

Report to the Pleasant Bay Alliance on the Turfgrass Fertilizer Nitrogen Leaching Rate

By

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The Town of Chatham, on behalf of the Pleasant Bay Alliance, has authorized me to conduct a scientific review and produce a report on the following:

1. Update the 1990 literature review article on turfgrass nitrogen leaching by Petrovic (1990).
2. Determine an appropriate overall turfgrass fertilizer leaching rate for Cape Cod, MA.
3. Determine fertilizer leaching rates for different turfgrass land uses including golf courses and lawns including residential, municipal and commercial sites.

What follows is a report including the above three parts.

Part 1: Literature review of the turfgrass nitrogen leaching literature since 1990

The literature review involved all research journal articles published since 1990 on the leaching of fertilizer nitrogen applied to cool-season turfgrasses, the ones used on Cape Cod. There were some research literature on warm-season grasses, but because of the much longer growing period, more precipitation and irrigation, deeper rooted grasses and over all different hydrology, this literature was not included in this review. There were 29 research journal articles published since 1990, much more than the 6 on cool-season turfgrasses that were cited in the 1990 review article (Petrovic, 1990). Nine of the 29 studies were conducted on golf course type conditions, while most of the studies were done on lawn type turf. Table 1 contains a summary of all of the research papers included in the review. This table has 302 values of fertilizer nitrogen leaching as a percent of the amount of applied, most often as nitrate, but sometimes as a total of nitrate plus ammonium. This table also contains detailed information about each study including the loading rate (LR) in units of lbs of nitrogen leached per 1000 sq. ft. per year or in studies lasting less than a year the amount is over the study period.

Golf Results

There were only nine studies on golf course turf with more than half being greenhouse studies. The studies covered a wide range of factors that influence nitrogen

leaching including cultivar and species differences, amendments of sand, nitrogen sources and rates of application, cultivars of bentgrass with different rooting depths, clipping management, soil types, and an actual green on a golf course.

The amount of leaching ranged from none to a high of 71% of the amount of fertilizer nitrogen applied with an average from all studies of 13.34%. Half of all the results (84 values) were below 3% of the amount applied. Field studies are considered a better representation of what actually occurs in the real world and greenhouse studies are good to compare factors and often give higher leaching values. When only considering the four field studies, the per cent of fertilizer nitrogen that leached averaged 3.0%, ranging from 0.02% to 13.2%. The actual golf green (USGA style green in Idaho) had the highest amount of fertilizer nitrogen that leached. The factors found to increase fertilizer nitrogen leaching were: applying increasing amount of nitrogen fertilizer especially to pure sand greens compared to ones with peat or other amendments, much more leaching occurred during the establishment phase that in subsequent years (up to 3yrs), bentgrass cultivars with shorter roots than ones with deeper roots had more leaching, the more irrigation was applied more fertilizer nitrogen leaching, the sandier the soil the greater the amount of fertilizer nitrogen that leached, and annual bluegrass had much more leaching than bentgrasses especially annual bluegrass from Canada.

Lawn Results

There were 20 studies on lawns with only three being greenhouse studies. The studies evaluated different nitrogen sources, rates and application timing, long term impacts, cultivar and species differences, bare soil compared to a lawn, lawns compared to corn, forests and septic systems, and the amount of irrigation.

The amount of fertilizer nitrogen that leached ranged from 0 to 95.1% with an average from all studies of 9.41%. If only field studies were considered the average leaching rate was just slightly higher (9.61% of the amount applied).

Some factors that affected the amount of fertilizer nitrogen leaching were very consistent: the higher the application rate of nitrogen, the more leaching occurred, especially when rates higher than the highest typical rate (1 lb N/1,000 sq.ft.) were applied; nitrate form of nitrogen fertilizer (ammonium or calcium nitrate) had much more leaching (nitrate forms are not typically used to fertilize lawns) than other sources (urea and slow release sources); excess irrigation caused more leaching; corn production and septic systems had much more nitrate leaching than fertilized lawns while unfertilized lawns had similar amount of nitrate leaching as a forest; and during lawn establishment more leaching occurred than in the next several years. Some species (and cultivars within a species) were more prone to nitrogen leaching. Kentucky bluegrass had higher leaching amounts than either perennial ryegrass or tall fescue (Liu et al., 1997).

The results involving several other factors were not as consistent. Four studies involved fall to late fall applications. Two (done on Long Island, NY and Connecticut) of the four clearly show the risk of applying nitrogen (as soluble sources) in mid (October)

to late fall (November and December). The studies done in Ohio and Ithaca, NY found much less or no additional nitrogen leaching from late fall applications. The difference is related to temperature conditions, the colder winters of Ohio and Ithaca results in less leaching compared to the milder coastal regions. Three studies considered the long term impacts. One study (Petrovic, 2004) showed that the source of nitrogen (except for calcium nitrate which is not used as a lawn fertilizer) had little to do with the amount of leaching when studies were conducted over a wide range (thus long term implications) of rainfall conditions (drier, normal and much wetter than normal). It has been suggested that younger sites with less organic matter would tie up a fair amount of fertilizer nitrogen for a long period of time (first 10-20 yrs), and thus less fertilizer nitrogen would be need. Frank (2006 & 2008 in Michigan) found that as the site became more mature (10 + yrs), if a high rate of nitrogen was maintained (5 lbs N compared to 2 lbs N/1000 sq.ft./yr) higher N leaching occurred. However, a study in Rhode Island (Duff et al., 1997) found older sites were no more prone to nitrogen leaching than younger sites. Generally, it was found that nitrogen fertilizer sources that were more water soluble had greater amounts of nitrogen leaching, except where noted above (Petrovic, 2004).

Part 2: An appropriate overall turfgrass fertilizer leaching rate for Cape Cod, MA

To answer this question, one must considered the conditions of the location in question, namely the soils, climatic factors and grasses. The best information would be from studies done on Cape Cod, MA. None of the studies were done on Cape Cod, MA, and only one was done in Massachusetts (Mancino and Troll, 1990, in the greenhouse). Therefore, the results from other studies will be used to extrapolate to the conditions of Cape Cod, MA. In general, only cool season grasses like Kentucky bluegrass, fine fescue, perennial ryegrass, annual bluegrass on golf courses and bentgrass are used on Cape Cod. Based on information from the Natural Resource Conservation Service (NCRS at <http://websoilsurvey.nrcs.usda.gov/app/>), a majority of the soils in the Towns of Chatham, Orleans, Harwich and Brewster, MA are Carver & Plymouth coarse sands & sands, Merrimac & Nantucket sandy loam, East Chop, Freetown and Deerfield sands, and a little silt loam (Boxford and Enfield). Thus, studies with sand to sandy loam soils would be most appropriate. The 30 year average annual rainfall for the eastern part of Cape Cod, MA (Chatham WSMO station, from the Northeast Climate Center database CLIMOD) is 46.03 inches. Thus, data from coastal New England states like Connecticut and Rhode Island and Long Island, NY that used sand to sandy loam soils in these studies would best approximate the conditions of Cape Cod, MA.

To approach the issue of how much fertilizer nitrogen leaches, there are several options. One could look at an average of all studies, thus include the worse case scenario studies, all soil types, grasses, fertilizer amounts and sources and irrigation variables. In this way it is like all sites found on Cape Cod, MA would likely be represented in at least one study. Therefore, using this approach the answer would be 10.51% including all 302 values found in Table 1. Half of the 302 values were below 4.15% of the amount applied. If only field studies were considered, which is considered the most realistic scenario, then the nitrogen fertilizer leaching rate would be 8.79% of the amount applied. A more conservative approach would be to use results from the greenhouse studies that are

generally considered to give higher leaching values, then the leaching rate would be 14.99% of the amount of fertilizer nitrogen applied. Using data from studies that are most like Cape Cod (the one MA study, the sand to sandy loam studies of Rhode Island, Connecticut and Long Island, NY) then the leaching rate would be 11.10%.

Part 3: Fertilizer leaching rates for different turfgrass land uses including golf courses and lawns including residential, municipal and commercial sites.

It may be appropriate and justifiable to have a nitrogen fertilizer leaching rate separate for golf course turf and for lawns. As was done in Part 2, there are several ways to approach determining a suitable fertilizer nitrogen leaching rate; consider all data, only field data, only greenhouse data and only data most appropriate for Cape Cod.

Golf Course

The amount of leaching from golf course studies ranged from none to a high of 71% of the amount of fertilizer nitrogen applied, with an average from all studies of 13.34%. Half of all the results (84 values) were below 3% of the amount applied. When only considering the four field studies, the per cent of fertilizer nitrogen that leached averaged 3.0%, ranging from 0.02% to 13.2%. From the more conservation greenhouse studies, the fertilizer nitrogen leaching rate was 16.95%. Using data from studies that are most like Cape Cod (the one MA study, the sandy loam study of Connecticut), the leaching rate would be 9.97%.

One other approach is to use groundwater quality data from an actual golf course and determine the fertilizer nitrogen leaching rate to correspond with the ground water nitrogen concentration. To do this with any degree of accuracy you need a sound understanding of the ground water hydrology of the site, many groundwater monitoring wells, and good knowledge of the amount of nitrogen that was applied. This was done by me on behalf of the Peconic Estuary Program for a golf course on eastern Long Island, NY (The Bridge in Bridgehampton, NY) where there are 14 groundwater monitoring wells that were sampled four times per year, a soil typical of Cape Cod (Carver sand) and a good knowledge of ground water hydrology. Based on the amount of fertilizer applied to the golf course (6,449 lbs on 113.27 acres/yr), the groundwater recharge amount based on rainfall and irrigation, and average nitrogen concentration in the ground water wells (0.81 mg nitrate/l), it was determined that 8.87% of the fertilizer nitrogen leached into the groundwater for this golf course. This value is close to the research studies similar to Cape Cod conditions (9.97%). Based on my analysis and conclusion that golf course turf on eastern Long Island, NY had a fertilizer nitrogen leaching rate of 10%, the Peconic Estuary Program made a voluntary agreement with the 35 east end golf courses to limit the amount of nitrogen applied to golf courses to be on average 2.8 lbs of nitrogen/1,000 sq.ft./yr. to meet a groundwater quality goal of 2 mg of nitrogen/L under golf courses.

Lawns

The amount of fertilizer nitrogen that leached based on 20 studies ranged from zero to 95.1%, with an average from all studies of 9.41%. If only field studies were considered the average leaching rate was just slightly higher (9.61% of the amount applied). Using data from studies that are most like Cape Cod then the leaching rate would be 11.10%.

Based on the nature of these studies it is difficult to separate out residential lawns from municipal or commercial lawns. It is, however, possible to separate lower maintenance lawns (0-2 lbs nitrogen fertilizer/1,000 sq.ft./yr), medium maintenance (2-4 lbs nitrogen fertilizer/1,000 sq.ft./yr) from high maintenance lawns (>4 lbs nitrogen fertilizer/1,000 sq.ft./yr). Low maintenance leaching rate is 9.66%, medium maintenance is 8.60% and 12.43% for high maintenance lawns.

Conclusions

The basic question that was posed to me; is the Massachusetts Estuary Program turfgrass fertilizer nitrogen leaching rate of 20% suitable for turfgrass in the Pleasant Bay region of Cape Cod? In my professional opinion, based on results from 35 studies published on the leaching of fertilizer nitrogen from cool-season turfgrasses, 20 % fertilizer rate leaching would be considered an overestimation by about two times. Only 14 % of the time in the 35 studies reviewed in this report was the leaching rate 20% or higher. Based on the analysis done above, an overall leaching rate of around 10% (10.5% was the overall average leaching rate) would be appropriate to cover the wide range of factors that could occur on Cape Cod such as: very sandy soil, over-irrigation, excessive nitrogen application rates, excessively wet years, improper timing of application, use of highly water soluble-high leaching potential fertilizers and all grasses that could be used on Cape Cod. There was not a substantial difference found overall between lawns and golf course turf, thus one number (10%) would be appropriate.

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Table 1. Summary of published research on the leaching of nitrogen fertilizer applied to cool-season turfgrass since 1990.

<u>Grass</u>	<u>Turf Type</u>	<u>Nitrogen source</u>	<u>Single N app Rate (lbs. N/1000 sq.ft)</u>	<u>Total N applied/yr (lbs. N/1000 sq.ft)</u>	<u>Season Applied</u>	<u>Soil Texture</u>	<u>Amount of Irrigation (inch/day)</u>	<u>% of applied N leached as NO3- N & NO3-Loading rate (lbs. N/1000 sq.ft/yr)</u>	<u>Conc. of NO3-N in water mg/L</u>	<u>Reference</u>	Notes
Creeping bentgrass – Oct. seeded, Washington	Greens-32 sq.ft. lysimeter (USGA profiles) 3 yr field study	Am. Phosphate Am. Sulfate urea Slow release*	0.02 0.10 0.02 <u>0.10</u> 0.18	4	2 week interval, Feb-Dec., 22 apps	Sand (3 layer-12” sand, 3” coarse sand, 3” pea gravel, pH 6.8	Amount not given	1 st yr - 5.4% 2 nd yr- 0.06% 3 rd yr- 2.7% Ave. 2.7 % Ave. LR of 0.11	-	Braun & Stahnke, 1995	Started at establishment
“	“	Am. Phosphate Am. Sulfate urea Slow release*	0.02 0.10 0.04 <u>0.20</u> 0.36	8	“	“	“	1 st yr -6.3% 2 nd yr-0.04% 3 rd yr-3.2% Ave. 3.2% Ave. LR of 0.26	Max. 10 in first yr.	“	
“	“	Am. Phosphate Am. Sulfate urea Slow release*	0.02 0.10 0.07 <u>0.36</u> 0.55	12	“	“	“	1 st yr -7.6% 2 nd yr-0.7% 3 rd yr-4.3% Ave. 4.2% Ave. LR of 0.50	Max 37 in first yr, 2-5 in 2 nd 7 3 rd yr	“	
Creeping bentgrass – Oct. seeded	Greens-32 sq.ft. lysimeter (USGA profile)	Am. Phosphate Am. Sulfate urea Slow release*	0.02 0.10 0.02 <u>0.10</u> 0.18	4	2 week interval, Feb-Dec., 22 apps	Sand-peat-soil (88% sand,10% sphagnum peat, 2 % silt loam) (3 layer-12” root zone, 3” coarse sand, 3” pea gravel	Amount not given	1 st yr-0.33% 2 nd yr- 0.40% 3 rd yr- 0.16% Ave. 0.30 % Ave. LR of 0.012	-	Braun & Stahnke, 1995	
“	“	Am. Phosphate Am. Sulfate urea Slow release*	0.02 0.10 0.04 <u>0.20</u> 0.36	8	“	“	“	1 st yr-0.91% 2 nd yr - 0.02% 3 rd yr - 0.17% Ave. 0.39% Ave. LR of 0.03	Max. 3 in first yr.	“	
“	“	Am. Phosphate Am. Sulfate urea	0.02 0.10	12	“	“	“	1 st yr - 3.4% 2 nd yr - 1.26% 3 rd yr – 2.31%	Max 10 in first yr,16 in 2 nd , 8 in 3 rd yr	“	

LR= loading rate in lbs of nitrogen/1,000 sq. ft. /yr