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

Basic Information

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Principal Investigators:	Karl Guillard, Karl Guillard

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1. Mangiafico, S.S. and K. Guillard, 2004, Use of Anion Exchange Membranes to Estimate Turfgrass Growth and Quality, in Agronomy Abstracts: Proceedings of the National Meeting of the American Society of Agronomy, Madison, WI.
2. Mangiafico, S.S., and K. Guillard, 2006, Anion Exchange Membrane Soil Nitrate Predicts Turfgrass Color and Yield, Crop Science, 46, 569-577
3. Mangiafico, S.S., and K. Guillard, 2005, CateNelson models of turfgrass relative color and yield predict critical AEM soil NO3N concentrations, In Northeast Branch Agronomy abstracts, ASA, Madison, WI.
4. Mangiafico, S. S. and K. Guillard, 2004, Desorbed Nitrate from Anion Exchange Membranes as a Predictor of Nitrate Leaching and Turfgrass Color., in Agronomy Abstracts: Proceedings of the National Meeting of the American Society of Agronomy, Madison, WI.
5. Mangiafico, S.S., and K. Guillard, 2006, Nitrate leaching from Kentucky bluegrass soil columns predicted with anion exchange membranes, Submitted to Soil Sci. Soc. Am. J, Vol, Pages.
6. Mangiafico, S.S., and K. Guillard, 2006, Cool-season lawn turfgrass color and growth calibrated to leaf nitrogen,Submitted to Crop. Sci.

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Final Report of the Project:

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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. Although these areas are not regarded as agricultural cropland, they may receive comparable or greater amounts of fertilizers than are applied to cropland. Because a large land area devoted to fertilized turf (residential and commercial lawns, golf courses, athletic and recreational fields, sod farms) 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 non-point sources of nutrients. Despite concerns with nutrient 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 guide N fertilization for turf, and only a 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 where N is applied on a schedule or at set rates based on history rather than being based on criteria of nutrient availability provided by an objective testing method like a soil test. This increases the likelihood of excess N applications that threaten water quality. Preliminary data suggest that handheld meters and anion exchange membranes (AEMs) have potential in fine-tuning N management for turf. Establishment of a database utilizing tristimulus and reflectance meter readings and desorbed nitrate–N (NO_3–N) from AEMs will allow for the determination of optimum N fertilization to turf that will decrease the chances of excessive N fertilization that can cause pollution problems.

Research Objectives

- Determine the relationship between AEM soil NO_3–N and turf growth and quality responses.

- Determine the relationship between AEM soil NO_3–N and nitrate leaching from turf.

- Determine the relationship between AEM soil NO_3–N and nitrogen recovery by turfgrass.

- Determine the relationship between color and reflectance meter readings and NO_3–N leaching from turf.

Methodology

Field experiments were conducted across two years at the University of Connecticut's Plant Science Research and Teaching Facility using established plots of mixed-species cool-season turfgrass managed as home lawns. Treatments consisted of nine N fertilization rates: 0, 5, 10, 20, 30, 40, 50, 75, and 100 kg N per hectare per month. Anion exchange membranes were inserted into each of the plots and replaced on two-week intervals to monitor soil nitrate dynamics *in situ*. A Minolta CR-400 tristimulus chroma meter and a Spectrum CM1000 chlorophyll meter were used to determine hue (greenness), lightness (brightness of color), chroma (saturation of color), and relative chlorophyll content of the turf. Measurements of the turf included shoot growth (clipping yield), color (hue, lightness, chroma), relative chlorophyll content (Spectrum CM1000 index), and total N concentration. These variables were correlated to nitrate–N desorbed from AEMs. Curvilinear models were used to suggest critical values for soil nitrate–N corresponding to optimum turf responses.

A soil monolith lysimeter experiment was conducted across two years in a greenhouse and consisted of 64 undisturbed soil columns that were collected from a sod farm in Wethersfield, CT. The columns were seeded to a Kentucky bluegrass blend and fertilized with 16 rates of N: 0, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 60, 70, 80, 90, and 100 kg N per hectare per month. Anion exchange membranes were inserted into each column and replaced on two-week intervals. A Minolta CR-200 tristimulus chroma meter and a Spectrum CM1000 chlorophyll meter were used to determine turf color quality, and clipping yield and total N concentration were measured every two weeks. The columns were irrigated weekly at 2.5 cm per week. The upper 1.5 cm of turf sod in the columns was removed after the natural growing season ended in November and irrigation was continued. This was done to prevent continued uptake of fertilizer N and allow for N to leach from the columns during a period of minimal turf growth, which would occur naturally during the winter and before regrowth in the spring. Percolate samples were collected weekly and analyzed for concentrations of NO_3–N. Nitrate leaching losses and meter readings were correlated to nitrate–N desorbed from AEMs. Curvilinear models were used to relate nitrate leaching to AEM soil NO_3–N and reflectance meter measurements.

Principle Findings and Significance

Results from the field study suggest that AEM desorbed soil NO_3–N can be used to predict a critical soil nitrate level needed for maximizing turf color and growth (Fig 1). Little change was noted in greenness of the turf (CIE hue), relative chlorophyll content (CM1000 index), and growth (clipping yield) above an AEM desorbed NO_3–N value of approximately 3 $\mu g/cm^2/day$. Any further increase in available soil N did not increase turf greenness, but presumably increased the chance of N losses with excess soil NO_3–N.

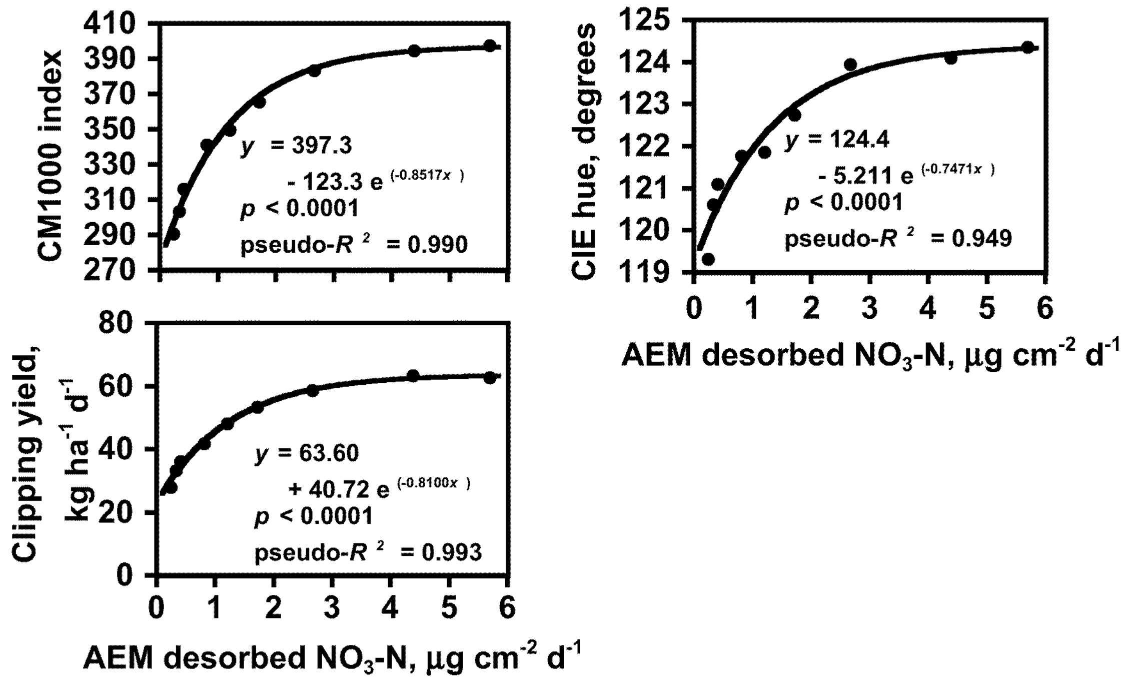

Fig 1. Relationship between soil nitrate–N desorbed from anion exchange membranes (AEMs) and CIE hue (greenness), CM1000 index (relative chlorophyll), and clipping yield (growth) collected from a Kentucky bluegrass–perennial ryegrass–creeping red fescue lawn. Each data point represents the mean of three replications averaged across two growing seasons.

Linear plateau models were found relating deviations from plateau values for clipping yield, CIE hue, and CM1000 index to leaf N concentration, for data pooled across sample dates, for the field experiment (Fig. 2). Critical concentrations in leaf N ranged from 29.2 to 31.7 g N kg^{-1} across clipping yield, CIE hue, or CM1000 index measurements. Approximate 95% confidence intervals constructed for estimates of the critical concentrations from these models were 26.9 to 31.6; 25.7 to 37.7; and 27.6 to 32.4 for clipping yield, hue, and CM1000 index, respectively. These confidence intervals may give some further indication of reasonable optimum ranges considering the variability of the pooled data. These models indicated small marginal improvements in growth or color when leaf N exceeded 28 g kg^{-1}, suggesting that a leaf N test can separate turf with optimum leaf N concentrations from turf with below optimum leaf N concentrations. Plateaus in leaf N concentrations with increasing N fertilizer rates suggest, however, that this test may be unable to identify sites with excess N.

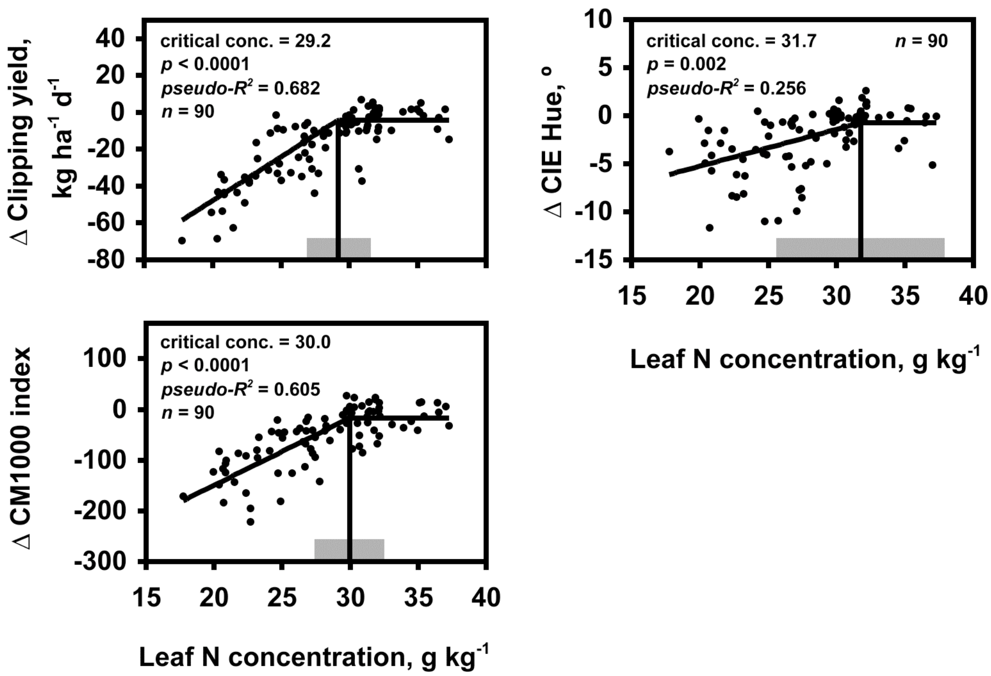

Fig. 2. Deviations from plateau turfgrass clipping yield, CIE hue, and CM1000 in relation to leaf N concentration for a mixed cool-season species lawn in Connecticut. Data are pooled from 10 sample dates across two growing seasons. Linear plateau models are shown. *Critical conc.* and vertical lines to the *x*-axes indicate critical concentrations from linear plateau models. Gray boxes on the *x*-axes indicate the extent of approximate 95% confidence intervals for the critical concentrations. Number of observations per plot is indicated by *n*.

In the column study, significant exponential ($p < 0.05$) models were found relating percolate flow-weighted mean NO_3–N concentration (Fig. 3A), cumulative NO_3–N mass in percolate (Fig. 3B), and cumulative mass as fraction of N applied (Fig. 3C) to AEM desorbed soil NO_3–N. A mean percolate NO_3–N concentration below the EPA maximum contaminant level (MCL) for drinking water of 10 mg NO_3–N L^{-1} was found for a mean AEM soil NO_3–N value of 2.9 μg cm^{-2} d^{-1} (Fig. 3A). Similarly, based on the curvature of the model, Fig. 3B suggests moderate cumulative percolate NO_3–N mass when AEM soil NO_3–N values did not exceed about 3 μg cm^{-2} d^{-1}. The fraction of applied N collected as NO_3–N in percolate generally increased as AEM soil NO_3–N increased (Fig. 3C). As a percent of N applied, mass loss in percolate predicted by the exponential model ranged from about 7% to 28% across treatments (Fig. 2 C). Because percolate NO_3–N concentrations of environmental concern may be much lower than the US EPA MCL for drinking water, target soil NO_3–N values should probably be lower than those producing percolate concentrations close to the US EPA MCL.

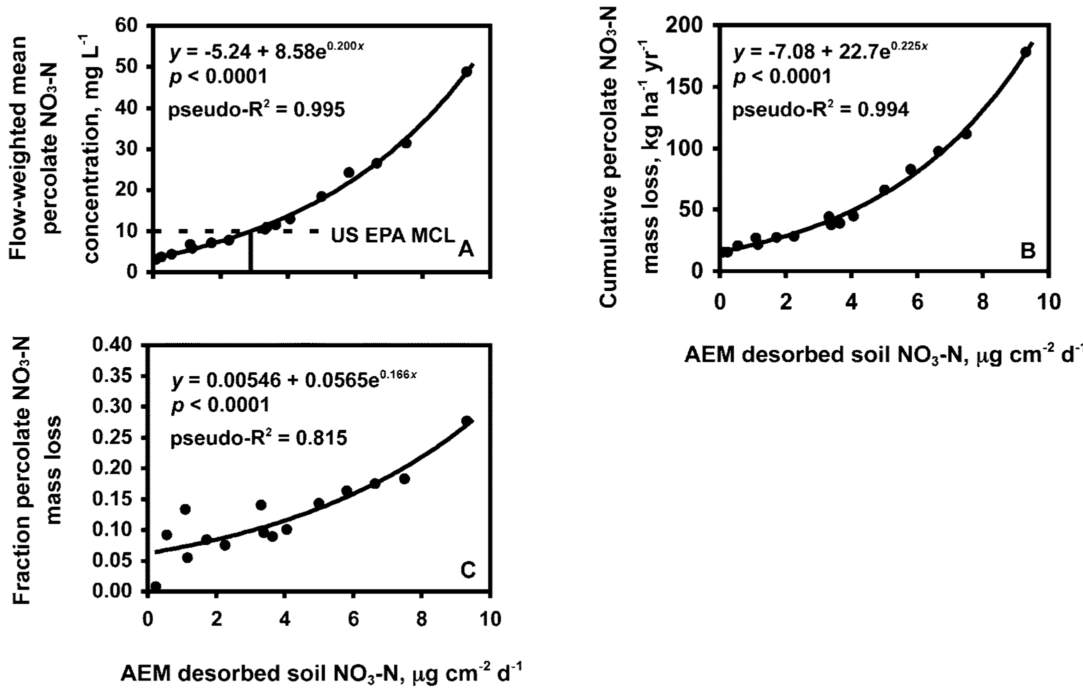

Fig 3. Flow-weighted mean NO_3–N concentration (A), cumulative NO_3–N mass (B), and cumulative mass as fraction of N applied (C) of percolate water from intact soil columns of fine sandy loam soil below Kentucky bluegrass (*Poa pratensis* L.) turf. Percolate data was collected on 54 dates across two yr, and is plotted in relation to mean soil NO_3–N desorbed from *in situ* anion exchange membranes (AEM). A fitted exponential curve is shown for each plot. Dashed horizontal line represents the US EPA maximum contaminant level (MCL) for drinking water of NO_3–N of 10 mg L^{-1}. Vertical line to the *x*-axis represents the soil NO_3–N value corresponding to the MCL.

Cumulative N uptake increased with increasing AEM soil NO_3–N, to a model-predicted maximum at 8.2 µg cm^{-2} d^{-1} of AEM soil NO_3–N (Fig. 4A). Apparent N recovery ranged from about 30% to 40% of applied N with a maximum corresponding to 4.7 µg cm^{-2} d^{-1} AEM soil NO_3–N (Fig. 4B). These results suggest that increased leaching losses may be a result of less efficient recovery of N by turf when AEM soil NO_3–N was above 4.7 µg cm^{-2} d^{-1}. Below this value, however, increased leaching losses occurred with increasing AEM soil NO_3–N leaching in spite of more efficient recovery.

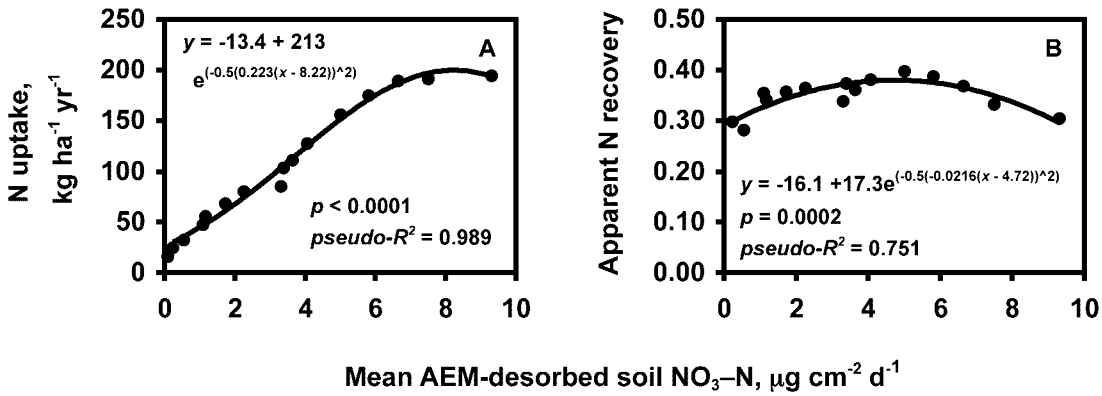

Fig 4. Cumulative N uptake (A), and apparent N recovery (B) of Kentucky bluegrass (*Poa pratensis* L.) turf in relation to soil NO_3–N desorbed from *in situ* anion exchange membranes (AEM). The turf was grown on a fine sandy loam soil in greenhouse conditions. A fitted Gaussian curve is shown for each plot. Data for AEM soil NO_3–N are averaged from 24 dates across two yr. Data for N uptake and recovery are from leaf tissue samples bulked from 24 dates across two growing seasons.

Significant ($p < 0.05$) Mitscherlich–Bray models were found relating mean chlorophyll index, hue, lightness, and yield measurements to mean AEM desorbed soil NO_3–N (Fig. 5). A higher CM1000 index implies a higher leaf chlorophyll concentration. A higher CIE hue in this range implies a greener leaf color. A lower CIE lightness implies a darker leaf color. Marginal changes in these variables with increases in AEM soil NO_3–N were greatest at low AEM soil NO_3–N values. However, these variables continued to change with increasing AEM soil NO_3–N at high AEM soil NO_3–N values. Color (Fig. 5C and D) and chlorophyll (Fig. 5A) development for our turf stand occurred at the expense of increases in NO_3–N leaching losses (Fig. 3). This effect was especially pronounced at high AEM soil NO_3–N values when incremental additions of soil NO_3–N increased turf color and chlorophyll only slightly but increased NO_3–N leaching losses exponentially. Considering this, water quality concerns would dictate that turf N application should be managed to achieve acceptable quality for intended turf use and conditions, and not to attempt to maximize turf color response.

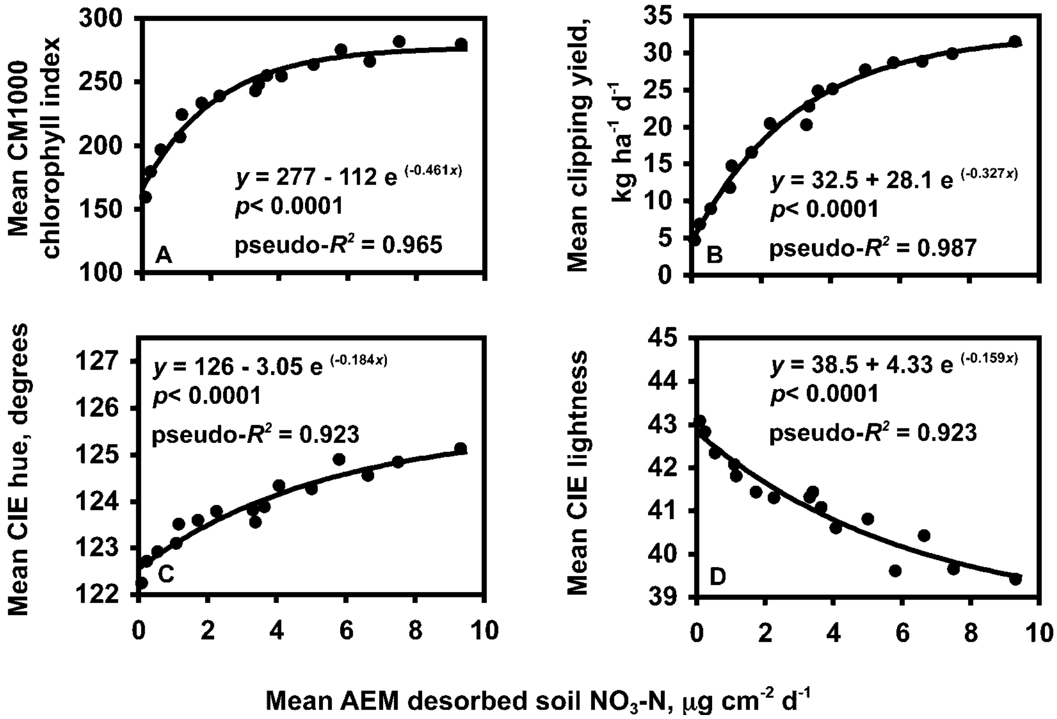

Fig. 5. Mean CM1000 chlorophyll index (A), clipping yield (B), hue (C), and lightness (D) measurements from a Kentucky bluegrass (*Poa pratensis* L.) turf plotted against mean soil NO_3–N desorbed from *in situ* anion exchange membranes (AEM). All measurements were averaged by treatment from 24 dates across two seasons. A fitted Mitscherlich–Bray model is shown for each plot. A higher CM1000 index implies a higher canopy chlorophyll content. A higher CIE hue in this range implies a greener leaf color. A lower CIE lightness implies a darker leaf color.

The chlorophyll meter was useful as well in predicting N leaching losses in the column study (Fig. 6). Nitrate–N leaching increased exponentially as turf greenness (CIE hue) and relative chlorophyll content (CM1000 index) increased. However, increases were moderate up to a CM1000 index value of approximately 250 and a CIE hue value of approximately 124. These data suggests that turf may be fertilized to some level of color quality with moderate NO_3–N leaching losses, beyond this incremental color changes will be achieved at the expense of exponentially higher NO_3–N leaching.

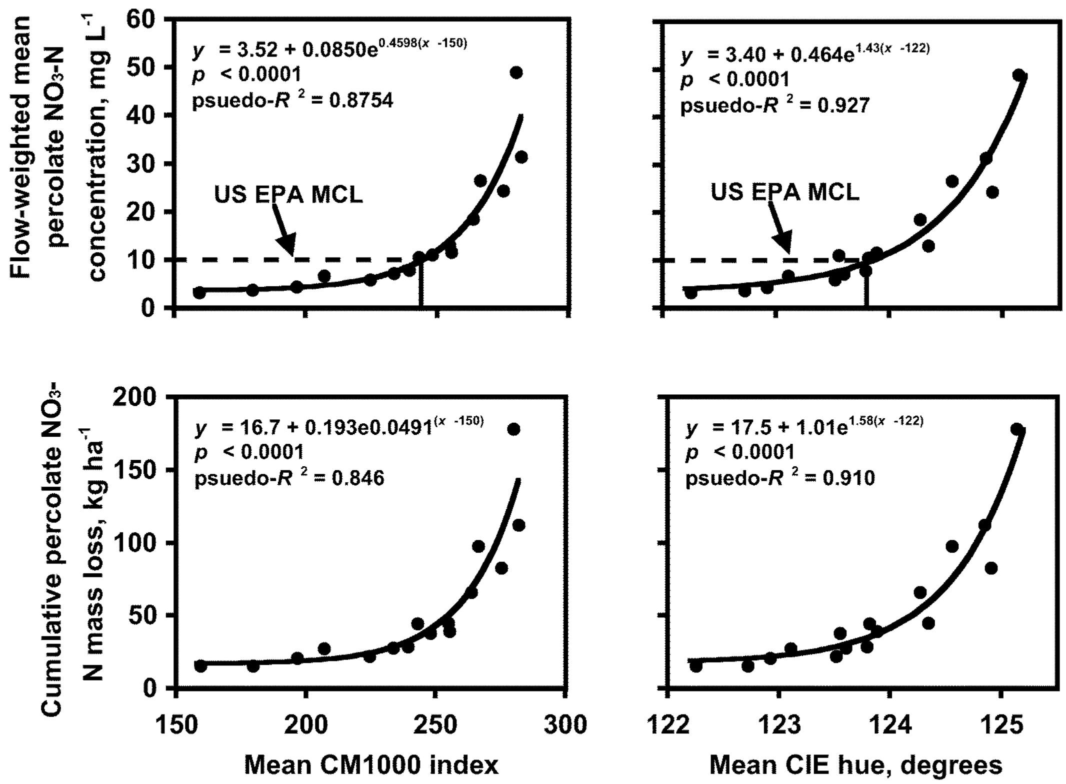

Fig 6. Relationship between CM1000 index (relative chlorophyll) and CIE hue (greenness) and flow-weighted nitrate–N concentrations and leaching losses of percolate collected from Kentucky bluegrass grown in soil columns. Each data point represents the mean of four replications averaged across two growing seasons.

Results from the field and column studies suggest that N management of turf can become less subjective and more reliable with the use of handheld reflectance meters and AEMs. The current N fertilization method for turf that relies on set schedules and set application rates increases the likelihood of over-application and a greater threat to water quality. These results caution against managing nitrogen applications to achieve color development beyond the requirements of the intended use of a specific turf stand. More objective-based tests need to be used to guide N fertilizer recommendations for turf.