Research Review of Nitrogen Losses from Turfgrass

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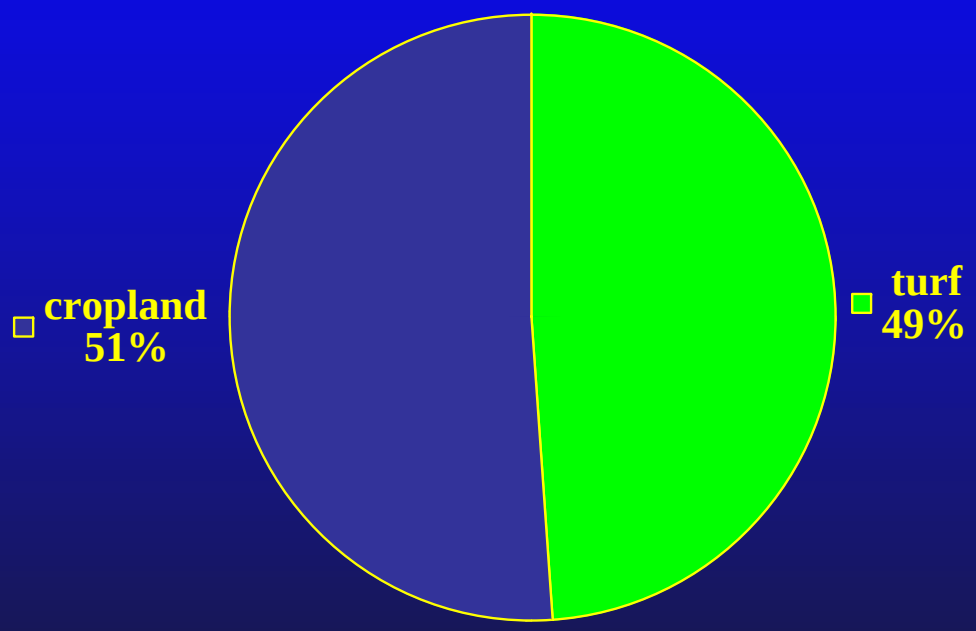
Why Are We Here?

Land in Turf vs. Land in Crops

(1996)



Overview

- Species Effect
- Infiltration Rate
- Runoff
- Nitrate Retained in Soil
- Nitrate in Leachate
- Carbon
- Clippings
- Attempt at Conclusions

Species

- Species affects nitrogen leaching in warm season grasses during establishment. St. Augustine retained approximately twice as much NO3-N as common Bermuda. - Bowman et al. (2002)
- Cool season grasses - not as dramatic

Infiltration Rate

Kelling and Peterson (1975)

Partsch et al. (1993)

Infiltration Rate

Kelling and Peterson (1975)

- Turf established over original profile infiltrated 2 to 4 times as much as sites with “standard” construction practices.
- One site with visibly heavy foot traffic (hence compaction) had less than half the infiltration capacity of other similar sites.

Partsch et al (1993)

- Compaction below 2 inches does not recover after 12 years of turf growth

Runoff

- Gross et al. (1990) and Gross et al (1991)
- 4.5 lbs N/1000 sq ft, split over 5 applications
- Runoff collected for 2 years
- First year, NO3-N losses not different between treatments and control
- Second year, NO3-N losses greater from treatments than from control, but still low
- Turfgrass stands reduce sediment loss

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Nitrate retained in soil

Rieke & Ellis (1974)

Spalding el at. (1988)

Lee et al. (2003)

Exner et al. (1991)

Experiment

Rieke and Ellis (1974)

- Fine sandy loam and sand, Ky bluegrass, Michigan
- Soil cores every 2 weeks for 2 years, 3 replicate plots
- 4 depths, 0-6”, 6-12”, 12-18”, 18-24”
- Ammonium nitrate, millorganite, ureaformaldehyde, IBDU - Single spring applications, one split into 3 applications (NH4-NO3)
- Fertilizer applied: 5.9 lbs N/1000 sq ft on fs loam, 8 lbs N/1000 sq ft on sand
- Water: sandy loam: 39.4” 27.8” (April-Oct., ‘70 & ‘71)
  sand: 48.0” 32.8 ” (April-Oct., ‘70 & ‘71)

Results - sandy loam

- Evidence of NO3-N movement into 6-12” and 12-18” depths through end of June
- NO3-N varied during season: increase throughout the profile for all treatments during July and August, decrease in Sept. to Spring levels
- Evidence of NO3-N movement into 6-12” and 12-18” depths delayed until early Aug. (1971)
- For split applications, NO3-N increased only in 0-6” depth
- On sand, evidence of NO3-N movement into 6-12” and 12-18” depths occurred within 2 weeks of application

Results - general

- Heavy spring N resulted in heavy top growth
- Clippings returned resulted in better turf quality
- Spring green-up slower with IBDU
- Soluble N lost over winter
- Leaching on sand more evident than on silt loam
- Combination of greater ET and lower precip resulted in less leaching in 1971 than in 1970

Experiment

Lee et al. (2003)

- 50 and 75 year old golf course fairways - well established
- 4 transects through trees, rough, and fairways
- 8 locations/transect
- Fertilizer applied: 117 to 161 lbs N/ac

  (2.7-3.7 lbs N/1000 sq ft)

  3-7 applications/year

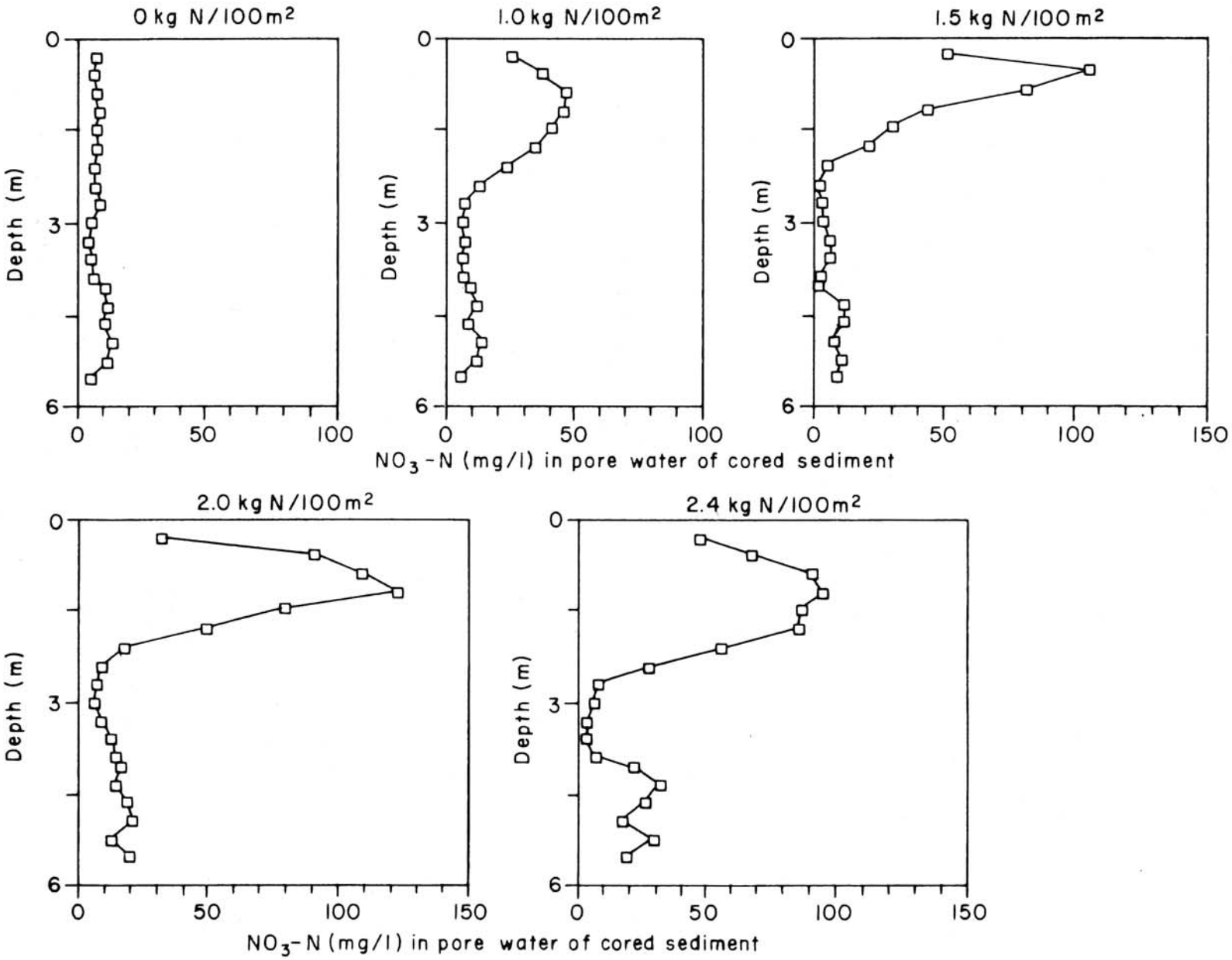
Results

- Range: 0.5 to 8 mg/kg nitrate in soil
- Varied during season: November lowest
- Fairways(2-4 mg/kg) 1 mg/kg nitrate higher than trees and rough (1-3 mg/kg)
- 4-6 times lower than a corn field
- Soil solution equivalent 12-24 mg/L nitrate-N

Exner et al., 1991

- Experiment
  - 5 6X6 m plots on athletic field in Sidney NE
  - Prior to experiment (May) 71 lbs N/ac (1.6 lbs N/1000 sq ft) applied to all plots.
  - 2, 3, 4, 5 lbs N/1000 sq ft (90, 134, 178, 214 lbs N/ac) applied at end of August
  - Beginning of October, 3 6-m long cores taken from plots

- Results



Average vertical NO_3-N profiles for pore water.

Exner et al., 1991

- Results
  - After 34 days, pulse of nitrate at 1.2 m depth for all rates except lowest (1.6 lbs N/1000 sq ft)

Application Rate (lbs N/1000 sq ft)	NO3-N (mg/L)
1.6	10
3.6	48
4.6	105
5.6	125
6.6	105

Exner et al., 1991

- Comments
  - Excessively irrigated
  - NO3-N in water at 9-12 mg/L
  - Turf can leach NO3-N
  - Amount of leaching increases as load increases

Overview

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Nitrate Lost in Leachate

- Nitrate loss studies
- Irrigation effect
- Seasonal effect
- N-source effect

Nitrate loss studies

Flipse et al. (1984)

Gold et al. (1990)

Cohen et al. (1990)

Geron et al (1993)

Frank (2006)

Experimental Design
Flipse et al. (1984)

- 15 shallow ground water wells, 1972-1979
- New housing development, 180 acres
- Possible sources studied: Fertilizer, precipitation, irrigation water, animal wastes, sewers, inflow from up-gradient

Results

- Initial (pre-development) Nitrate-N: 0.2 to 1.2 mg/L
- Large variations in results: 0.09 to 2.94 mg/L
- 10 of 14 wells had significant increases in NO3-N over time (average rate of 0.22 mg/L/year)

Experimental Design
Gold et al. (1990)

- Suction lysimeters, 20 cm (8 in) depth, 3/ fert. treatment, 2 years data collection
- Silt loam or sandy loam
- Lawns established 7 years prior to experiment
- 5 lbs N/1000 sq ft/year, 5 applications/year and zero fertilizer

Results

	Unfertilized Lawn	Fertilized Lawn	Urea-fertilized Corn
Annual Avg. Nitrate-N Concentration	0.22 0.20 (mg/L)	1.62 0.26 (mg/L)	14.90 15.56 (mg/L)
Nitrate-N Losses	1.16 1.25 (lbs N/ac)	8.30 1.70 (lbs N/ac)	65.22 71.20 (lbs N/ac)

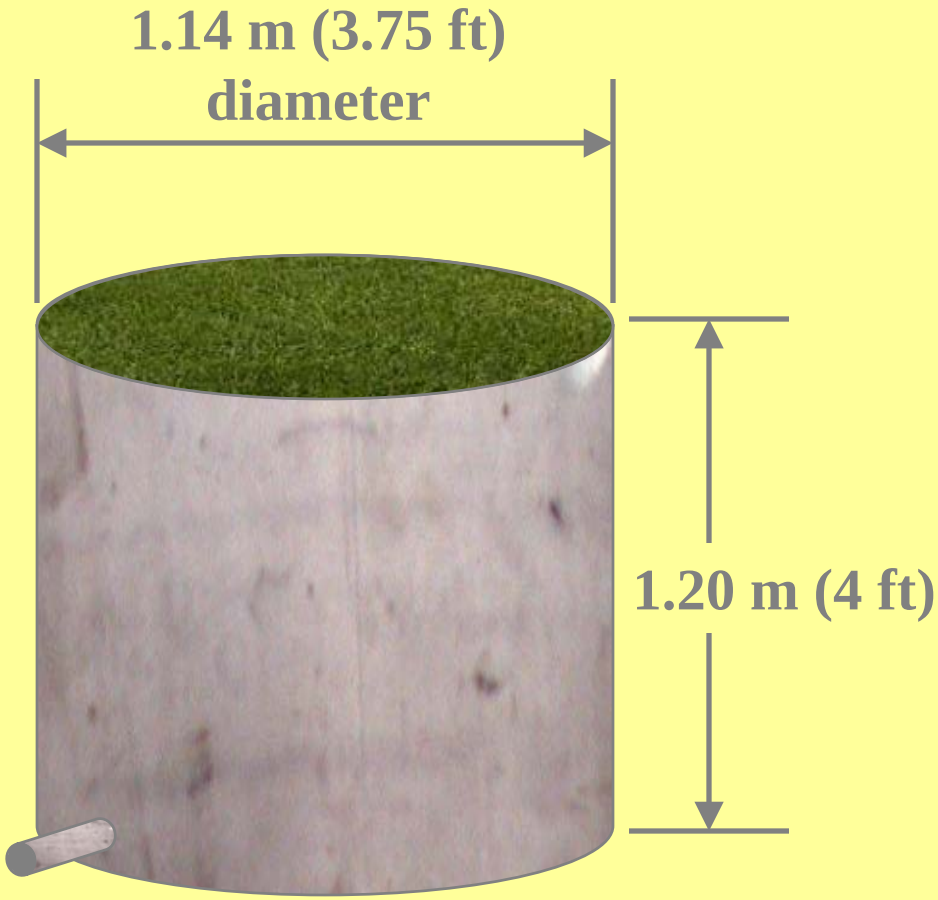
Annual precipitation was 43.7 and 50.0 inches, respectively
Most N-losses from the turf were during spring.

Experimental Design
Kevin Frank - Michigan

- Ky. Bluegrass, monolith lysimeters
- ‘91-’98: 3-4 lbs N/1000 sq ft, 5 applications
- “A well-maintained turf intercepts & immobilizes N quickly making leaching an unlikely avenue of N loss from a turf system.” (Miltner, et al. 1996)

Monolith Lysimeters

Marlette fine sandy loam
(66% sand, 23% silt, 11% clay)

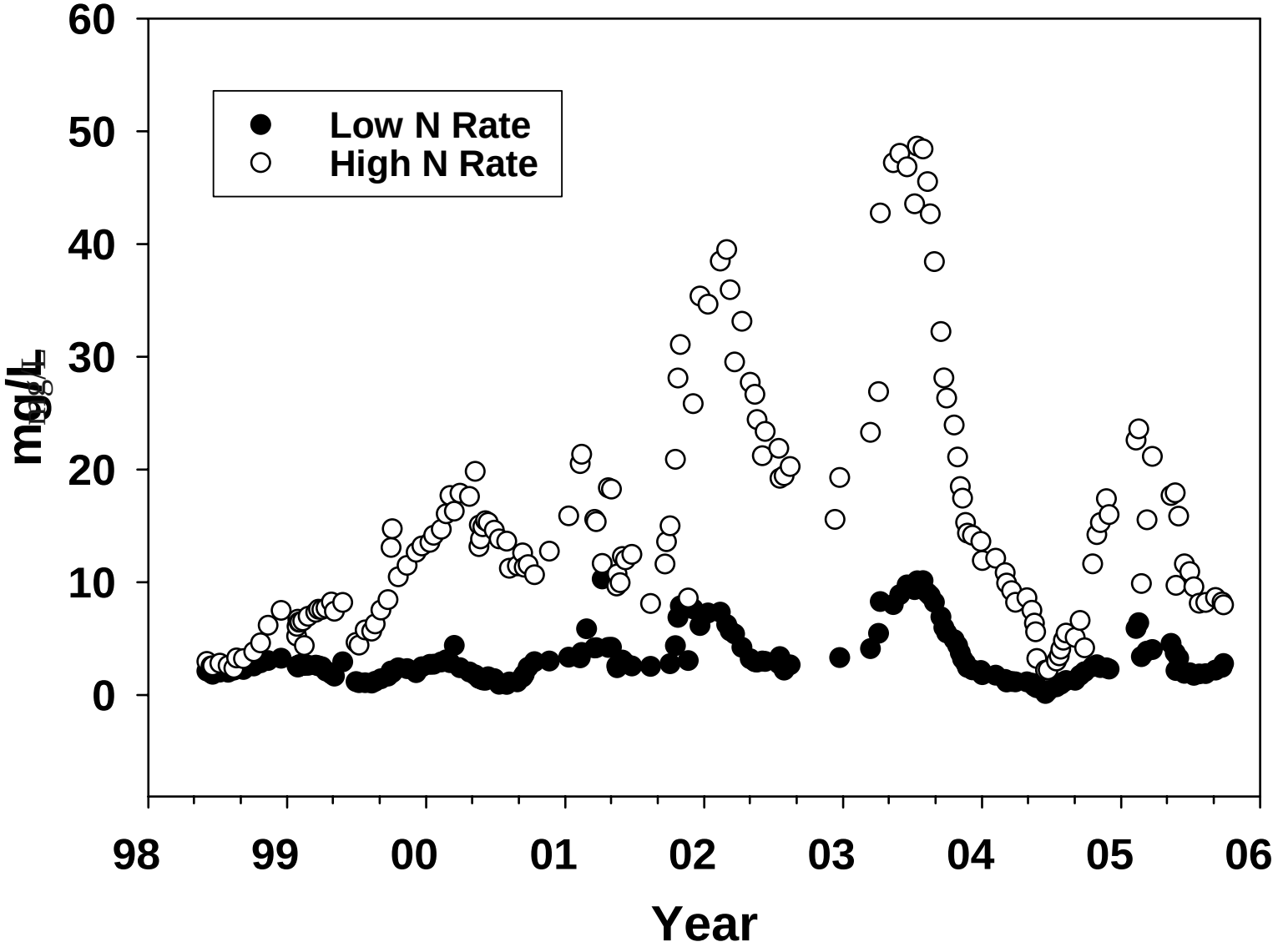


Constructed 1989-1990

Fertilizer Treatments (1998-2005)

- Nitrogen Source - unlabeled urea
- Clippings returned
- Low N Rate
  - 98 kg N ha^{-1} yr^{-1} (2.0 lb. N/M)
  - 24 kg N ha^{-1} $app.^{-1}$ (0.5 lb. N/M)
  - Dates: May 1, June 1, July 1, and Oct. 15
- High N Rate
  - 244 kg N ha^{-1} yr^{-1} (5.0 lb. N/M)
  - 49 kg N ha^{-1} $app.^{-1}$ (1.0 lb. N/M)
  - Dates: same as low rate + Sept. application

Nitrate-Nitrogen 1998-2005



Flow Wt. Means NO_3-N (mg L^{-1})

	Low N Rate	High N Rate
1998	2.6	5.0
1999	2.0	8.5
2000	2.1	14.7
2001	3.7	18.9
2002	4.8	25.3
2003	6.3	29.7
2004	2.6	8.8
2005	3.6	11.6

Conclusions

- Porter et al. (1980) theory - organic N accumulates under turf as the turf ages
- Most accumulation of organic nitrogen occurs during the first 10 years after establishment
- Mature turf sites should be fertilized at a reduced rate to minimize potential for nitrate leaching

Nitrate Lost in Leachate

- Nitrate loss studies
- Irrigation effect
- Seasonal effect
- N-source effect

Irrigation Effect

- Morton et al. (1988), 0, 2, 5 lbs N/1000 sq ft
- Irrigation: “scheduled”, 1.5 inches/week
- Sandy loam, RI
- Overwatering with excess fertilization results in NO3-N losses in percolate
- Overwatering on low N treatments results in NO3-N losses in percolate
- “Scheduled” irrigation was not significantly different from control

Irrigation Effect

- Starrett et al. (1995); 1, 4 lbs N/1000 sq ft
- Irrigation: 4 1-inch applications and 16 1/4-inch applications
- 20 cm dia X 50 cm long undisturbed soil columns
- Loam, IA
- Overwatering increases volitilization N loss
- Overwatering increases leachate loss

Seasonal Application Effects

- Oral and Acikgoz (2001)
- N as ammonium nitrate at 6.1 lbs/1000 sq ft (annual)
- 3 years, 6 fertilizer regimes 1, 2, 3, 6 applications/year
- Factors: color, quality, clipping weight, shoot density
  - Heavy Fall N ==> dark color and uniformity in Spring
  - Spring N ==> highest shoot density
  - Frequent, low N ==> lower clipping weights, best tiller density

Seasonal Application Effects

- Miltner et al. (1996)
- N as urea at 4.0 lbs/1000 sq ft (annual)
- 2 years, 2 fertilizer regimes 5 equal applications/year
- “Spring”: April-September, “Fall”: June-November
- Intact monolith lysimeters, fine sandy loam
- Results, first 2.7 years (980 days)
  - NO3-N mostly less than 1 mg N/L
  - 3 ”peaks” 3.1, 1.8, 1.5 mg/L
  - Thatch was a “sink” for fertilizer N
  - “Fall” application proved better at retaining fertilizer N

Nitrogen Source

- Brown et al. (1982)
- Quiroga-Garza et al. (2001)
- Easton and Petrovic (2004)
- Guillard and Kopp (2004)

Nitrogen Source

- Brown et al. (1982)
- Experiment
  - Golf Course greens, bermudagrass, irrigated
  - Urea, 12-12-12, milorganite, IBDU, ureaformaldehyde
- Results
  - Urea resulted in greatest leachate N loss
  - Up to 300 mg NO3-N/L
  - Much lower losses from milorganite, IBDU, ureaformaldehyde
  - 0-20 mg NO3-N/L, mostly, less than 10 mg NO3-N/L

Easton and Petrovic (2004)

- Sandy loam, NY, Ky. Bluegrass, 2 years
- 4.1 lbs N/1000 sq ft, 4 applications and

  8.2 lbs N/1000 sq ft, 6 applications
- 2 composts, biosolids, 35-3-5, and sulfur-coated urea (24-5-11)
- Source was significant, with readily available urea being the only source with significantly more NO3-N in runoffNutrient leaching was a function of source, time, soil infiltration rate, AMC

Guillard and Knopp (2004)

- Fine sandy loam, CT, 3-4 lbs N/1000 sq ft for 2 years prior to experiment
- Ky. Bluegrass, perennial rye, creeping red fescue
- Ammonium nitrate (AN), polymer coated sulfur coated urea (PCSCU), organic, and non-fertilized control
- 3 lbs N/1000 sq ft, 3 applications/year, 3 year experiment
- 3 year flow rates NO3-N mass losses in percolate: AN - 0.53 lbs N/1000 sq ft, PCSCU - 0.08 lbs N/1000 sq ft, organic - 0.04 lbs N/1000 sq ft, control - 0.02 lbs N/1000 sq ft,
- Greatest losses during winter

Carbon

- Thatch has high microbial content, compared to underlying soil. Soil beneath thatch develops a carbon sink. - Raturi et al. (2004)

Clippings

- Starr and DeRoo (1981)
- 4 lbs N/1000 sq ft, 2 applications (May, Sept.)
- Sandy loam, CT, Ky Bluegrass, 3 years, 4 plots
- Total dry matter from clippings greater where clippings returned
- Total nitrogen taken up in plant greater where clippings returned

Some Sort of Summary

- Evidence of NO3-N movement into 6-12” and 12-18” depths (i.e.leaching below root zone)
- Soluble N lost over winter
- Fall fertilization loses less NO3-N than spring fertilization
- Amount of leaching increases as load increases
- Organic N accumulates under turf as the turf ages. Accumulation occurs during the first 10 years.
- Mature turf sites begin to leach at higher rates and should be fertilized at a reduced rate to minimize potential for nitrate leaching

More Summary

- Compaction below 2 inches does not recover after 12 years of turf growth
- NO3-N runoff losses greater from treatments than from control, but still low
- Turfgrass stands reduce sediment loss
- Overwatering increases volitilization N loss
- Overwatering increases leachate loss
- Nitrate leaching rates are 4 to 8 times less than corn.
- Only urea appears to greatly exacerbate leaching. All slow release fertilizers reduce leaching.
- Total nitrogen taken up in plant greater where clippings returned
- Clippings returned resulted in better turf quality