1. Project number:

2. Title: Handheld Light Meters and Anion Exchange Membranes to Reduce the Threat of Water Pollution from Turfgrass Fertilizers

3. Focus Categories: NC (nitrate contamination), NPP (non point pollution), NU (nutrients) WQL (water quality)

4. Keywords: Nitrogen, Fertilizers, Water Quality Monitoring, Water Quality Management, Leaching, Solute Transport, Plant Growth, Turfgrass Management, Ion Exchange

5. Duration: 03/01/03 to 02/28/05

6. Federal funds requested: $26,690

7. Non-Federal Funds: $55,816

8. Principal Investigators: Karl Guillard, Department of Plant Science, University of Connecticut

9. Congressional District: 2nd

10. Statement of Critical Regional or State Water Problem:

Traditional agricultural crop production in southern New England has declined rapidly during the last 30 years. As urban and suburban development encroaches into rural landscapes, turf is replacing cropland as the principal managed land cover in the region. This situation is not unique to this region of the country; turf is replacing cropland along the entire Eastern Seaboard of North America. Residential and commercial lawns, golf courses, sod farms, athletic and recreational fields, parks, highway medians and shoulders, and cemeteries represent the major areas of managed turfgrass. Although these areas are not regarded as agricultural cropland, they may receive comparable or greater amounts of fertilizers than are applied to cropland.

Nonpoint source contamination of surface and ground water by nitrogen (N) has been widely documented and attributed principally to agricultural and urban/suburban runoff and leaching. In Connecticut, median concentrations of nitrate-N ($NO_3$-N) in ground water have been reported to be more than 5 to 20 times higher under agricultural and residential land uses than under forested undeveloped land (Grady, 1994; Zimmerman et al., 1996). It was concluded that sources of $NO_3$ in ground water under unsewered residential areas were attributed mainly to on-site septic effluent, but the median $NO_3$-N concentration was similar to the median concentration measured in ground water under sewered residential areas (Grady, 1994) . Increased lawn and garden fertilizer use was suspected as the cause for the additional sources of N in the sewered areas, thereby replacing the release of N from on-site domestic septic systems as the principal source of this constituent in ground water. Earlier studies have suggested that the fertilization of lawns has a high potential to degrade water quality in this region (Baier and Rykbost, 1976).

Many aquatic environments are N-limited and relatively small concentrations of this nutrient can accelerate eutrophication. Because a large land area devoted to fertilized turf (residential and commercial lawns, golf courses, athletic and recreational fields, sod farms, parks, etc.) in Connecticut and other Eastern states is located adjacent to pond, lake, river, and coastal shorelines, N losses from turf may contribute significantly to the degradation of sensitive N-limited ecosystems when the total N load over a larger geographical area is considered. This is particularly critical for Connecticut coastal, bay, and estuarine ecosystems that have been documented as experiencing frequent hypoxia events attributed to nonpoint sources of nutrients (LISS, 1990).

11. Statement of Results or Benefits:

Despite concerns with N fertilizer losses from turf, there has been relatively little research and improvements in traditional fertilization practices of turfgrass in the past 30 years. There are no soil-based N tests currently used to reliably guide N fertilization for turf, and only a scant few golf course superintendents use tissue N testing on a routine basis. The majority of turf managers and homeowners still rely on decades-old fertilization recommendations and practices where N is applied on a schedule at a set rate (usually 1 lb N / 1,000 $ft^2$ at each application) rather than being based on nutrient availability as measured by an objective testing method like a soil test. Soil tests are now routinely used in agricultural crop production, and expected as part of nutrient management plans for most crops. It is time for such tests to be developed and implemented for turf. The problem is that up until now, no reliable N test has been developed for turf. Preliminary data from my laboratory suggest that handheld meters and anion exchange membranes (AEMs) have great potential in fine-tuning N management for turf

Establishment of a database utilizing tristimulus and reflectance meter readings and desorbed nitrate-N from AEMs will allow for the development of a rapid and reliable N management program for turf that can be customized for specific sites and not based on subjective determinations. Quantitative measurements that allow determination of optimum N fertilization to turf will decrease the chances of excessive N fertilization that can cause pollution problems. Reduction of N loading to surface and ground water is a goal of state and federal agencies such as the CT DEP and US EPA and is contained within the program areas determined to be of special concern by the Northeast Regional IWR Program. The results of this research will have wide applicability throughout the region and will provide the framework for the development and implementation of educational programs designed to minimize pollution of sensitive N-limited ecosystems located near urban and suburban areas from over-fertilized lawns, golf courses, athletic fields, parks, and sod farms.

12. Nature, Scope, and Objectives of the Research:

It can be reasonably expected that the results of the proposed work will provide conclusive evidence to show that AEMs and handheld meters can provide rapid, site-specific recommendations to optimize N management for various turfgrasses used for various purposes. It is my belief that these technologies, once refined, will provide professional turf managers, lawncare companies, and homeowners a more reliable tool by which to gauge the efficiency of their N management programs for turf areas.

Currently, no reliable soil-based N test is used for turf. Therefore, N management for turf traditionally has been based on subjective quality responses or on historical fertilization programs set on a schedule with predefined rates. No attempts are made to take into account the existing available N or N-supplying capacity of the soil. Tissue testing is another method available for nutrient management in turf, but is expensive and only a few golf courses with large budgets are capable of using the test on a routine basis. Furthermore, few calibration studies have been published that establish critical tissue levels for turf quality or performance. Preliminary greenhouse studies from my laboratory indicate that soil nitrate-N, desorbed from AEMs, has great potential to predict the clipping yields (Fig. 1). The data show that clippings will increase with increasing N availability in the soil. The quality of the turf (color, density), however, does not increase past a critical level of nitrate desorbed from the AEM (data shown below). This suggests that more N applied to turf only increases the need for mowing and increases the probability of N loss, and does little to improve the quality of the turf once a sufficient level of availability is reached.

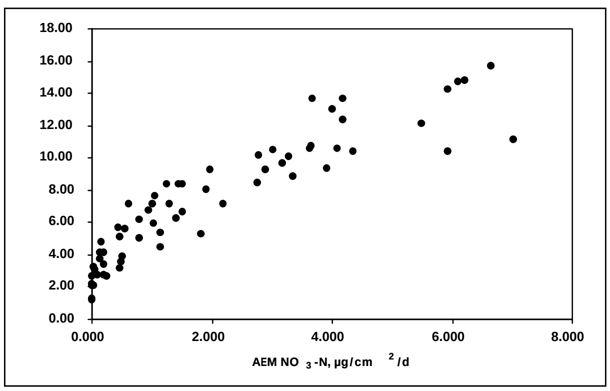


Fig 1. Relationship between soil nitrate-N desorbed from AEMs and clipping yields of a Kentucky bluegrass-perennial ryegrass-red rescue mixture.

Current research from my laboratory also suggests that tristimulus and reflectance meters have great promise as tools that can be used in the N management of turf. The Minolta chroma meters allow turf color to be quantified, which up until now, has been subjectively based on a relative rating scale for color (1=yellow, 9=dark green). Slight color changes that are not discernable with the eye, can now be measured very accurately with these tristimulus meters.

The Spectrum CM-1000 is a new handheld meter that reportedly gives readings that can be correlated to tissue chlorophyll. We have measured chlorophyll concentrations of turf in an ongoing study and correlated those concentrations with readings from the Spectrum meter. Preliminary results suggest that readings from the meter can be highly correlated with chlorophyll, measured by wet chemistry methods, and to hue angle (color) as measured with a tristimulus meter (Fig. 2).

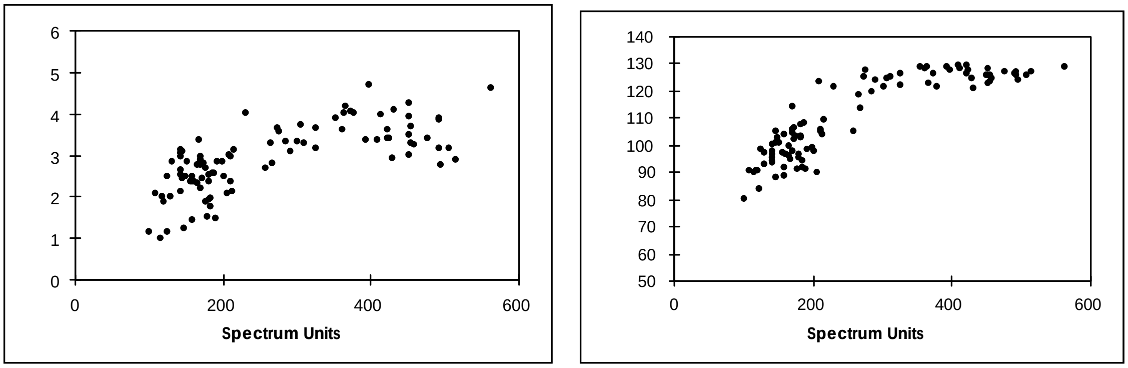


Fig 2. Relationship between chlorophyll content (measured by standard wet chemistry methods) and hue angle (color) of a Kentucky bluegrass-perennial ryegrass mixture and reflectance units from the Spectrum CM-1000 meter.

Perhaps some of the most exciting preliminary data from my laboratory indicate that critical levels of soil nitrate-N can be measured by AEMs to determine maximum color and chlorophyll responses as obtained by handheld light meters (Fig. 3). The results from the combined use of meters and AEMs have significant environmental and economic implications. They suggest that it is possible to determine when color and chlorophyll can be maximized without over supplying N. These technologies will decrease the uncertainty of N management of turf, and should replace the “insurance policy” of N application based on subjective, visual determinations or set fertilization schedules.

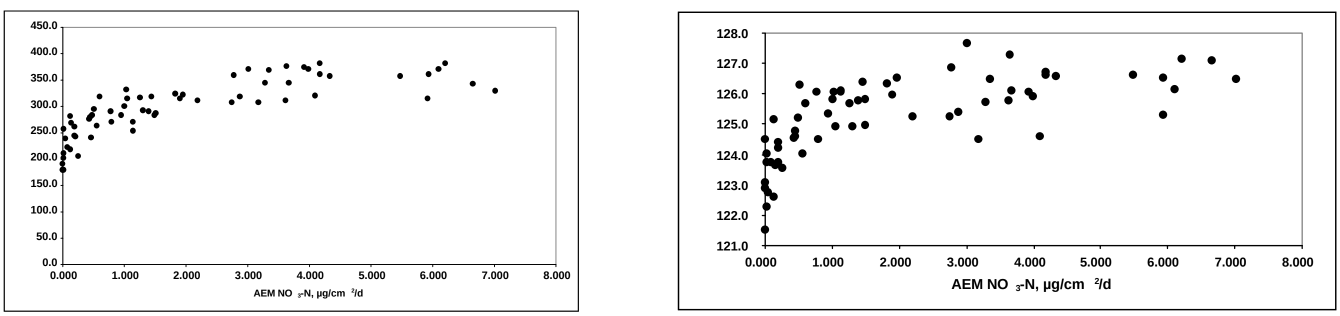


Fig 3. Relationships between hue angle (color) from Minolta CR-200 tristimulus meter and Spectrum reflectance units from a Spectrum CM-1000 meter from a Kentucky bluegrass-perennial ryegrass-creeping red fescue mxiture and soil nitrate-N desorbed from AEMs.

My data suggest that AEMs have potential to be used as a site-specific soil-based N test for turf that will account for available nitrate-N from virtually any source. Contributions of N from organic matter mineralization in turf systems are frequently overlooked or ignored in most N management programs, but AEMs will account for this and most all other sources. The AEMs also have the advantage of being much more easily used than traditional soil sampling. No cores are required. The AEMs are paper-thin strips that are inserted into the rootzone via a slit made by a mason’s trowel. They can be inserted and removed very quickly and there is less soil disturbance than core removal by probes or augers. These preliminary greenhouse results provide tantalizing evidence that N management of turf can become less subjective and more reliable with the use of handheld light meters and AEMs. More reliable N management programs for turf will lessen the potential for over-fertilization. This will decrease the N losses from turf to receiving waters, and reduce the economic loss of applying N that is not needed.

These technologies also have the potential of being used as proxies for estimating nitrate leaching losses. It is my hypothesis that a certain critical level of desorbed-N for AEMs or readings from the handheld light meters will correlate well with nitrate leaching losses from turf. This, of course, remains to be determined.

Objectives:
The overall goal of the proposed research is to show that handheld tristimulus and reflectance meters and AEMs can be used as tools to guide N fertilization management of turf. Most of my preliminary work was conducted under a controlled environment in the greenhouse and now must be confirmed with field studies.

The specific objectives of the proposed research are:

- Determine the relationship between tristimulus and reflectance meter readings and turf color quality responses under field conditions.

- Determine the relationship between soil nitrate-N (desorbed from anion exchange membranes) and turf growth responses under field conditions.

- Determine the relationship between tristimulus and reflectance meter readings and soil nitrate-N (desorbed from anion exchange membranes) under field conditions.

- Determine the relationship between soil nitrate-N (desorbed from anion exchange membranes) and nitrate leaching from turf soil monolith lysimeters under controlled conditions.

13. Methods, Procedures, and Facilities:

Field experiments. A field study will be conducted at the University of Connecticut's Plant Science Research and Teaching Facility using established plots of Kentucky bluegrass. This species will be selected because it is the most widely used turfgrass in our climate for lawns, golf courses, athletic fields, parks, and sod farms. The experiment will be set out as a replicated, randomized complete block designs with varying N fertilizer rates. Treatments will consist of nine N fertilization rates: 0, 0.1, 0.2, 0.4, 0.6, 0.8, 1.0, 1.5, and 2 lbs N per 1000 $ft^2$ per month. Applications will be made in May through October, resulting in a total rate of 0, 0.6, 1.2, 2.4, 3.6, 4.8, 6.0, 9.0, and 12.0 lbs N per 1000 $ft^2$ per season. This range of rates includes those applied by turf professionals and homeowners or lawncare companies, and should provide a wide range of soil nitrate levels by which to model turf responses. Other nutrient needs will be determined by soil tests. Irrigation and pest control will be provided as needed. Plot sizes will be 5 by 5 ft.

The AEMs (type 204-U-386) used in this study are made of cross-linked vinyl copolymer reinforcing fabric embedded with $NH_4^+$ anion exchange groups (Ionics, 1990). Anion exchange membranes will be inserted into each of the plots to monitor soil nitrate dynamics *in situ*. Three strips of pre-treated AEMs each measuring 6.25 cm long by 2.5 cm wide will be placed in each of the plots via a vertical slit made in the soil using a hand trowel. This will place the AEMs in the most active nutrient uptake region of the turfgrass roots (between 2 and 4 inches below the soil surface). Complete contact will be established between the AEMs and the soil by pressing the slit closed by hand and lightly stepping on it. A monofilament line is attached to the AEMs to facilitate removal and small flags will mark points of insertion. The AEMs will be collected from the plots at two-week intervals across the growing season. Immediately upon removal of the AEMs from the plots, new AEMs will be inserted. Nitrate-nitrogen sorbed on the AEMs will then be extracted and determined by using a cadmiumreduction, colorimetric method on a Scientific Instruments Continuous Flow Analyzer (WESTCO, Danbury, CT).

A Minolta CR-200 tristimulus light meter will be used to determine hue angle (color), lightness (brightness of color), and chroma (saturation of color) of the turf. These readings provide a quantitative measurement of turf color that typically is appraised on a subjective, visual rating scale. A Spectrum CM-1000 reflectance meter will be used to estimate chlorophyll content in the leaf tissue. Tristimulus and reflectance meter readings will be taken every two weeks during the growing season to correspond with AEM analyses.

Measurements for turf will include shoot growth (clipping yields), shoot density, color (hue, lightness, chroma), chlorophyll concentration, and total N concentration. These variables will be correlated to meter readings and nitrate-N desorbed from AEMs. Plateau models (linear, quadratic) and/or Cate-Nelson techniques will be used to analyze the response curves resulting from these analyses. If the meters and AEMs are effective methods to measure turfgrass growth and quality responses, critical values for soil nitrate-N or meter readings needed for optimum response (plateau values) will be obtained for the dependent variables.

Leaching Studies. This study will determine if desorbed nitrate from AEMs, or readings from light meters can be used to predict nitrate leaching losses. It will be conducted in the greenhouse for the following reasons: 1) soil monolith lysimeters are already available and preliminary data have been collected from them (Figs. 1 and 3), and 2) large scale field lysimetery studies would be cost prohibitive for this program. The leaching data collected from this proposal would be used to attract funding from other extramural sources. The soil monolith set-up consists of 64 undisturbed soil columns that were collected from a sod farm in Wethersfield, CT. The soil at the site was an Agawam fine sandy loam (coarse-loamy over sandy, mixed, active, mesic Typic Dystrudept). Schedule 40, polyvinylchloride (PVC) pipe was cut into 64 columns measuring 20.3-cm in diam. and 76.2-cm in length. The bottom end of each column was beveled to a 45º angle using a router to facilitate pressing into the soil. The columns were pushed into bare soil using the bucket of a tractor with a front-end loader until about 3 cm of PVC pipe remained above ground. Once all of the columns had been pressed into the ground, trenches were dug around them and they were broken off at the base with a slight push. Both ends of the columns were wrapped in plastic to prevent desiccation and they were transported to the Plant Science Research and Teaching Farm in Storrs.

At the Plant Science Research and Teaching Farm, four wooden frames were constructed on four greenhouse benches to hold 16 columns each. High-density polyethylene (HDPE) funnels were placed in the base of the wooden frames to support the columns. Funnels were lined with glass fabric and then filled with pea stone to support the soil in the columns. Glass fabric was also placed between the soil at the base of the columns and the pea stone to prevent soil loss. Flexible PVC tubing (2.54-cm diam.) was run from the funnel outlets to collection vessels beneath the columns. Low-density polyethylene (LDPE) containers of 1 L are used as collection vessels for column effluent. An automated irrigation system is arranged using drip stakes (1.44 L per hour) to irrigate the soil columns to provide the equivalent of 1 inch (2.5 cm) of precipitation weekly.

The columns will be seeded to a Kentucky bluegrass blend and allowed to establish before experimental treatments are applied. The experiment will be arranged in a randomized complete block design with four replicates. Treatments will consists of 16 N fertilization rates: 0, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1.0, 1.2, 1.4, 1.6, 1.8, and 2 lbs N per 1000 $ft^2$ per month. Applications will be made in May through October, following the current scheduling of turf fertilization in New England. Reagent grade $NH_4NO_3$ will be dissolved in deionized water and applied to the columns at the designated rates. A soil test will determine appropriate amounts of K and P needed.

After the first N application, the turfgrass in the columns will be clipped every two weeks by hand, and measured using the light meters. The clippings will then be dried in a forced-draft oven (70• C) until a constant weight is reached, and ground in an Udy Mill to pass through a 0.5-mm screen.

Clippings will be analyzed for total N concentrations by using a LECO FP-2000 Carbon/Nitrogen Analyzer.

Since I cannot simulate a winter period in the greenhouse that would cause the cessation of turf growth and induce dormancy, the upper 2.5 cm of turf sod in the columns will be cut and removed from the columns after the natural growing season ends in November. This will be done to prevent continual uptake of fertilizer N that naturally would not occur and allow for N to leach from the columns during a period of minimal turf growth that receives precipitation. I realize that this is not ideal, but it is not far from actual practices that would occur on a turf sod farm that harvests sod late in the fall and early winter.

Percolate samples will be collected weekly and volume will be determined. Subsamples of the percolate (25 to 50 ml) will be taken to the laboratory for $NO_3$-N concentrations on a Scientific Instruments Continuous Flow Analysis System (WESTCO, Danbury, CT) using a Cd-reduction, colorimetric method. When $NO_3$-N concentrations are below the detection limit of 0.05 mg $L^{-1}$, a value of 0.025 mg $L^{-1}$ will be substituted. The mass of $NO_3$ leached will calculated as the concentration of $NO_3$-N $\times$ percolate volume. Flow-weighted $NO_3$-N concentrations were calculated as the total mass of $NO_3$-N leached divided by the total volume of percolate collected. Percentage of applied N lost by leaching was calculated after subtracting losses of N from the unfertilized control.

Nitrate leaching losses and meter readings will be correlated to nitrate-N desorbed from AEMs. Plateau models (linear, quadratic) and/or Cate-Nelson techniques will be used to analyze the response curves resulting from these analyses.

Facilities and Equipment

The Research Laboratory for Soil, Water, and Tissue Analyses in the Department of Plant Science and the University of Connecticut Soil Nutrient Testing Laboratory will be available for the sample preparation and analyses. The following pieces of equipment relevant to the project are located in these laboratories:

- Analytical balances
- Apple PowerMac G3
- Backsaver soil augers
- Barnstead NANOpure ultrapure water system
- Fisher Scientific combination pH/ion meter
- Fisher Scientific incubator
- Fisher Scientific Isotemp oven
- Fisher Scientific refrigerator
- Gateway 2000 P5-133 and 166
- Hamilton microlab 500 dilutor/dispenser
- LabConCo pipetter
- LECO FP-2000 Carbon and Nitrogen Analyzer
- Minolta CR-200b chroma meter
- Orbital shaker
- Scientific Instruments Continuous-Flow Analyzer with computer data acquisition interface
- Spectrum CM-1000 Chlorophyll meter

A large machine and fabrication shop is available for the construction of lysimeters and the maintenance of field equipment. In addition, the Water Quality Analysis Laboratory of the Department of Natural Resources Management and Engineering has a Latchat Flow Injection System that can be used as a backup for nitrate analyses.

14. Related Research:

There are many existing methods for monitoring available N in soils. Traditional chemical extractions are the most common methods, however, these measurements provide only a "snapshot" measurement of available N. They are unable to measure fluxes that occur with changing environmental conditions. Exchange resins, in the form of capsules or spheres, provide another technique for measuring available soil N (Binkley and Hart, 1989). Exchange resins are superior to traditional methods because they are able to measure N availability with time. Even so, the three-dimensional nature of exchange resins necessitates a great deal of soil disturbance when they are deployed. Consequently, *in situ* conditions, as well as the measure of available soil N, are compromised. In addition to concerns regarding soil disturbance, the prevailing view of exchange resins as "infinite sinks" to which ions may be adsorbed but never desorbed limits their use as an index of bioavailability (Cooperband and Logan, 1994). A further limitation of exchange resins involves their three-dimensional (3-D) nature. Because of their 3-D shape, exchange resins do not completely contact the soil. Furthermore, it is possible that the adsorption of ions by resins is governed by two distinct diffusion coefficients, an internal and an external coefficient (Cooperband and Logan, 1994). Therefore, there is uncertainty in the calculation of exchangeable nutrients on a per weight basis from data collected using exchange resins. This is of particular concern when exchange resins are not in contact with soil long enough to negate diffusion limitations (Bhadoria et al., 1991).

Ion exchange membranes (IEMs), by virtue of their two-dimensional nature and dynamic exchange properties, provide an alternative to traditional measurements of available soil N and exchange resin techniques (Abrams and Jarrell, 1992). The nascent study using IEMs for measuring *in situ* soil N availability was performed by Subler et al. (1995) and involved the use of AEMs buried in a silt-loam soil with various amendments. Subler et al. (1995) found that AEMs successfully measured soil N processes and availability during a one-month period in soils with widely variable mineralization-immobilization rates. Other important findings of Subler et al. (1995) were that nitrate uptake by AEMs was non-linear with time and that the membranes had the potential to influence some soil processes. However, they acknowledged the potential influence of the small amounts of soil used in the study (20 g) and suggested that in the field, the AEM techniques' influence on soil processes might be relatively small.

Subsequent studies using AEMs to measure available soil N have been performed. Pare et al. (1995) compared soil nitrate extracted by KCl to that adsorbed by AEMs and found that the quantity of nitrate-N adsorbed on AEMs was correlated ($R^2$=0.78) to the amount extracted using the traditional KCl method. Qian and Schoenau (1995) assessed the contribution of N mineralization from soil organic matter to plant-available N using AEMs and correlated the results to a 0.001 *M* $CaCl_2$ extraction. They found that two-week AEM incubations were more closely correlated with plant N uptake than were $CaCl_2$ extractions. Wander et al. (1995) compared AEM extractions to traditional KCl extractions for measuring changes in nitrate concentration in a field over winter and found that $NO_3^-$ availability declined with both methods. However, only the AEM method produced statistically significant results.

Anion exchange membranes have been used in the field to measure nitrate fluxes in soils of grass hay crops. In a field study of grasslands, Ziadi et al. (1999) found that nitrate fluxes from AEMs were significantly correlated to water-soluble nitrate concentrations in soil and that nitrate sorbed on AEMs increased as N fertilization rates increased. In addition, forage uptake of N was better related to fluxes of desorbed nitrate from AEMs than to water-soluble $NO_3^-$ concentrations measured in the soil (Ziadi et al., 1999). Collins and Allinson (1999) reported that AEMs had highly significant relationships to relative yield and applied N rates in grasslands. In addition, they were able to predict a critical level of nitrate -N in the soil, as measured by AEMs, necessary to reach maximum yield during two harvest periods.

Anion exchange membranes have great potential to assess nitrate relationships in turfgrass. Simard et al. (1998) reported the preliminary results of a study in which the decreasing N content in cuttings from bentgrass (*Agrostis stolonifera* L.) golf greens was related to similar decreases in nitrate desorbed from AEMs. Simard et al. (1998) corroborated the results of Pare et al. (1995) and Wander et al. (1995) in finding that nitrate fluxes from AEMs were better related to plant N uptake than were traditional KCl extractions of soil. Kopp and Guillard (2002) reported that AEMs had promise for use in turfgrass N management. They were able to show that desorbed nitrate from AEMs placed in the rootzone of lawn turf could predict turf growth and quality during certain times of the growing season. This study, however, lacked a wide range of soil nitrate values and accurate critical values were not predicted because of gaps in the data.

Assessing N deficiency in turfgrass is relatively easy due to the chlorotic color that generally accompanies insufficiency as well as decreased tillering and shoot density. However, it is difficult to determine when turfgrass has reached sufficient or optimum N status without exceeding optimum levels. In these situations, reflectance light meters may prove to be superior to subjective visual determinations. Thorogood (1995) reported that turfgrass color could be described in several numerical parameters using a Minolta chroma meter. In particular, hue angle could be used to note color change in turfgrasses due to varietal differences, changing environmental conditions, or the interaction of these variables. Landschoot and Mancino (2000) concluded that a Minolta chroma meter could be used to measure the relative color differences of bentgrass cultivars and provide a consistent measurement among evaluators. New methods for determining the optimum N status in turfgrass need to be developed so that N fertilizers are not over applied, threatening water quality of receiving waters.

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15. Investigator's Qualifications:
CV attached

16. Training Potential:
One Agronomy graduate student (Ph.D. level) will be involved in all field, laboratory, and/or data analyses aspects of the project. Two undergraduate students (one Agronomy and one Environmental Science) will assist the PI and graduate student in field and laboratory activities.

17. Information Transfer Plan:

A. This study will demonstrate that N fertilizer losses from turf can be decreased by using AEMs and handheld light meters to guide fertilization. Lower amounts of fertilizer applied to turf is less susceptible to loss by leaching or runoff.

B. Results of the study will be directed towards individuals and associations that utilize and manage turf. This would include, but not be limited to: homeowners, commercial lawncare companies, the Connecticut Groundskeepers Association, Connecticut Association of Golf Course Superintendents, New England Sod Producers, New England Sports Turf Managers Association, and municipal officials responsible for water quality issues. Lake associations and wetland commissions will also be interested in turf practices that reduce the potential for nutrient contamination of water. Academic interests will be served by information about fate and transport of nutrients in a turf system.

C. Fact sheets detailing the results of the studies will be published through the New England Consortium. The University of Connecticut Soil Testing Laboratory will supply information to homeowners about lawn-care BMPs when soil sample results are returned. Newspaper and trade journal articles will reach a large number of homeowners and lawn-care practitioners. Articles will be posted on the Cooperative Extension System's Residential Water Quality web site and should be applicable for posting on the IWR's web site. The data will be presented to the Northeast Regional Committee on soil testing for distribution in the mid-Atlantic region. The water quality data will be shared with personnel from the Bureau of Water Management of the Connecticut Department of Environmental Protection and to the various state Soil and Water Conservation Districts. This information will be pertinent to newsletters and fact sheets produced by these agencies in addition to newsletters produced by the various professional turf related associations in the state. Preliminary results of the project will be reported at state and regional professional lawncare meetings, and at academic regional and national meetings and conferences. Final results will be submitted to peer-review journals for publications.

D. In addition to faculty from the Department of Plant Science, the following agencies or associations will be utilized for information transfer: University of Connecticut Extension System , The Bureau of Water Management of the Connecticut Department oEnvironmental Protection, state Soil and Water Conservation Districts, the Connecticut Groundskeeper's Association, Connecticut Association of Golf Course Superintendents, New England Sod Producers, and New England Sports Turf Managers Association.