The Effect of Salinity on Nitrate Leaching from Turfgrass

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Column lysimeters planted to tall fescue or bermudagrass used to collect leachate in the greenhouse portion of the study.

SOIL SALINITY is a problem in the western United States due to the occurrence of soluble salts in many desert soils and irrigation with moderately saline water. In southern Nevada, irrigation has leached native salts below the root zone, creating a perched saline aquifer estimated at approximately 100,000 acre feet. Having an electroconductivity (EC) of 9 dS m^{-1} (approximately one fifth of seawater), this aquifer represents a potential threat to the deeper primary aquifer. As a resource, however, this aquifer contains enough water to satisfy the irrigation needs of many of the existing golf courses in Las Vegas for the next 20 years. If properly managed, this water supply could be used as an alternative or supplemental irrigation source, decreasing the demand on high-quality water while reducing the potential for contamination of the primary aquifer.

One concern about the use of saline water for turf irrigation, and the focus of our study, is that salinity might increase nitrate (N) leaching from turf. Since nitrogen is the most heavily used nutrient in turfgrass management, this concern is justified. In the case where N application exceeds the ability of the turfgrass to absorb the nitrogen, excess N could move from the soil-plant system into water supplies. The degradation of lakes and streams, the possible permanent contamination of groundwaters, and possible health hazards related to waters high in nitrate are all consequences of inefficient or improper use of nitrogen fertilizers.

Numerous studies have documented the effects of environmental factors and management practices on nitrate leaching from turfgrasses. For example, Brown et al. (2) measured concentrations of nitrate as high as 74 ppm N in the leachate below bermudagrass following application of ammonium nitrate, with total leaching loss of 23% of the applied N. For comparison, 10 ppm NO_3-N is considered the maximum for safe drinking water. Snyder et al. (9) found peak NO_3-N concentrations between 20 and 40 ppm N in

Table 1
Nitrogen Uptake Efficiency for Tall Fescue and Bermudagrass at Three N Application Rates

Efficiency is calculated as average daily N removed in clippings (based on regression analysis) divided by the average daily N addition (monthly divided by 30, amounting to 1.52, 3.03, and 4.55 mg N/column/day for the low, medium, and high N rates, respectively).

Species	N Rate	N Removed in Clippings (mg N/column/day)	N Uptake Efficiency
Tall Fescue	Low	1.38	93
	Medium	2.30	77
	High	3.31	74
Bermudagrass	Low	1.42	95
	Medium	2.60	87
	High	3.68	82

the soil solution below the turf rootzone 5 to 10 days after applying 1 lb N/1000 sq ft as NH_4NO_3. Up to 56% of the applied N was lost during a 3-week period. However, minimizing the downward movement of water by carefully controlling irrigation with tensiometers reduced losses from 56% to 2% (10).

In contrast to these findings, Rieke and Ellis (8) reported little effect of fertilization on nitrate leaching following application of 6 lbs N/1000 sq ft per year to a mixed turf. Starr and Deroo (11) found similar low leaching losses. Mancino and Troll (7) investigated nitrate leaching from a creeping bentgrass turf under conditions favoring heavy leaching losses (sand rootzone, soluble nitrate-based fertilizers, and 46% leaching fraction). When the fertilizers were applied weekly at a rate of 0.2 lb N/1000 sq ft, nitrate leaching averaged less than 0.5% of the applied nitrogen. Even at the rate of 1 lb N/1000 sq ft, cumulative losses averaged only 3.5% for the nitrate sources. Gold et al. (6) reported a maximum flow-rated NO_3 concentration of 1.62 ppm N in the leachate from a home lawn fertilized with 5 lbs N/1000 sq ft per year. Approximately half of the leachate samples had NO_3 concentrations at or below 0.1 ppm N. Cohen et al. (3) monitored NO_3-N in wells at four golf courses on Cape Cod over a two-year period. Nitrate concentrations in the shallow groundwater increased over background in response to turfgrass fertilization at three of the four courses. However, average concentrations were all below 10 ppm NO_3-N. Bowman et al. (1) presented data indicating that rapid biological immobilization, both by the turf and soil microorganisms, may reduce leaching losses by limiting the period of time that the fertilizer N is resident in the soil. However, no studies have investigated the effects of salinity on nitrate leaching.

Since salinity inhibits nitrogen uptake in a number of species, the use of saline irrigation water on turfgrasses could increase nitrate leaching and contamination of groundwaters. The objectives of this research were 1) to determine the effects of salinity and N application rate on nitrate leaching and N mass emission from turfgrass under greenhouse conditions, and 2) to determine the effects of salinity and leaching fraction on nitrate leaching and N mass emission from a bermudagrass and tall fescue turf under field conditions.

Two experiments were conducted to examine the effects of salinity on NO_3 leaching from turfgrasses. The first was a greenhouse study conducted from February through December, 1992, to address the objectives under tightly controlled environment conditions. Monarch tall fescue and NuMex Sahara bermudagrass were grown in PVC columns filled with a loamy sand and outfitted with a vacuum sampling system to collect drainage. Treatments consisted of three N levels (0.5, 1, and 1.5 lbs N/1000 sq ft per month applied as NH_4NO_3) and three irrigation salinity levels (ECs of 0, 1.5, and 3 dS m^{-1} for tall fescue and 0, 3, and 6 dS m^{-1} for bermudagrass) in a 3 × 3 factorial arrangement. The salinity ranges were chosen as being potentially stressful but non-lethal. Irrigation was scheduled twice each week to provide a relatively high leaching fraction of 30%. This leaching fraction was imposed to rapidly equilibrate rootzone salinity while increasing the potential for NO_3 leaching. Leachate was collected after every irrigation and analyzed for salts and NO_3-N. Clippings were collected and analyzed for total N.

Salt content of the leachate rose steadily during the first four months of the experiment and then leveled off, indicating that a constant salt profile had been attained. Leachate ECs for the 0.1, 1.5, 3.0, and 6.0 dS m^{-1} salt treatments stabilized at approximately 0.3, 4.5, 9, and 15 dS m^{-1}, respectively. These values are close to those predicted based on a leaching fraction of 30%.

Total monthly irrigation data for the April through September period were used to examine the effects of N and salinity on irrigation requirement. In both grasses, the high salinity treatments reduced irrigation by 9% compared to the low salinity treatments, whereas high N increased irrigation 10-14% relative to low-N treatments. Similar effects of N rate (4) and salinity (5) have been reported for water use by bermudagrass turf.

Average monthly NO_3-N concentrations in the leachate ranged from less than 0.1 to 1.2 ppm N in the bermudagrass (Figure 1) and from less than 0.1 to 3.3 ppm in the tall fescue (Figure 2). Highest NO_3 concentrations occurred during February and April, whereas consistently low values were found from June through December. Since the two grasses were growing slowly during late winter/early spring, the high values could be due to a lower growth demand for N. Expressing the NO_3-N concentration as an average based on the total volume of leachate, approximately 0.2-0.25 ppm N is calculated for the bermudagrass leachate and 0.75-1.0 ppm N for the tall fescue leachate. When compared to the tap water, which contained 0.1-0.2 ppm NO_3-N, it is apparent that N applied to bermudagrass contributed very little to net NO_3 leaching. While greater amounts of applied N leached from the tall fescue, the average concentrations were very low, considerably below the critical 10 ppm N level. There were no obvious effects of either salinity or N application rate on the concentration of NO_3 in the leachate from either grass. Significantly, of the nearly 2100 samples analyzed during this study, none was above the critical level of 10 ppm N. These data are consistent with previous results demonstrating the ability of turfgrass systems to rapidly immobilize applied N (1) but further suggest that the N uptake systems of turf roots and associated microorganisms were not appreciably impaired by the moderate salinity levels used in this study.

Cumulative nitrate-N leached over the 11-month experimental period amounted to approximately 10 mg N/column for the tall fescue and 2-3 mg N/column for the bermudagrass, representing 1.0% and 0.3% of the applied N, respectively. This does not consider the amounts of N present in the irrigation water. Much of the total loss occurred during March through May, with very little additional loss recorded thereafter. This pattern was probably due to the unintentionally high volumes of leachate collected during March and May. Again, there was no apparent or consistent effect of salinity or N application rate on nitrate leaching in either species.

Clipping dry weight and percent N in the tissue were used to calculate the amount of N partitioned to leaf tissue and removed in clippings (Table 1). Nitrogen removal increased with increasing N application rate, but there was no effect of salinity. The average daily N allocations to leaf tissue

Figure 1
Monthly Average NO_3 Concentration in the Leachate from Bermudagrass Turf (Study 1) Fertilized with Three Rates of N and Irrigated with Three Levels of Salinity

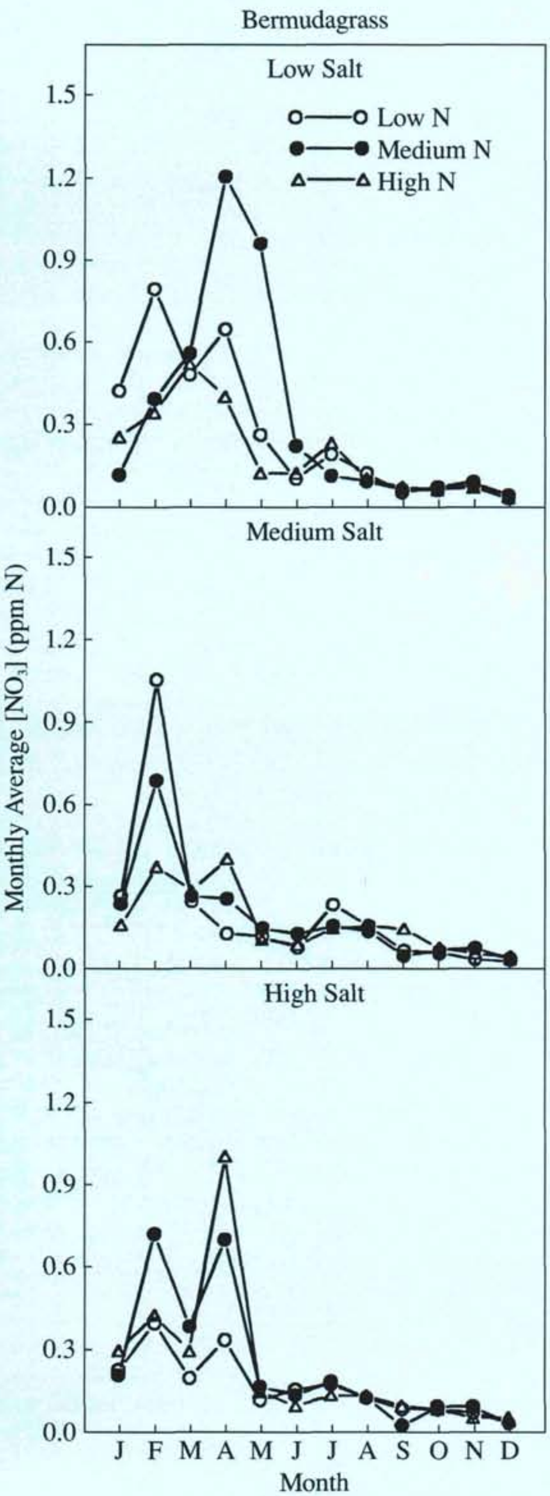
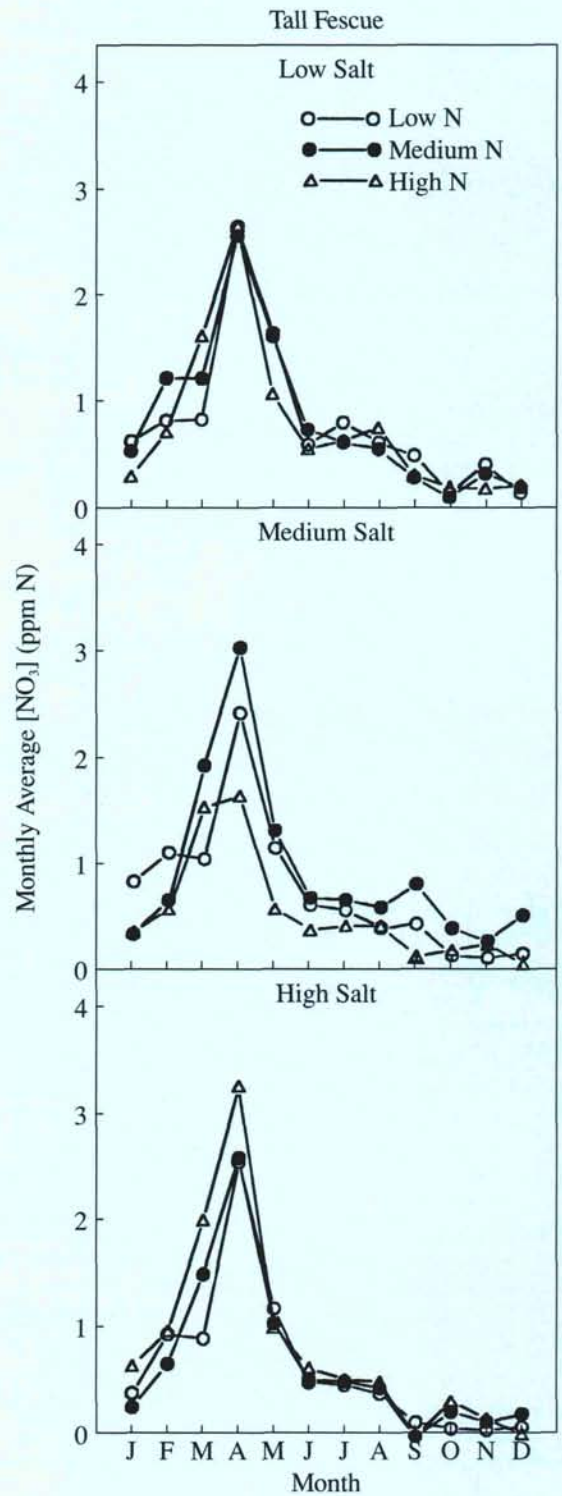


Figure 2
Monthly Average NO_3 Concentration in the Leachate from Tall Fescue Turf (Study 1) Fertilized with Three Rates of N and Irrigated with Three Levels of Salinity



were compared to the N addition rates and used to estimate long-term uptake efficiency. Uptake efficiency decreased in both turf species with increasing N rate (Table 1). At the low N rate, N recovery in clippings was greater than 90% for both species, whereas at the medium and high N rates, bermudagrass clippings contained approximately 10% more of the applied N than the tall fescue clippings. These values indicate very efficient absorption of applied N by the turfgrasses, and suggest that over the long term, a mature turf allocates most acquired N to new leaf tissues. It must be considered that this research was performed on a young turf system with clippings removed, and in which very little soil organic N is likely to have accumulated. Consequently, mineralization of organic N would supply little N to the turf. If mineralization of soil organic N contributed significantly to the N nutrition of the turf, as might be the case in an older turf system, it is probable that additional applied N would not be absorbed as efficiently. Under such conditions, NO_3 leaching might be higher than found in this study.

The results of the first study indicate that irrigation of tall fescue and bermudagrass turf with moderately saline water should not increase NO_3 leaching as long as adequate leaching prevents salts accumulating to toxic levels in the root zone. Measures of growth, such as clipping production or N allocation to leaf growth, were not affected by moderate salinity. This indicates that the grasses were under relatively low stress, and may explain why there was no effect of salinity on NO_3 leaching. If salinity stress were greater, or if multiple stresses were imposed, it is possible that N use efficiency would decline and NO_3 leaching increase. This question is addressed in the field study discussed next.

The second phase of this project was conducted from April 1991 through December 1993 at Horseman's Park, Las Vegas, to examine the effects of salinity and irrigation regime on NO_3 leaching from turfgrasses. This was part of a larger study examining the individual and combined effects of nitrogen application rate, salinity, and drought on turfgrass performance. The plot area measured 131 by 220 ft, with half planted to bermudagrass and half to tall fescue. The present study was confined to those sub-plots at the east and west end of the field receiving NH_4NO_3 at the rate of 1 lb N/1000 sq ft per month.

Seed of NuMex Sahara bermudagrass and Monarch tall fescue was sown June 3-7, 1991, at 1 lb and 8 lbs/1000 sq ft, respectively, and the turfgrasses established by accepted procedures. Good quality water (EC less than 1.0 dS/m) was used to irrigate the turfgrass during establishment. Bermudagrass was overseeded with Palmer Prelude perennial ryegrass (*Lolium perenne* L.) in early October.

A linear gradient irrigation system (LIGIS) supplied the irrigation treatments, with a gradient ranging from 125% of potential evapotranspiration to 0. Briefly, 6 parallel irrigation lines were installed 44 feet apart, with heads spaced at 22 feet (double overlap) on each line. The three lines at the east end of the field supplied good quality municipal water while the three lines at the west end supplied saline water (during turf establishment all lines supplied fresh water). Water from the saline aquifer was blended with fresh water to an EC of 6.0 dS m^{-1} and stored in an on-site reservoir from which it was pumped for irrigation. The established turf was irrigated with all lines for 10 months of the year. The irrigation gradient treatment was imposed for a 60-day period beginning July 8, 1992, and July 7, 1993, by shutting off the outside irrigation line on both the freshwater (east) and saline water (west) sides of the plot. This provided a water gradient on the fresh side and a combined water/salt gradient on the saline side. The experiment thus consisted of four separate treatment combinations, with two species and two salinity levels combined in a factorial arrangement. Outside irrigation lines were turned on again after the 60-day treatment period, reestablishing constant volume irrigation across the plots. Irrigation was scheduled 3 to 5 days per week to supply 125% of tall fescue ET.

Prior to planting, lysimeters (20" diameter by 43" deep) were installed at ground level either close to the gradient irrigation line (full irrigation, non-stressed) or toward the outside of the gradient (deficit irrigation, drought stressed). Lysimeters were equipped with suction extraction cups buried at the bottom. After each irrigation, a vacuum was applied to the extraction cups to collect leachate. Leachate samples were then analyzed for NO_3 concentration, with mass emission of nitrogen calculated as the product of concentration and volume. Total N content of clippings was used to estimate nitrogen absorption by the plant.

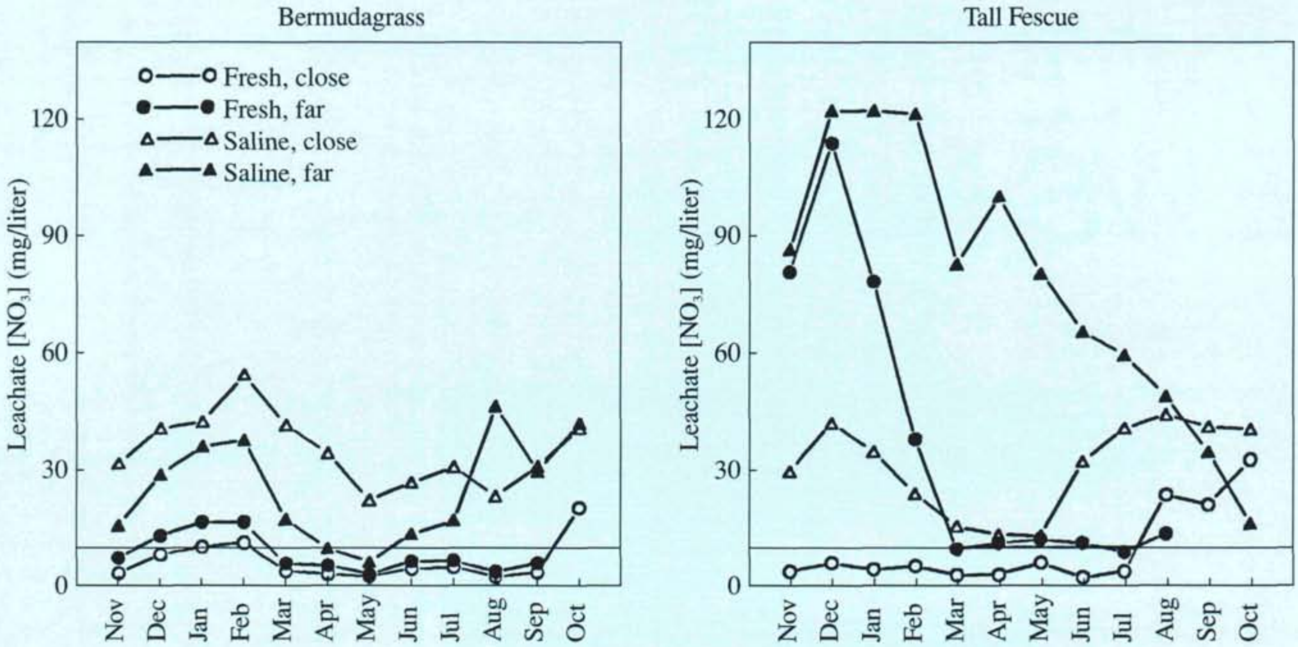
The data presented are from the second year of measurements and represent the more significant leaching data in terms of concentration and amount. However, it is helpful to understand the condition of the turf following the first year of treatment. Turfgrass growing in the lysimeters receiving adequate irrigation did not exhibit stress symptoms during the 60-day dry-down period. Bermudagrass irrigated with fresh water but growing in the outside lysimeters (drought stressed) was significantly impaired by water deficit, with considerable thinning to approximately 25% cover going into the fall of 1992. The combined stresses of drought and salinity (outside lysimeters, saline water) had a similar effect on the bermudagrass, with 25% cover at the end of the 1992 growing season. Tall fescue in the outside lysimeters was severely affected by both drought and the combined stresses to the extent that very few if any individual plants survived the 60-day stress period. Consequently, the outside lysimeters were sodded in late October, 1992, to reestablish the turf.

Nitrate leaching from bermudagrass irrigated with fresh water peaked during January and February, 1993, with concentrations exceeding 10 ppm N (Figure 3, left). It must be noted that the bermudagrass was dormant during this period, and it is unlikely that the overseeded perennial ryegrass had developed an extensive root system. From March through September, leachate NO_3 concentrations from bermudagrass irrigated with fresh water were low, ranging from 2 to 6 ppm N. Salinity increased NO_3 concentrations in the leachate up to 6 fold, with the highest values measured in February and then again in August and October. The highest NO_3 concentrations (nearly 60 ppm N) were associated with the inside saline lysimeters (adequate irrigation), although the bermudagrass appeared healthy and under little stress. It is possible that salinity affected rooting depth or density without appreciably inhibiting shoot growth, thus reducing plant uptake and increasing leaching potential.

The monthly pattern of NO_3 leaching from tall fescue differed from that of bermudagrass (Figure 3, right). Nitrate concentrations were generally low in turf irrigated with adequate amounts of fresh water. Concentrations were higher in turf irrigated with adequate amounts of saline water, with peaks during December, 1992, and then again in late summer, 1993. In both cases, the turf appeared to be under little stress. However, it is possible that heat stress alone or in combination with salinity affected either root activity or shoot demand for N, resulting in lower N absorption and greater leaching.

Very high NO_3 concentrations (up to 120 ppm N) were found in the outside lysimeters (drought stress) during the winter months, regardless of water quality. However, it must be remembered that the turf in these lysimeters died in 1992, and the new sod likely had not developed a deep root system. Further, monthly N applications continued in spite of the turf condition. Coupled with mineralization of the dead root system, it seems likely that there was considerable inorganic N present in the soil. This N would be easily leached when full irrigation was reestablished. Nitrate concentrations from the outside lysimeters irrigated with fresh water declined rapidly during January

Figure 3
Monthly Average NO_3 Concentration in the Leachate from Bermudagrass (left) and Tall Fescue Turf (right) for Inside and Outside Lysimeters Irrigated with Fresh or Saline Water in Study 2



through March, leveling off at approximately 10 ppm N. This may reflect the establishment of a deeper root system in the newly sodded turf, resulting in more efficient N absorption. Concentrations also declined in the outside lysimeters irrigated with saline water, but at a much slower rate. Again, the decline in concentration may be due to new root growth and better N absorption by the tall fescue. The slower rate of decline might indicate that rootzone salinity was restricting normal root growth or that N absorption was affected directly.

Mass emission of NO_3 was calculated based on the average daily N application rate and expressed as N leached relative to applied. Over the course of 1993, approximately 15-25% of the applied N leached from bermudagrass irrigated with fresh water, while 75-100% of the applied N leached from the saline treatments. This compares to approximately 5% of the applied N leaching from the inside, freshwater lysimeters planted to tall fescue. However, salinity alone or in combination with drought increased leaching from the tall fescue to 30-100% of applied N.

Comparing the results of the field study with the greenhouse column study, it is apparent that much higher concentrations and amounts of NO_3 are leached under the field conditions. This may be the result of higher rootzone salinity in the field, the severe impact of drought, or both. Based on growth data, the turf in the greenhouse study was under very little stress, in spite of soil solution salt concentrations approaching 9 and 18 dS m^{-1} for the tall fescue and bermudagrass, respectively. These salt concentrations, however, are low to moderate compared to those developing in the field under deficit irrigation (in excess of 40 dS m^{-1}). Collectively, the data suggest that where rootzone salinity is maintained at moderate levels and in the absence of other stresses, NO_3 leaching from turf is unlikely to be a concern. However, where salts build up in the soil to high levels, or when other stresses such as drought or heat are limiting turf growth, NO_3 leaching may be a very serious problem. Under such conditions, careful fertilizer and irrigation management may help to reduce the potential for NO_3 contamination of groundwater.

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