Fate of Nitrogen and Phosphorus

The degree of nitrate leaching from turfgrass systems, as noted in the literature, has been found to be variable. In previous research, dramatic differences in nitrate leaching were reported by different researchers ranging from 0 percent to 80 percent of the total applied nitrogen (Walker and Branham, 1992). Factors that influence the degree of nitrate leaching include soil type, irrigation and rainfall, temperature, nitrogen source and rate, and season of application. Currently, several research projects are focusing on the fate of applied nitrogen and phosphorus compounds under different turf and climatic regimes. The research being conducted on nitrogen movement and transport is addressing many of these factors (Table 1).

Although the experiments have not been completed, some comparisons are possible from the data generated thus far. These include gross comparisons on nitrate leaching observed per annum in all projects, comparisons between nitrate leaching in different climatic zones with different soil types, and comparisons between application method and source of nitrogen. As more data is collected, and the scientists conducting the studies have time to review their results, these preliminary conclusions may be strengthened or refuted.

Subsurface Loss of Nitrogen

Thus far, the three most interesting factors affecting subsurface nitrogen loss are application rate, soil type, and irrigation method. Preliminary results suggest a very strong trend exists between rate of nitrogen application and leaching losses of nitrogen as nitrate (Figure 1). This data is from all five research projects reporting data which was summarized earlier (Table 1). As noted here and in other publications, the subsurface loss of nitrogen is most dependent on total rate of application.

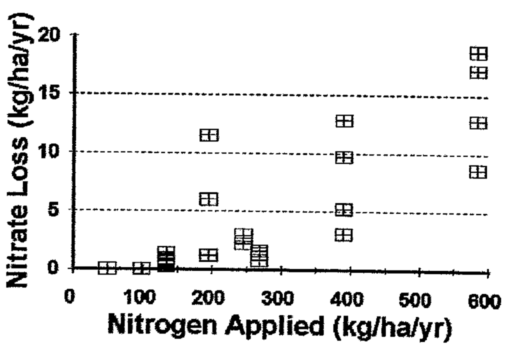

Figure 1. Effect of nitrogen application rate on subsurface nitrogen loss (1 lbs./A = 1.12 kg ha^{-1}).

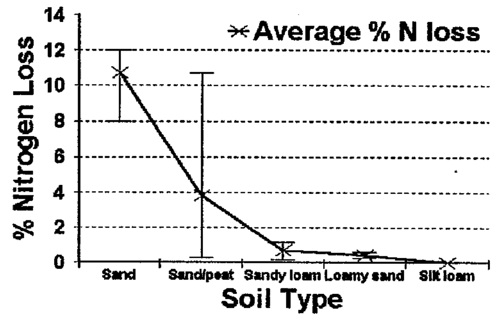

Figure 2. Effect of soil type on subsurface nitrogen loss. Percent nitrogen loss is averaged over studies reporting results for the various soil types. The range of values reported is represented with the 'I' bar.

The relationship between soil type and subsurface loss of nitrogen agrees closely with previous research conducted on both turf and agricultural systems (Figure 2). For this report, the results were compiled from the five university research projects (Table 1) for all soil types (sand, sand/peat, sandy loam, loamy sand, and silt loam) and all nitrogen application rates (ranges from 134 to 580 kg N ha^{-1} yr^{-1} or 120 to 518 lbs. per A annually). As noted earlier, the greatest percent loss of nitrogen was observed for the sand and sand/peat mixtures compared to the loamy sand, sandy loam, or silt loam soils. However, it is important to note that the addition of the peat to sand significantly reduced the amount of nitrogen loss through subsurface leaching compared to the sand alone. As the rates of nitrogen application decreased from high levels to more moderate levels (less than 300 kg N ha^{-1} yr^{-1} or 268 lbs. per A annually), the results from sand/peat mixtures were virtually indistinguishable from the sandy loam or loamy sand soils.

At Pennsylvania State University (Watschke et al.), 49 and 98 kg N ha^{-1} yr^{-1} (44 and and 88 lbs. per A, respectively) of granular soluble nitrogen were and perennial ryegrass. The higher rate was applied in two (spring and fall) 49 kg ha^{-1} treatments. The plots were irrigated to produce runoff with a total of 37.8 cm (15 inches) of water applied per year (August 1991 to September 1992). In most cases, nitrate found in leachate was equal to or significantly below the amount found in the irrigation water (typically 1 to 6 mg L^{-1}). Mean annual nitrate concentrations from all sampling events was usually less than 1 mg L^{-1}, indicating that less than 0.5 percent of the total applied nitrogen was leached through the turf and silt loam soil.

Research at Michigan State University (Branham et al.) examined nitrate leaching following both early spring and late fall applications of urea at 196 kg N ha^{-1} yr^{-1}. Thus far, an accumulated total of 2.3 kg ha^{-1} of nitrate has been found within the 38 leachate samples collected from the early spring treatment or only 0.9 percent of the total applied (sampling occurred for more than a year; thus, total applied N for the entire study duration is 245 kg ha^{-1}). Average nitrogen concentrations in the samples were only 0.5 mg L^{-1}. The highest observed leachate concentration for the entire sampling period was slightly less than 3 mg L^{-1}. There was no detectable nitrate in any of the leachate samples collected in the most recent sampling (October 1992).

For the late fall treatment, slightly greater nitrogen leaching occurred, or 1.2 percent of the total N applied. The mean concentrations in leachate samples were also slightly higher, or 0.76 mg L^{-1}. For this treatment, both nitrate and ammonium were still detectable in the most recent leachate samples, but it represents a very low level of nitrogen leaching. The fact that little difference was noted between early spring and late fall nitrogen applications suggests that turf systems are much more efficient users of nitrogen compared to agricultural systems. In agricultural systems, late fall application rates tend to increase the potential for spring "flushes" of soluble nitrogen and subsequent off-site transport as leachate or snow-melt runoff.

Researchers at Washington State University (Brauen et al.) have examined the effect of nitrogen application timing and rate on leaching from putting green rootzone mixes of sand and amended sand/peat mixtures. The rates of application were moderate to high (195, 390 and 585 kg N ha^{-1} yr^{-1}). Application frequency varied from 11 times annually to 22 times annually. Highest leaching percentages were noted for nitrogen applied to sand alone (mean = 10.7 percent of the total N applied regardless of application timing) compared to the amended sand/peat mixtures (mean = 6.0 percent of total N leached). In addition, the total nitrogen leached was always highest for the higher rates of nitrogen application, although this did not necessarily correlate when expressed as percent released as a function of the total nitrogen applied.

Total nitrogen leached also was not well correlated to application timing, as little difference was noted in leaching characteristics of the 22 applications per year versus the 11 applications per year treatment. One interesting observation was that despite the relatively high percentages of nitrogen leached, the leachate concentrations never exceeded 10 mg L^{-1}. Data from the 1992-1993 season should provide an interesting comparison since the turf should be better established with a more mature root system.

Researchers at Iowa State University (Starrett et al.) reported that single 2.54 cm (1 inch) or four 0.63 cm (0.25 inch) irrigation applications to silt loam soil columns removed from an established Kentucky bluegrass turf had little effect on the leaching characteristics of applied nitrogen (49 kg N ha^{-1}). In both cases, applied N was found primarily in the thatch layer (about 12 to 16 percent of total applied N) and the first 10 cm (4 inches) of soil below the thatch layer (24 to 26 percent of the total applied). Leachate from the columns was always less than 1 percent (cumulative) of the total applied (Figure 3).

At University of California (Yates et al.), nitrogen movement was examined in field plots after application of urea or sulfur coated urea at rates of 134 or 268 kg ha^{-1} yr^{-1} (120 or 240 lbs. per A annually) to amended sand putting greens or fairway loamy sand and sandy loam soils. As with the other projects, it was noted in all cases that less than one percent of the applied nitrogen leached

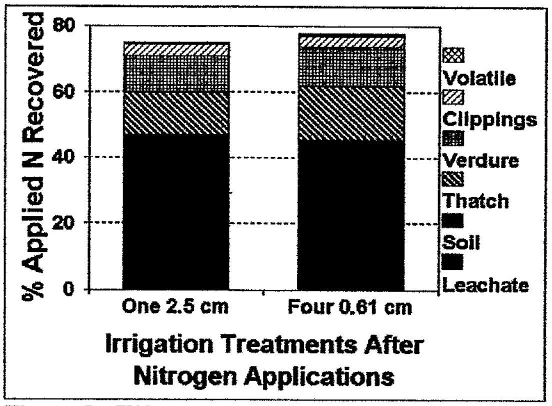

Figure 3. Effect of irrigation method on nitrogen balance after fertilizer application.

during the course of the study. Highest leachate concentrations were noted for either sulfur coated urea or urea applied to sandy loam soils. Two concentrations reported were equal to 128 mg L^{-1}, but occurred for turfgrass establishing in disturbed soil. Most leachate samples ranged from less than detectable to about 6 mg L^{-1}. The few treatments that produced high concentrations were also noted for having the least amount of applied water leach through the profile; hence, the annual concentrations would be expected to be high. Samples with higher concentrations still represented less than 0.5 percent of the total nitrogen applied.

Surface Loss of Nitrogen

Researchers at Pennsylvania State University (Watschke et al. 1992) observed runoff following nitrogen applications on sloped fairway plots established to creeping bentgrass and perennial ryegrass. Prior to nitrogen application, hydrographs for the different plots were observed as the turf matured. They noted that a significantly different hydrograph developed for each species over time. Runoff was found to occur more quickly and with greater peak flow from the ryegrass plots than from the bentgrass plots. By midsummer 1992, it was found that twice the amount of applied water was required to produce runoff on the bentgrass compared to the ryegrass plots.

Regardless of the turf cover used, runoff concentrations of applied nitrogen did not appear to be different for the different species of turfgrass. These results are consistent with those of other researchers: runoff decreases with an increasing amount of soil cover (whether turf or row crop), and turfgrass, due to its dense cover, not only attenuates surface losses of water but reduces the potential for surface and subsurface losses of nitrogen as well.

Subsurface and Surface Loss of Phosphorus

Pennsylvannia State University researchers (Watschke et al. 1992) also have examined phosphorus leaching and runoff from the same plots noted earlier. The two application rates of monoammonium phosphate were either 5 or 10 kg ha^{-1} yr^{-1} (where the higher rate of application was performed in two split applications). Phosphate concentrations in leachate never exceeded the irrigation water content of 1 to 2.5 mg L^{-1} (1 to 2.5 ppm) through the duration of the study. This is not surprising given the high affinity of phosphate for soil particle surfaces, which effectively decrease leaching potential.

Phosphate concentrations in surface runoff were found to be higher than those observed in the irrigation water for 8 of the 11 samples examined after application of the second 5 kg ha^{-1} treatment. The concentrations observed were still less than 6 mg L^{-1} (6 ppm) phosphate, and represented a low percentage of the total applied. Loss of phosphate in both agricultural and turf systems usually occurs through sediment loss and transport during golf course construction or turf establishment. Once turf matures, it is likely that significant losses of phosphorus will only occur during runoff events immediately after fertilizer application.

Fate of Pesticides

A variety of research projects are underway that address several key pesticide fate issues concerning golf courses. These include studies that determine the persistence and mobility of pesticides commonly used in golf course construction and maintenance, the principal turfgrass components where applied pesticides tend to reside, the effect of different turfgrass components (i.e., thatch, soil, clippings) on the fate of applied pesticides, the dislodgability of applied pesticides, and the volatility patterns of applied pesticides. Current understanding of how turfgrass systems respond to and alter pesticide persistence and mobility has considerable gaps compared to agricultural systems. The research results reported here and in future reports will provide the basis for sound and scientific assessment of pesticide fate and transport in turfgrass systems.

Mobility and Persistence of Pesticides

Thus far, four research projects have provided preliminary data relating to the fate of applied pesticides in turfgrass systems. At the University of Florida (Snyder et. al.), results on the mobility and persistence of five different organophosphate pesticides applied to a bermudagrass green were reported. The compounds include fenamiphos, fonophos, chlorpyriphos, isazophos, and isofenphos (Figure 4). In the first study, both fenamiphos and fonophos were applied at rates of 11.25 and 8.8 g m^{-2}, respectively, followed by a second application at the same rates approximately 90 days later. Following application, the plots were irrigated and