EXECUTIVE SUMMARY – NUTRIENT LEACHING

PROJECT 1 – NITRATE LEACHING FROM NEWLY SODDED GRASSES

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. Generally, research suggests that leaching losses are greatest during establishment periods due to the lack of an extensive root system capable of mining applied and antecedent nutrients and the increase in irrigation typically applied to the establishing turf.

In our work across all three locations, we consistently observed increase nitrate-N leaching immediately following the installation of the new sod – often even before any fertilizer was applied.

In south Florida, seasonality may have influenced results. Trials 1 and 3 (March – May) bracketed an active growth period for St. Augustinegrass. During these two trials, 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 day after initiation (DAI). Conversely, Trial 2 (September – November) corresponded to a less active growth period. Perhaps at this time, the turfgrass was less resource efficient, which may explain the higher nitrate-N concentrations and greater leaching due to fertilizer treatments documented during the 31-60 DAI.

Though phosphorus application rate was not a treatment in these "Newly Sodded Grass" studies, in Ft. Lauderdale a 6-6-6 fertilizer was applied and percolate was analyzed for orthophosphate. During the three trials conducted in Ft. Lauderdale, orthophosphate concentrations during the first half of the trial ranged from 0.02 to 7.46 mg l^{-1}, which exceeds the EPA criteria of 0.05 mg l^{-1} for stream discharge into lakes or reservoirs (USEPA, 1986). Similar to nitrate-N leaching, orthophosphate leaching was greater during the first 30 days of the experiments compared to the second 30 day time period. Additionally, during this time, less orthophosphate leaching from the St. Augustinegrass maintained with the ALT irrigation schedule (0.25 inch twice daily for 30 days, then 0.50 inch every other day for 30 days) and fertilized at 30DAI compared to the St. Augustinegrass not fertilized, or fertilized at 0DAI.

In central Florida, research was conducted to determine the extent of nitrate–N leached from newly sodded St. Augustinegrass and zoysiagrass due to applied N rate and irrigation. Nitrogen was applied at various rates on day of sodding and half of the plots received additional treatments 30 days after planting. During these studies, it was observed that nitrate-N loads ranged from 20.3 to 64.8% of applied N from St. Augustinegrass and 21.3 to 74.9 from zoysiagrass. Averaged across all treatments, delaying fertilization of new sod for at least 30 days resulted in a 23 – 34% reduction in nitrate-N leaching. Therefore, it is recommended that no nitrogen be applied to these species following sodding for a minimum of 30 and up to 60 days after planting.

In north Florida the predominant lawn grass is centipedegrass and it can be established from seed or sod. As such, we looked at nitrate-N leaching from both establishment methods in separate studies. Fertilizer was applied at three different rates prior to the time of seeding or sodding (PTS) or 30 days after seeding or sodding (DAS). In the seeded studies, fertilizer application timing and N rate did not influence seedling density (i.e., rate of establishment). Furthermore, there were no significant differences between the total nitrate-N leached regardless of when the nitrogen was applied or the rate applied. When combined across the two trials, 48% of the applied N leached when applied PTS and 38% of applied N leached when applied 30 DAS – although this is not significantly different.

During the initial centipedegrass sod establishment study, no differences in nitrate-N leaching were attributed to N application timing or rate. When applied PTS, only 2.1% of applied N leached versus 1.4% of applied N leached when applied 30 DAS. During the second study 187% of applied N leached when applied PTS and 161% of applied N leached when applied 30 DAS – a 16% increase in plots receiving fertilizer PTS versus plots receiving fertilizer 30 DAS. The profoundly different results between the two experiments are likely attributed to total rainfall and evapotranspiration (ET) levels. During the first sod establishment experiment, 102mm (4.02") of rain fell during the 60 day experiment and the total ET was 224 mm (8.83"). Leaching events were not prevalent during Trial #1. During the second experiment, abnormally high leaching events were observed due to rainfall exceeding ET nearly 2:1.

Key Findings:

- Results of this research indicate that N fertilization should be withheld for a minimum of 30 to 60 days after sodding to reduce potential nitrate-N leaching. Higher leaching rates are due to lack of a root system following harvest and greater soil mineralization.
- There were few differences in nitrate-N leached due to irrigation rate
- Orthophosphate leaching was greater during the first 30 days of the experiments compared to the second 30 day time period and is likely attributed to the increase in rooting of the newly laid sod.
- Fertilizer timing and N rate did not influence the speed of centipedegrass establishment from seed.

PROJECT 2 – NITRATE LEACHING FROM ESTABLISHED GRASSES

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, N source, irrigation management, maturity of the grass, and root architecture. Current N fertilization recommendations for maintenance of lawn grasses in Florida are geographically based to account for differences in the length of the growing season. These regions are "North Florida" defined as everything north of Ocala; "Central Florida" defined as south of Ocala extending from Vero Beach to Tampa; and "South Florida" which includes the remaining portion of the

state. Furthermore, within each region, a range of fertility rates (basic – moderate – high) are defined for each species commonly grown in Florida.

Given that Florida currently has regulations at both state and local levels regarding fertilization of lawngrasses and due to a lack of nitrate-N leaching data on the lawngrasses, this research was undertaken as part of a larger project to obtain specific information for Best Management Practices (BMP) verification on nitrate-N leaching as a result of lawngrass fertilization. The objectives of this research were to evaluate total nitrate-N leaching and turf response from a wide range of N rates and from two different irrigation regimes.

At Ft. Lauderdale, four N rates (sprayed urea) were applied to both St. Augustinegrass (98, 196, 294, and 588 kg N ha^{-1} yr^{-1}) and bahiagrass (49, 98, 196, and 294 kg N ha^{-1} yr^{-1}). Additionally, the turf was maintained under 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).

Irrigation regime had no effect on nitrate-N leaching in both St. Augustinegrass and bahiagrass. The climate of south Florida is broadly characterized as having an extended wet and dry season period. The first three 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 three cycles bracketing the wet season with over 60% of the total rain. The low irrigation rate accounted for approximately 800 mm and the high irrigation rate supplied over 1900 mm of water. As a result, there was significantly more percolate for the high irrigation throughout the year for both turfgrasses. Increasing N rate reduced percolate for three of the six cycles in St. Augustinegrass but not in bahiagrass presumably due to greater vigor and density as increased amounts of N were applied to plots.

In both for years 1 and 2, St. Augustinegrass and bahiagrass no significant differences were observed between the rate of N applied and the amount of N leached. Overall N concentrations and N leaching regardless of treatment were very low. For example, at the highest N rates (294 and 588 kg N ha^{-1}) in St. Augustinegrass, N leaching was approximately 0.03% and 1.1%, respectively of that applied. For bahiagrass, percent leached was 0.05% and 0.03% for the 196 and 294 kg N ha^{-1} rates, respectively. Nitrate concentrations were generally less than 0.1 mg L^{-1} with a few exceptions.

For both years, N rate significantly affected quality, color, and density in both St. Augustinegrass and bahiagrass. In both studies, quality, color and density increased with increasing N rate. For St. Augustinegrass, fertilization of 196 kg N ha^{-1} yr^{-1} was required to sustain at least minimally acceptable adequate turf quality throughout the duration of a fertilization cycle. For bahiagrass 49 kg N ha^{-1} yr^{-1} was capable of sustaining adequate turf quality for the duration of a cycle during the experiment

In central Florida, N was applied at annual rates of 32, 64, 128, and 196 kg ha^{-1} in 2005 and at 49, 196, 343, or 490 kg ha^{-1} in 2006 and 2007 to St. Augustinegrass and zoysiagrass. Irrigation treatments consisted of 1.3 cm (1/2”) applied twice weekly or 2.6 cm (1”) applied once weekly.

In general, nitrate-N leaching was greater from zoysiagrass. In 2007, annual nitrate-N leached varied due to the interaction of N rate, irrigation rate, and species. There was little association between N rate and increased nitrate-N leaching in St. Augustinegrass in any year. While St. Augustinegrass had no differences in nitrate-N leached within N rate due to irrigation rate, there were some differences in leaching from zoysiagrass at some N levels, with greater nitrate-N leached from the more frequent irrigation regime.

Zoysiagrass receiving the higher rates of applied N had an increased presence of Large Patch (*Rhizoctonia solani* J.G. Kuhn) causing significant deterioration in turf health. This deterioration led to increased nitrate-N leaching. Maintenance of a healthy turfgrass cover is an important strategy for reducing potential nutrient movement from fertilizer application. The currently recommended rates for St. Augustinegrass provide good turf cover and health and result in minimal nitrate-N leaching. Zoysiagrass N rates may need to be revised downward to reduce disease, improve turf cover and reduce nitrate-N leaching.

In north Florida, N was applied at annual rates of 32, 64, 128, and 196 kg ha-1 in 2005 and at 49, 196, 343, or 490 kg ha-1 in 2006 and 2007 to St. Augustinegrass and centipedegrass. Irrigation treatments consisted of 1.3 cm applied twice weekly or 2.6 cm applied once weekly. irrigation rate had little effect on nutrient leaching across the three years of research. More nitrate-N leaching occurred in the inaugural year of the study – most coming from nutrient import with the new sod. The winter of 2006 through spring 2007 produced an appreciable level of winter injury which resulted in increasing levels of nitrate-N leaching. N applied at 98 kg ha^{-1}(single application) numerically yielded greater nitrate leaching from St. Augustinegrass compared to rates ≤ 65.17 kg ha-1 (single application).

Centipedegrass leached less N than did St. Augustinegrass. As was observed with St. Augustinegrass, the inaugural year yielded more nitrate-N leaching and is attributed to nutrient import on the new sod. Irrigation rate did not influence nitrate-N leaching.

Key Findings:

- Maintenance of a healthy stand of turfgrass mitigated NO_3-N losses from all species, particularly St. Augustinegrass, even at high rates of applied N. Where grass was not healthy or did not provide good cover, NO_3-N losses were much higher and increased as rate of applied N increased.
- There were few differences in NO_3-N losses in response to irrigation at the rates tested here.
- NO_3-N losses were greater from zoysiagrass than from St. Augustinegrass in Citra and greater from St. Augustinegrass than from centipedegrass in Jay.
- Zoysiagrass is susceptible to large patch at high N rates, resulting in turf injury and high NO_3-N losses at the high rates. The currently recommended rates for zoysiagrass fertilization should be revised downwards to reflect this. This can especially contribute to NO_3-N losses in the spring, when the disease tends to be prevalent in conjunction with the slower spring green-up that this species typically has.

- The south Florida results suggest that bahiagrass N fertilization rates could also be reduced.
- In general, once grass was established, NO_3-N losses were lowest during the summer growing period than they were in spring and fall. In the spring, root growth is typically still developing in the spring, which may account for greater NO_3-N losses. In the fall, growth (both shoot and root) begins to taper off, which may also account for greater leaching.
- Long term fertilization with extremely high rates of N results in greater turf injury and disease and therefore greater NO_3-N losses. This was clearly seen in Citra in both species in the high end plots by year 3 in the plots that had now received 25 lbs of N 1,000 ft^{-2} in the past 2.5 years.
- Based on the results from the combined locations, it would be possible to consider increasing the rates for application of both soluble and controlled release N products from the current recommendations in the Green Industry BMPs and Urban Turf Fertilizer Labeling Rule as long as application is to healthy turf.

PROJECT 3 – NITRATE LEACHING DUE TO NITROGEN SOURCE AND TIMING

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

In central Florida, when differences existed due to the interaction of grass and N source, no differences in loading occurred in response to N in St. Augustinegrass, while zoysiagrass had greater loading from ammonium nitrate. These data suggest that consideration could be given to allow application of up to 49 kg of water soluble N ha^{-1} on an established, healthy turf. In 3 of 4 years of research, there was no increased loading from 98 kg N ha^{-1} of a polymer sulfur coated product applied every 120 days, however, in 2011, that treatment produced greater nitrate-N loading than 49 kg ha^{-1} applied every 60 days.

In north Florida, centipedegrass leached 53% less N than St. Augustinegrass following the initial application of fertilizer in 2008. Leaching in 2009 was considerably less than in 2008 and no differences due to turf species or fertilizer source were noted. The winter of 2009/2010 was colder than normal, resulting in significant deterioration of the St. Augustinegrass. In 2010 St. Augustinegrass leached more N than centipedegrass throughout the study.

The four 60-day treatment cycles averaged leaching losses of 4.87 kg N ha^{-1} for St. Augustinegrass and 0.22 kg N ha^{-1} for centipedegrass. Several of the 60-day cycles in 2010 showed a significant Species X Fertilizer Source interaction. In all cases, the centipedegrass X fertilizer source treatment interaction was not significant.

There were differences in leaching from St. Augustinegrass due to fertilizer source treatment. Leaching from St. Augustinegrass ranged from 1.5 (PCU @ 49 kg ha^{-1}) to 22.9 (urea) kg N ha^{-1}. In 2011, leaching from St. Augustinegrass continued to be greater than leaching from centipedegrass.

Key Findings:

- When applied to a healthy stand of St. Augustinegrass, there were few differences in NO_3-N losses due to source.
- In some fertilizer cycles, greater leaching occurred from ammonium nitrate in zoysiagrass than from other N sources.
- Consideration could be given to increasing the amount of soluble N that can be applied and to increasing the amount of controlled release products, particularly in areas where a summer fertilizer ban is in effect.

PROJECT 4 – NITRATE LEACHING DURING FALL/WINTER MONTHS

This research was undertaken to observe how NO_3–N loading was impacted by N fertilization in at Citra and Jay throughout the winter months. Nitrogen was applied monthly throughout the winter to Floratam St. Augustinegrass (both locations), UltimateFlora® zoysiagrass (Citra), and centipedegrass (Jay).

In Citra, there were differences in nitrate-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 nitrate-N fluxes greater than those of control plots, but also did not enhance turf quality and color. 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 nitrate-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 nitrogen fertilizer in the winter in north central Florida.

Similar results were observed at the Jay Research Facility. Over the three year study, leaching was highest during 2006 and is likely attributed to nutrient import from the sod production farm. 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. No significant differences in nitrate-N leaching between N application rates were detected until March 2009 through June 2009 sampling periods. During this time period N applied at 49 kg ha^{-1} had the highest leaching (10.9 kg ha^{-1}); more than the other rates applied. Leaching events consistently followed major rain events and led to the total nitrate-N leaching being highest at the 49 kg ha^{-1} rate.

Key Findings:

- Dormant grass has less ability to take up N fertilizer than grass that is actively growing.
- Nitrate-N leaching following sod installation was heightened.

- NO_3-N losses increased with N application rate, with NO_3-N losses at the highest rates being generally greater than losses from the studies looking at leaching during the growing season.
- If a nitrogen application needed 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.
- Annual N applications should not be made until grass has begun spring green-up or N should be applied at very low rates.
- Turf quality and color were not enhanced enough to warrant winter N application.
- In Jay, winter rain events are common and led to greater NO_3-N losses from the dormant grasses. particularly at the higher N rates.
- NO_3-N losses were greater from Ultimate zoysiagrass than from Floratam St. Augustinegrass at the higher N rates.

PROJECT 5 – PHOSPHOROUS REQUIREMENTS AND LEACHING

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

Key Findings:

- Based on tissue analysis, maximum P application rates should be 0.54 g P m^{-2} per application (1.07 g P m^{-2} per year) to St. Augustinegrass and 0.2 g P m^{-2} per application (0.8 g P m^{-2} per year) to zoysiagrass.
- Ortho-p leaching was greater from zoysiagrass than from St. Augustinegrass.

PROJECT 6 – SLOW RELEASE NITROGEN STUDY

The Slow Release N Source study was initiated during the summer of 2008 at the Jay site only. 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: PCU + SCU (39-0-0), XCU (43-0-0), Methylene Urea (40-0-0), PCU – 120 day (43-0-0), Florikan (15-2-15), and Corn Gluten Meal (9-0-0). From 2008 – 2010, turf quality differences were minimal. PCU – 120 Day and Corn Gluten Meal generally produced acceptable results but lagged behind all other SRN sources. The consequence of providing a cumulative rate of 196 kg N $1,000^{-2}$ per year on centipedegrass was fully realized in 2011. The rate of nitrogen exceeds the annual N rate by

200 to 400% depending on the level of maintenance given. No differences in turf quality and turf density were observed in 2011; however, all ratings were significantly below an acceptable level. In 2008 and 2009, no differences in nitrate-N leaching occurred between the six SRN sources. In 2010, The PCU – 120 Day and Florikan fertilizers sources leached the greatest quantity (5.5 and 4.5 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 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}). 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). Over the 120 day total, the leaching as a percent of applied nitrogen ranged from 7% (Corn Gluten Meal) to 70% (PCU – 120 Day).

Key Findings:

- Initial applications of high rates of N to healthy turf have limited impact on nutrient leaching.
- Subsequent applications of high rates led to significant turf deterioration which resulted in substantial nitrate-N leaching.
- Fertilizers with nutrient release dictated by microbial action (methylene urea and natural organics) had the lowest levels of nitrate-N leaching.