified using SAS analysis of variance procedures (SAS Institute, 1989).

RESULTS

Hydrology

The hydrology in southern Florida involves a wet season (June–November), when rainfall is abundant, and a dry season (December–May), in which relatively little rainfall is received (Fig. 1). During the first cycle, which was entirely in the dry season, only 195 mm of rainfall was received. In contrast, approximately 1160 mm was received during the second cycle in the wet season. The third cycle encompassed both seasons and accordingly 700 mm of rainfall was measured. Almost 90% (1838 mm) of the total rainfall was in the wet season, with only 216 mm in the dry season. Two particularly intense storm events brought an excess of 250 mm per event, illustrating the potential for substantial precipitation in subtropical southern Florida. The mean concentration of inorganic N measured in the rain was 1.23 mg L^{-1} (n = 4). Thus, based on this mean N concentration and 2054 mm of rainfall, 25.3 kg N ha^{-1} were received during the year via wet deposition. In addition to rainfall, supplemental irrigation was applied to both treatments (Fig. 1). The mean concentrations of NO_3^-–N and NH_4^+–N in the irrigation were <0.2 and 1.0 mg L^{-1}, respectively (n = 6). The St. Augustinegrass received 9% more irrigation than the mixed-species throughout the study (951 and 872 mm of irrigation were applied to the turf and the mixed-species, respectively). Both landscapes were planted in the dry season; therefore more than one-half of the supplemental irrigation was applied to the grass (507 mm) and the mixed-species (474 mm) during the

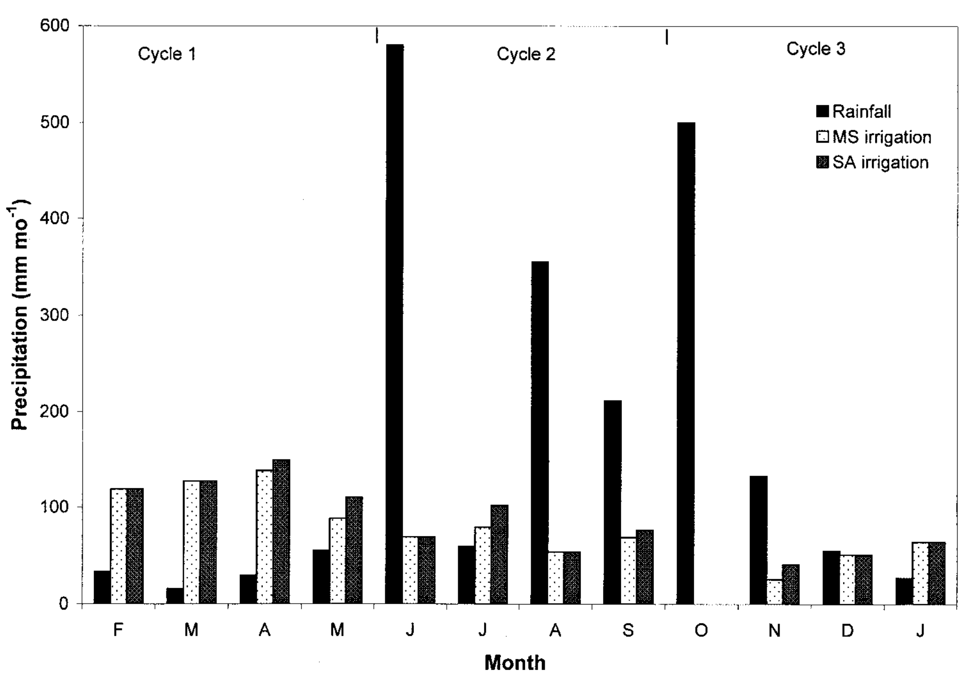

Fig. 1. Rainfall and irrigation inputs (mm mo^{-1}). Irrigation was measured by a flow meter in the main irrigation line. Approximately 9% more irrigation was applied to the St. Augustinegrass plots.

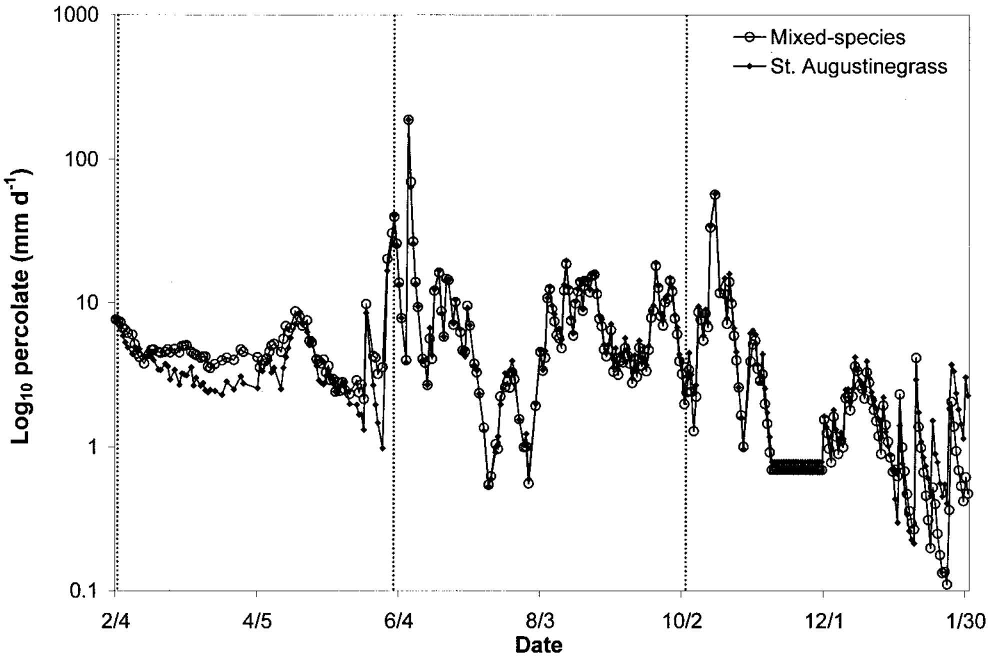

Fig. 2. Mean daily movement of percolate water (mm d^{-1}) over time (n = 4). Dotted vertical lines represent data cycles corresponding with fertilization dates on the mixed-species landscape. The effect of rainfall on percolate volume can be seen during the wet season with little variation between the treatments following the first cycle.

first cycle. The relative annual savings in irrigation on the mixed-species will probably be even greater than what we observed under fully established conditions.

During the study intense rainfall events occurred frequently, however, surface runoff was insignificant throughout the study. Only one runoff event was measured on the sandy soil when 220 mm of rainfall produced <1 mm of surface runoff. In contrast to surface runoff, monthly percolate was positively related to the amount of rainfall received on both treatments. Annual measurements of percolate were 2082 and 2237 mm on the St. Augustinegrass and mixed-species landscapes, respectively. Although ET was highest in the wet season, more than one-half of the percolate was measured in the second cycle, which further illustrated the influence of rainfall on percolate volume. A significant difference ($P < 0.05$) in percolate volume was observed between the treatments in Cycle 1, probably as a result of the immaturity of the mixed-species landscape (Fig. 2). However, no significant differences were seen in percolate quantity between the two landscapes in the subsequent cycles. Finally, estimates of ET were determined for each landscape treatment based on the rainfall, irrigation, and percolate data measured above. Mean dry season ET was estimated to be 43.7 and 21.2 mm mo^{-1} on the St. Augustinegrass and mixed-species, respectively, while mean wet season ET was 104.5 mm mo^{-1} and 97.2 mm mo^{-1} on the respective landscapes.

Nitrogen Loadings

As mentioned above, only one runoff event (<1 mm) was measured during the 12-mo study. Inorganic N concentrations measured in the runoff were not different from those measured in the rainfall. Therefore, despite the 10% slope of the plots, there was no significant inorganic N runoff from either landscape treatment.

Even though no significant N runoff was measured on the sandy soil, N losses were observed in the percolate. Significantly greater N (NO_3^-–N + NH_4^+–N) leaching was observed on the mixed-species landscape in each of the three cycles (Table 2). During the study period, the mixed-species landscape leached 10 times more N than the St. Augustinegrass. Although a fertilizer with approximately 40% slow release N was used, the majority of the fertilizer N leached from the mixed-species landscape each cycle occurred shortly after fertilization (Fig. 3). The quantity of inorganic N leached from the mixed-species treatment was quite substantial in Cycle 1 in spite of moderate percolate volume. While similar quantities of N were leached in subsequent cycles, intense rainfall (percolate) events occurred following fertilization in Cycles 2 and 3 (Fig. 2). The effect of a severe rainfall event on the mixed-species treatment was

Table 2. Summary of inorganic N (NO_3^-–N + NH_4^+–N) leaching losses (kg ha^{-1}) during each 4-mo fertilizer cycle. One-hundred kilograms N per hectare was applied to the St. Augustinegrass and 50 kg N ha^{-1} to the mixed-species landscape in each cycle. Values are treatment means based on n = 4.

Fertilizer cycle (4 mo)	St. Augustinegrass	Mixed-species
	kg ha^{-1}	
1 (Feb.–May)	1.2	18.2***
2 (June–Sept.)	2.0	12.6***
3 (Oct.–Jan.)	0.9 (0.6)†	17.5*** (4.3**)
Annual total	4.1	48.3***

** Indicates statistical difference ($P < 0.01$).
*** Indicates statistical difference ($P < 0.001$) within a row by ANOVA procedures.
† Values in parentheses omit 5 d during which data from only one replication was usable due to storm related complications.

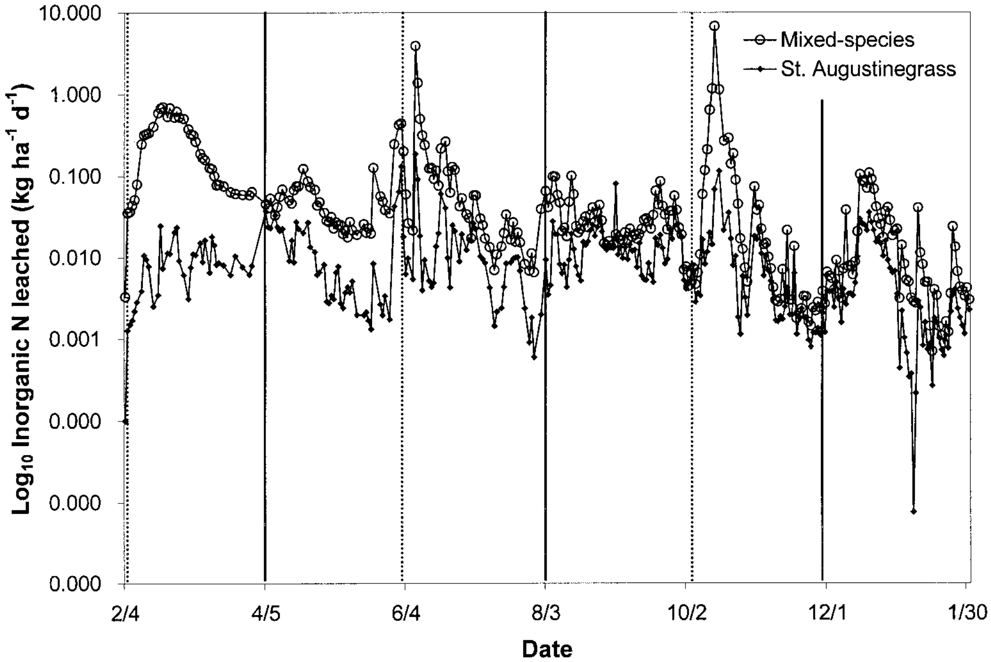

Fig. 3. Mean daily inorganic N leached (kg ha^{-1}) over time (n = 4). Dotted vertical lines represent fertilization events for both treatments while solid vertical lines represent additional St. Augustinegrass fertilizations. Increases in N leaching following fertilization were generally seen on both treatments, but to a lesser magnitude on the St. Augustinegrass.

evident during the third cycle, where approximately 75% of the N loss for the cycle was related to one storm event (Table 2). In contrast, despite routine fertilization and frequently intense rainfall events, mean N quantities leached from the St. Augustinegrass exhibited relatively little variability and remained consistently low. Still, there was some indication that inorganic N losses in the percolate were slightly higher following fertilization on the St. Augustinegrass (Fig. 3). This slight increase in N loss from the turf following fertilization was in the NH_4^+–N form with no evident increase in NO_3^-–N loss (data not shown). Overall, the majority of the N leached from the St. Augustinegrass was ammoniacal in nature (87%), while NO_3^-–N was predominant (83%) in the mixed-species percolate. Accordingly, NO_3^-–N concentrations were generally higher in the mixed-species percolate with peaks following fertilization events. The mean NO_3^-–N concentrations in the mixed-species percolate ranged from <0.2 to 15.2 mg L^{-1} with an overall mean concentration of 1.46 mg L^{-1}. In contrast, mean NO_3^-–N concentrations in the St. Augustinegrass percolate never exceeded 0.4 mg L^{-1}, resulting in an overall mean concentration <0.2 mg L^{-1}.

DISCUSSION

Fertilizer N management practices on residential landscapes are important with respect to maintaining both vigorous landscape vegetation and environmental quality. The fate of fertilizer N in a landscape system involves plant uptake, soil storage, atmospheric loss (denitrification and NH_3 volatilization), runoff, and leaching (Petrovic, 1990). Atmospheric loss, surface runoff and deep percolation losses of applied N means a loss to the growing vegetation, an economic loss to the homeowner, and potential adverse environmental impacts. Therefore, the obvious goal when fertilizing any landscape is to immobilize fertilizer N in the landscape system through plant uptake and soil storage. The data presented in this paper are intended to provide some quantitative information regarding fertilizer N runoff and leaching needed to assess the potential for adverse environmental impacts from newly planted contrasting residential landscapes.

Nitrogen losses from surface runoff were insignificant from both landscape types even with a 10% slope and frequently intense rainfall. This provided valuable information regarding the surface runoff of nutrients from sandy soils in a subtropical climate. These results corroborate previous research conducted under temperate environmental conditions in which minimal surface runoff from cool-season turfgrasses was observed (Gross et al., 1990; Morton et al., 1988).

While surface runoff was insignificant from either treatment, more than 30% of applied fertilizer N was leached from the mixed-species. In contrast, very little N (<2%) leached from the St. Augustinegrass. The large differences in N leaching between the landscape treatments were seen in all three cycles across varying environmental conditions. Thus, it appears that the applied N behaved quite differently between the treatments during the first year of this study. Atmospheric N loss was not measured, so it is possible that atmospheric loss was greater from the turfgrass treatment, accounting for the differences observed. However, it seems more likely that the differences were in soil–thatch storage and plant uptake because management practices were used that have been shown to minimize gaseous loss, such as irrigation following fertilizer application and a 40% slow release fertilizer source (Bowman et al., 1987; Kelling and Peterson, 1975; Petrovic, 1990). Turfgrasses respond rapidly to applied N and are relatively efficient at N uptake (Cixar et al., 1985; Star and DeRoo, 1981). We speculate that the St. Augustinegrass sod system was more efficient than the mixed-species landscape at retrieving applied N during the study period, due in part to the complete vegetative cover of the grass and dense rapid adventitious rooting into the substrate. The mixed-species plant materials were well rooted at planting, but the density of the plantings was less than the turfgrass as the ornamental landscape was designed for growth with time.

In addition to reduced vegetation density, the results reflected a longer establishing period required by the mixed-species landscape. For example, significantly greater percolate volume and reduced ET (similar dry season conditions) were seen on the mixed-species treatment immediately following planting (Cycle 1) relative to the end of the study. Furthermore, NO_3^-–N concentrations in the percolate were substantially elevated for several weeks following the initial fertilization on the mixed-species landscape.

Nutrient losses were most severe during the first cycle, however, significantly greater N losses on the mixed-species occurred throughout the study. Large pulses of leached inorganic N were observed on the mixed-species treatment following each fertilization event. This post-fertilization pulse in N leaching occurred to a much lesser degree on the turfgrass, again suggesting differences in vegetative uptake or soil storage (Fig. 3). Still, the quantities of N leached from the mixed-species treatment probably could be reduced. Inorganic N losses in the percolate have been related to N source and rate, precipitation and irrigation, vegetation, soil properties, and timing of fertilization (Petrovic, 1990). Growth and vigor of St. Augustinegrass with respect to N has been well studied (Cisar et al., 1991). However, clear management practices for maintaining the mixed-species landscape as a whole were not well developed because of the complexity (e.g., palms, woody shrubs, and herbaceous species) of the landscape and the relative infancy of the FYN program. While it is possible that too much fertilizer was applied to the mixed-species landscape, visible signs of nutrient stress, such as stunted growth and chlorotic leaves were seen on several of the species, most notably the liriope [*Liriope muscari* (Dcne.) Bailey], firebush (*Hamelia patens* Jacq.), and thyrallis (*Galphimia glauca* Cav.). Therefore, a reduction in the rate of fertilizer and more frequent applications might reduce the N leaching we observed while increasing plant vigor. Another possibility would be to consider organic soil amendments that release N much slower than the fertilizer blend used in this study.

In this study, we tested the hypothesis that fertilizer N runoff and leaching would be statistically equal between the two newly established contrasting landscape types. The results of the study showed that St. Augustinegrass was efficient at retrieving applied N and minimizing N leaching, despite relatively high fertilizer N requirements. In contrast, significantly greater N losses in the percolate were observed from the alternative mixed-species landscape during first-year establishing conditions. Therefore, we rejected the hypothesis that there would be no difference in N pollution between the two contrasting landscape types. In summary, the data indicated that adverse environmental impacts associated with N pollution are minimal from properly established St. Augustinegrass landscapes. In addition, while alternative landscapes may currently offer other environmental benefits such as wildlife habitat, further research on plant selection and fertilizer management practices for the landscape at a lawn scale are needed to minimize their environmental impact via N leaching during establishing conditions. Finally, continued monitoring of both landscapes through time is needed and will provide valuable data regarding N runoff and leaching from well-established landscapes.

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Comparative Responses of Two Kentucky Bluegrass Cultivars to Salinity Stress

Y. L. Qian,* S. J. Wilhelm, and K. B. Marcum

ABSTRACT

Little information is available concerning physiological responses of Kentucky bluegrass (*Poa pratensis* L.) (KBG) cultivars to salinity. Growth and physiological responses of 'Limousine' and 'Kenblue' KBG to a range of salinity levels were investigated. Grasses were grown in solution culture and exposed to salinity levels of 2.2, 5.2, 8.2, 11.2, and 14.2 dS m^{-1} for 10 wk. Though both cultivars exhibited increased leaf firing with increasing salinity, Limousine exhibited less leaf firing than Kenblue at salinity levels above 5.2 dS m^{-1}. In addition, salinity levels that caused 25% shoot growth reduction were 3.2 dS m^{-1} for Kenblue and 4.7 dS m^{-1} for Limousine, indicating that Limousine has better salinity tolerance. Under moderate (8.2 dS m^{-1}) salinity stress, Limousine produced ~50% more root growth than Kenblue. Water relations diverged between cultivars at 8.2 and 14.2 dS m^{-1}, as Limousine had higher leaf water and osmotic potentials, as well as more positive turgor. While glycinebetaine was not detected in either cultivar, proline increased in leaves with increasing salinity, and was higher in Kenblue than Limousine at 8.2, 11.2, and 14.2 dS m^{-1}. This suggests that compatible solute accumulation is not a salinity tolerance mechanism of KBG, and that proline accumulation is merely an indication of salt injury. Limousine maintained 52% lower shoot Na^+, 30.4% lower Cl^-, and 52% higher shoot K^+/Na^+ ratio than Kenblue at the highest salinity level. These results suggest that salinity tolerance in KBG is largely attributable to maintenance of higher root growth, and more positive turgor, higher K^+/Na^+ ratio, and less Cl^- accumulation in shoots. These traits may serve as useful selection criteria in breeding efforts to develop salt tolerant KBG.

SALT PROBLEMS are of great concern in arid and semiarid regions, where soil salt content is naturally high and precipitation is insufficient for leaching. With accelerated urban development in western states, turf is increasingly grown on soils where salinity problems already exist, or may develop subsequently from the use of saline irrigation water. One of the most efficient methods of improving turfgrass growth in salt-stressed situations is to use salt tolerant species and/or cultivars. Though KBG is the most widely used cool-season turfgrass in the USA (Christians, 1998), it is considered to be salt-sensitive, reported to tolerate less than 4 dS m^{-1} soil salinity (Butler et al., 1974; Harivandi et al., 1992). In previous studies, cultivar Limousine suffered substantially less leaf firing under saline conditions than did Kenblue (Qian, unpublished results). Limousine, released by Jacklin Seed in 1992, is classified as an aggressive KBG that exhibits compact vertical growth, but aggressive lateral growth. Because of its aggressive lateral growth, Limousine tolerates close, frequent mowing, and is frequently used on golf course fairways in temperate climates. Kenblue, released in 1967 by the Kentucky Agricultural Experiment Station, is a Common-type (Midwest ecotype) KBG that has a relatively fast shoot elongation rate and low density.

Salt tolerance in plants is a complex phenomenon involving morphological, physiological, and biochemical processes (Jacoby, 1999). Salinity tolerance mechanisms of KBG have not been elucidated. Comparing growth, morphological, and physiological responses of KBG cultivars having different salinity tolerances may aid in defining salt tolerance mechanisms and identifying criteria for breeding salt resistant KBG cultivars.

Objectives of the present study were to (i) compare plant growth, water potential components, ion content, and compatible solute content of a salt-sensitive (Kenblue) vs. a salt-tolerant (Limousine) KGB cultivar across a range of salinity levels and (ii) examine growth and physiological characteristics that might relate to variability in KBG salinity tolerance.

Y.L. Qian and S.J. Wilhelm, Dep. of Horticulture and Landscape Architecture, Colorado State Univ., Fort Collins, CO 80523-1173; K.B. Marcum, Dep. of Plant Sciences, Univ. of Arizona, Tucson, AZ 85721-0036. Received on 31 Oct. 2000. *Corresponding author (yaqian@lamar.colostate.edu).

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Abbreviations: Kentucky bluegrass, KBG.