CORNELL UNIVERSITY TURFGRASS TIMES

CUTT

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Nitrogen Fertilization: How Much Is Enough?

You may think there is a simple answer to how much nitrogen is needed to fertilize turf. At this time soil or tissue testing are not reliable means of determining the amount of nitrogen to apply. Often the color, density and the amount of clipping growth are used to judge the need for nitrogen. Many people also use published standard application rates as a guide, but textbooks give a large range of possible annual nitrogen amounts for each cool-season grass species or level of maintenance.

For example, in the only turfgrass textbook on soil fertility, *Turfgrass Soil Fertility and Chemical Problems: Assessment and Management*, by Carrow, Waddington and Rieke, published in 2001, the authors recommended nitrogen fertilizer amounts ranging from a low of 0.9–1.5 lbs. N/1,000 sq.ft. for a low level of maintenance, to a high of 3–6 lbs. N/1,000 sq.ft. for high maintenance turf during a six month growing season for areas like Upstate New York. The levels were slightly higher for the longer growing season in Southeastern New York.

Cornell University's recommendations for nitrogen fertilizer amounts for New York lawns in are in *Lawn Care and Water Quality Almanac* by Gussack and Rossi, published in 2000, where the amounts depend on the species of grass: Kentucky bluegrass at 3–4 lbs. N/1,000 sq.ft./yr., perennial ryegrass at 2–6 lbs. N/1,000 sq.ft./yr,, tall fescue at 2–4 lbs. N/1,000 sq.ft./yr,, and fine fescues at 1–2 lbs. N/1,000 sq.ft./yr.

Why So Different?

The range in nitrogen rates reflects that fact that site conditions and expectations vary from site to site. Factors that are important in determining the amount of nitrogen required include: soil properties (such as drainage), level of traffic, extent of irrigation, amount of sunlight, age of site (determined by how much organic matter is present), how the clippings are managed, and the desired level of quality (equivalent to the amount of maintenance). Some examples: sandy, well-drained sights may require more nitrogen; more traffic requires more nitrogen; irrigated lawns need more nitrogen; shady lawns need less nitrogen; older lawns need less nitrogen; removing clippings requires more nitrogen; and the higher the expectation of lawn quality the more nitrogen is often needed.

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This Times

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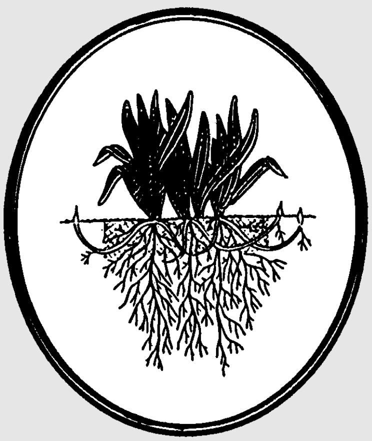
Clippings

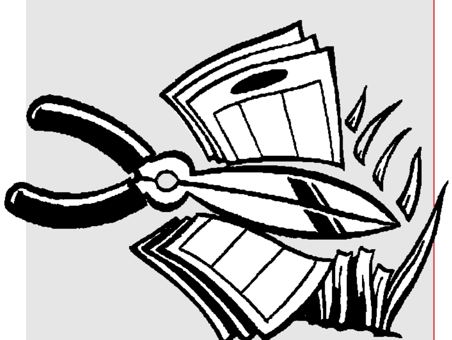
It's time to learn!

Come to Field Day 2005
June 21



Take a Short Course

- *Landscape Architects*
- *Landscape Professionals*
- *Landscape Managers*



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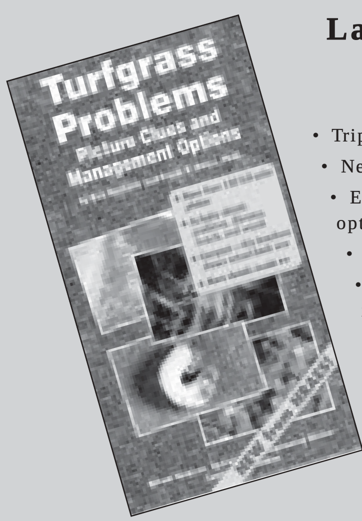

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Seed Lot Influences on Turf Establishment

It is common practice in cool season grass management to establish turf on athletic fields and golf courses using seed mixtures of two or more grass species. Differences in germination characteristics of grass species can have a significant impact on the successful establishment of turf.

Researchers at The Royal Veterinary and Agriculture University in Denmark used a curve-fitting procedure to investigate the variation in germination characteristics within and among cultivars of three turfgrass species: slender creeping red fescue (*Festuca rubra* L. var. *littoralis* Vasey), perennial ryegrass (*Lolium perenne* L.), and Kentucky bluegrass (*Poa pratensis* L.).

Cultivars differed in final germination percentage in all three species, with Kentucky bluegrass having the slowest and least uniform germination, as well as the lowest final percentage. Cultivars of Kentucky bluegrass and red fescue differed significantly in mean germination time and time from 25% to 75% germination.

Seed lots within cultivars also differed considerably in germination characteristics. Researchers noted that previous studies were conducted using only one seed lot per cultivar. These results suggest that cultivar differences should be tested against seed lot differences by representing each cultivar by more than one seed lot.

From: Larsen, S.U. and B.M. Bibby. 2004. Use of germination curves to describe variation in germination characteristics in three turfgrass species. Crop Sci. 44:891-899.

Landscape Water Quality Effects Still Uncertain

Lawn turf is perceived to be an intensively managed system requiring large amounts of fertilizers and pesticides, thereby posing significant risk to environmental quality, specifically water pollution.

In contrast, native plant systems that utilize plant material thought to be well-adapted to regional climatic conditions are thought to provide environmental benefits and require fewer inputs, thereby protecting water quality.

Researchers at the University of Florida (and Cornell alum Professor John Cisar) evaluated the phosphorus and potassium leaching of a turfgrass system compared to a native landscape on a sandy soil prone to leaching losses. The soil was typical of Florida situations and similar to Long Island and other sandy soils in NY.

The researchers found that leaching losses were very high during the establishment phase and during periods of high rainfall in both systems. However, after the planting phase the native system had high leaching losses even though much less fertilizer was applied compared to the lawn system. Over time as less fertilizer was applied the leaching losses declined.

At the end of the study the researchers concluded that minimizing leaching losses for residential landscapes is complex. It is not simply a matter of excluding certain types of vegetation, but rather consideration for species, diversity, fertilization, and water use that must be understood before real progress in improving environmental quality can occur.

From: Erickson, J.E., J.L. Cisar, G.H. Snyder, and J.C.Volin. 2005. Phosphorus and potassium leaching under contrasting residential landscape models established on a sandy soil. Crop Sci. 45:546-552.

Send Us A Letter

We enjoy receiving letters from readers reacting to the articles and information presented in *CUTT*. Encouraging a free-flowing, two-way communication between our readers and Cornell's Turfgrass Team can only make *CUTT* a better, more relevant publication.

Send your comments to *Cornell University Turfgrass Times*, 134A Plant Science Building, Cornell University, Ithaca, NY 14853, or via email to fsr3@cornell.edu.

Scanning the Journals

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Minimizing leaching losses is not simply a matter of excluding certain types of vegetation. Rather, species, diversity, fertilization, and water use must be understood before real progress in improving environmental quality can occur.

CUTT

Nitrogen Fertilization

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Some golf courses on eastern Long Island are volunteering to lower nitrogen applications, where possible, and to have total nitrogen in the groundwater under their course not to be above 2 mg L^{-1}, or a fifth of the drinking water standard, in order to protect the health of the estuaries.

Unfertilized turf had greater amounts of phosphorus runoff compared to lawns (after establishment) that were fertilized with a range of different fertilizers.

To be sure that turfgrass quality is always high, why not fertilize at the highest nitrogen rate listed? Some turfgrass managers do follow this philosophy, especially if they are guaranteeing high quality or may be responsible for only part of the maintenance, like fertilizing and pest control, and are only on-site occasionally. In some cases the highest rate may overfertilize the grass, leading to several consequences such as lowering the stress tolerance and increasing the likelihood of some diseases. Also, fertilizers are costly and may use a lot of natural resources to produce. Thus, over-fertilization can be very wasteful and possibly hazardous to turf.

Water Quality Problems

Excess nitrogen also can have a very harmful effect on drinking water sources and aquatic habitats. Parts of New York, such as Long Island, have had decades of groundwater quality problems associated with nitrogen, especially as a drinking water source where nitrate-nitrogen levels above 10 mg L^{-1} are considered unsafe. In marine habitats, nitrogen is often the nutrient limiting algae growth that damages marine life and is thus of great concern in coastal areas of southeastern New York. In consideration, some golf courses on eastern Long Island are volunteering to lower nitrogen applications, where possible, and to have total nitrogen in the groundwater under their course not to be above 2 mg L^{-1} , or a fifth of the drinking water standard, in order to protect the health of the estuaries. To accomplish this, golf courses need to average no more than 2.9 lbs. N/1,000 sq.ft./yr. on the areas they fertilize.

There is also public concern about how much nitrogen is used to fertilize lawns on eastern Long Island. One might ask, why fertilize lawns at all? Yes, there are aesthetic reasons for fertilizing—you get a dark green color with fewer weeds—but there are good environmental reasons for fertilizing as well. According to a 2004 article I wrote with Zach Easton, unfertilized turf had greater amounts of phosphorus runoff compared to lawns (after establishment) that were fertilized with a range of different fertilizers.

So, How Much?

Back to the central question, how much should lawns be fertilized with nitrogen. Using the amounts shown for different grasses is one way. If the lawn is dominated by fine fescue then fertilize from 1–2 lbs. N/1,000 sq.ft./yr. If the lawn is dominated by Kentucky bluegrass, more nitrogen should be used, 3–4 lbs. N/1,000 sq.ft./yr. With perennial ryegrass the highest level should be applied, 2–6 lbs. N/1,000 sq.ft./yr.

What does the latest research show on how much nitrogen is needed by lawns? The New York State Turfgrass Association has been funding a project that Joann Gruttadaurio, Jeff Barlow and I have been conducting for the past

Table 1. Impact of nitrogen application rates on average turfgrass quality.

Site	Nutrient Applied	Annual Rate lbs. N/1,000 sq.ft./yr.	Visual Quality
Ithaca (2 year average)	N	0	6.2*
		2	7.1
		4	6.9
		8	7.1
	N-K	8-1.8	7.2
		LSD (P≤0.05)	0.3
Long Island (1 year average)	N	0	5.6
		2	5.7
		4	5.9
		8	6.1
	N-P-K	8-1.8-3.6	6.1
		LSD (P≤0.05)	0.3
Lake Placid (2 year average)	N	0	5.3
		2	5.3
		4	6.3
		8	5.9
	N-P-K	8-1.8-3.6	7.1
		LSD (P≤0.05)	1.0

* Visual quality on a scale of 1-9, where 6.5 is considered acceptable.

two years. The study involves soil test calibration for phosphorus and potassium but also contains treatments with different nitrogen rates of 0, 2, 4, and 8 lbs. N/1,000 sq.ft./yr. The study is being conducted at three sites: in Central New York at the Robert Trent Jones Golf Course at Cornell University in Ithaca, on Hudson silty clay loam; in northern New York at the Lake Placid Resort Club in Lake Placid, on a Monadnock sandy loam; and the third in southeastern New York at Bethpage State Park in Farmingdale, on an Enfield silt loam.

The sites were seeded with a mixture of typical lawns grasses (70:20:10, by weight, of Kentucky bluegrass varieties "Midnight", "Total Eclipse" and "Washington"; "Attila" Hard Fescue; and "Manhattan III" perennial ryegrass. We found (see Table 1): at Ithaca only 2 lbs. N/1,000 sq.ft./yr. was needed to have acceptable turf (>6.5), whereas on Long Island even 8 lbs. N/1,000 sq.ft./yr. did not produce season-long acceptable quality. At Lake Placid, 8 lbs. N/1,000 sq.ft./yr., along with additional phosphorus and potassium, was needed to have acceptable turf. This is a long-term study and there will be updates to help answer the question of how much nitrogen is enough.

Other Research

Research also has been done at other northeastern universities. At Connecticut, Kopp and Guillard reported in 2002 on the influence of nitrogen rate and soil factors on lawn quality, using 35% Kentucky bluegrass, 35% creeping red fescue and 30% perennial ryegrass. Nitrogen was applied at 0, 2, 4, 6, and 8 lbs. N/1,000 sq.ft./yr. The study had two sites, one with a fine sandy loam soil with good water holding capacity and the other was a gravelly sandy loam that was excessively well drained and droughty.

On the first site, turfgrass quality was always acceptable at 2 lbs. N/1,000 sq.ft./yr., where even the unfertilized plots had acceptable quality during a dry summer period. On the excessively well drained site, only 50% of the time did applying nitrogen improve the quality—and not even 8 lbs. N/1,000 sq.ft./yr. consistently produce acceptable quality lawns. Kopp and Guillard also compared the effect of clipping removal and turfgrass quality. On the excessively well drained soil, returning clippings had no effect on turfgrass quality, but on the site with soils having better water holding capacity, only a third of the time turfgrass quality was better when clippings were returned. This information illustrates the need to consider a range of nitrogen applications since site factors like soil properties can dramatically influence quality and the amount of nitrogen that is needed to produce an acceptable quality lawn.

Environmental Concerns

Environmentally, what do we know about the effect of lawn fertilizing on water quality? For example, what if you fertilize a Kentucky bluegrass lawn at the highest recommended rate (4 lbs. N/1,000 sq.ft./yr.), what would the influence be on groundwater quality? I conducted a three year study to answer this question, where Kentucky bluegrass was fertilized either twice a year or 4 times per year for a total of 4 lbs. N/1,000 sq.ft./yr. The study, reported in 2004, was conducted at Riverhead, Long Island, with ten different nitrogen sources.

During a dry or normal precipitation year, nitrogen leaching for water-soluble sources ranged from 0.9–5% of the amount applied, whereas slow-release sources had 0.5–7.4% leaching. During a year with 11 inches of rainfall more than normal, water-soluble sources had nitrogen leaching values 12–29% of the amount applied whereas slow-release sources had much less leaching (2–7%). The average of all sources over all three years was 5.2% of the amount of nitrogen applied was leached. This amount of leaching would have resulted in an estimated groundwater nitrate-nitrogen concentration of 1.8 mg L^{-1}, far below the drinking water standard of 10 mg L^{-1} and less than the target set by eastern Long Island golf courses.

Summary

Understanding how much to fertilize lawns with nitrogen is complex. Site factors such as the species of turf (sometimes even cultivars) and soil properties drastically affect the amount of nitrogen needed to have an acceptable quality lawn. At least for Kentucky bluegrass, fertilizing at a rate within the recommended range did not drastically affect ground water quality.

Researchers are working on a better way to judge nitrogen fertilization responses and environmental impacts by measuring the amount of nitrate collected in the soil by anion exchange membranes. Some day this or other techniques may be used to allow us to refine nitrogen applications on site-by-site case and remove the range of rates now commonly used.

A. Martin Petrovic, Ph.D.

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CUTT

The "Best" Soil Test

Program Spotlight

I believe that, in fact, the saturated paste test and other water-based extractions are among the easiest of tests to interpret, and that the results are useful, but they are often misinterpreted. No one disputes the appropriate use of saturated paste tests to assess soil salinity, but rather the disputes are over the usefulness of the mineral nutrients extracted by a saturated paste.

Two recent articles have described the saturated paste extraction, and the authors of the respective articles could not have more divergent views on this relatively recent addition to turfgrass soil analysis.

Dr. Carrow from the University of Georgia, along with numerous coauthors from across the United States, wrote in the September 2003 issue of *Golf Course Management* that with the saturated paste extraction, extracted nutrients do not equal soil fertility, and that water-based extraction procedures are inferior to other extraction methods, even for sand-based rootzones.

A different view was presented in the February 2004 issue of *TurfNet Monthly*, where Joel Simmons outlined his thoughts on the usefulness of the saturated paste method. Mr. Simmons has found the saturated paste test to be an essential tool, and he stated that "paste extracts have proven valuable in quantifying problems and indicating sustainable solutions," while finding, in contrast to Carrow et al., that in sand root-based greens, the paste extract becomes a driving factor in fertility determinations.

Who Is Right?

How are we to know which view is correct? The subject of soil testing is complicated enough without having to worry about whether a particular test is useful or not. I have been studying water-based extraction methods (saturated pastes are a type of water-based extraction) on sand-based rootzones for the past few years, and I believe that, in fact, the saturated paste test and other water-based extractions are among the easiest of tests to interpret, and that the results are useful, but they are often misinterpreted. (I should note here that no one disputes the appropriate use of saturated paste tests to assess soil salinity, but rather the disputes are over the usefulness of the mineral nutrients extracted by a saturated paste.)

As the previous authors have clearly described the saturated paste procedure, I will jump right into the interpretation of the results. Why do I say that water-based extractions are among the easiest to interpret? First, water mixed with a soil can only extract water-soluble ions. The water-soluble ions are either the ions in soil solution or the ions present as soluble salts. We know exactly which ions are extracted. Unfortunately the same cannot be said of other methods, such as Mehlich 3, ammonium acetate or Morgan.

Next, water extractions adjust to the pH of the soil, unlike other extraction methods which extract at a different pH than the soil. Since we know that roots take up only those ions that are in solution, and because the roots are growing in a soil with the same pH as the water extracts, it seems likely that the ions extracted are actually readily available to the roots. While the ions extracted in a saturated paste are certainly meaningful, it is not possible to take the numbers and decide that they are low enough to justify fertilizer applications. If you want to use your soil test results to develop a fertilizer program, use a different extraction method.

Some Recommendations

With that said, how should the saturated paste results be interpreted? Here are some suggestions:

- Expect the amount of nutrients extracted to be low. Most of the nutrients in soils (and that includes sands too) are in minerals or organic matter or on exchange sites. Water-based extractants access only the soluble ions.
- Soluble ions are important because those are the ones that the roots can access.
- Low concentrations of soluble nutrients should not be taken as an indication that the nutrient is deficient. In the absence of calibration data relating soil nutrients to turfgrass function, it is not possible to determine if nutrient uptake is limited or not.
- We do know this: tissue calcium concentrations have decreased in experimental plots at Cornell University as we have increased the potassium application rate. Other studies have shown a decrease in potassium uptake when calcium application

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CUTT

A Preliminary Assessment of Putting Green Mowers

This is a preliminary report on the effect of mower type and cutting frequency on putting green performance in 2004.

Four walk-behind greens mowers were evaluated for their influence on creeping bentgrass putting green performance.

Experimental plots were established at the Cornell University Turfgrass Research Facility in Ithaca, NY on a creeping bentgrass/annual bluegrass (*Agrostis palustris/Poa annua*) soil-based putting green (pH = 6.7). Plots were 8 ft. x 10 ft. (2.4 m x 3.0 m) in size, and there were three replications of each treatment arranged in a randomized complete block design.

Plots were topdressed with straight sand once prior to the beginning of the trial. Contec 19-2-15 fertilizer was applied during the first week of the experiment at the rate of 1 lb. N/1,000 sq. ft. (92.9 m^2). Approximately 12 inches of rain was received during the 9 weeks of the trial, nearly twice the normal amount. Therefore, no supplemental irrigation was applied. Average daily temperatures ranged from a low of 55˚ F (13˚ C) to a high of 75˚ F (24˚ C).

Technical specifications for the mowers used in the study are presented in Table 1.

Table 1. Technical specifications of four greens mowers under study.

	Toro Greensmaster Flex 21	**Toro Greensmaster 1000**	**Jacobsen Tournament Cut-22** Independent Floating Reel	**Jacobsen Greens King 518A**
Width of Cut	21" (53.3 cm)	21" (53.3 cm)	22" (55.9 cm)	18" (45.7 cm)
Height of Cut	1/16-19/64" (1.5-7.5 mm)	5/64-1" (1.9-25 mm)	3/64-7/16" (1.2-11.1 mm)	3/64-7/16" (1.2-11.1 mm)
Weight	238 lbs. (108 kg)	208 lbs. (94.3 kg)	178 lbs. (81 kg)	215 lbs. (97 kg)
Reel Diameter	11 blades 5" (12.7 cm)	11 blades 5" (12.7 cm)	11 blades 5" (12.7 cm)	11 blades 5" (12.7 cm)
Bedknife	High carbon through-hardened steel	High carbon austempered steel	Hardened carbon steel	Hardened carbon steel
Roller	Grooved	Grooved	Grooved	Grooved

Treatments began on June 21 and continued through August 20. Table 2 shows the various cutting heights and frequency of cut.

Table 2. Cutting heights and frequency of cut.

Mower Type	**Bench Height (inch/mm)**	**Frequency**
Toro Greensmaster 1000 Fixed	0.125/3.17	7 d single
Toro Greensmaster 1000 Fixed	0.125/3.17	5 d single + 2 d double
Toro Greensmaster 1000 Fixed	0.125/3.17	4 d single + 3 d double
Toro Greensmaster Flex 21	0.100/2.54	7 d single
Toro Greensmaster Flex 21	0.100/2.54	5 d single + 2 d double
Toro Greensmaster Flex 21	0.100/2.54	4 d single + 3 d double
Jacobsen Cut-22 Floating Reel	0.075/1.90	7 d single
Jacobsen Cut-22 Floating Reel	0.075/1.90	5 d single + 2 d double
Jacobsen Cut-22 Floating Reel	0.075/1.90	4 d single + 3 d double
Jacobsen Greens King 518A Fixed	0.125/3.17	7 d single
Jacobsen Greens King 518A Fixed	0.125/3.17	5 d single + 2 d double
Jacobsen Greens King 518A Fixed	0.125/3.17	4 d single + 3 d double

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Program Spotlight

Four walk-behind greens mowers were evaluated for their influence on creeping bentgrass putting green performance.

Approximately 12 inches of rain was received during the 9 weeks of the trial, nearly twice the normal amount. Therefore, no supplemental irrigation was applied.

Soil Test

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rate is increased. Turfgrass plots at Cornell University receiving no potassium or calcium fertilizer for the past two years have maintained normal levels of tissue calcium and potassium. Grasses are able to take up sufficient levels of many nutrients from the soil as long as they are supplied with enough nitrogen. Be wary of creating nutrient imbalances rather than eliminating them when making applications of calcium or potassium.

• Wheat produces 95% of maximum yield at soil solution phosphorus at 0.028 parts per million (ppm). For corn the 95% yield threshold is only 0.025 ppm. I would not concern myself with low phosphorus levels in a saturated paste extract. The forms of phosphorus in soil are either insoluble or are bound to soil particles. To diagnose a phosphorus deficiency I would collect a few tissue samples, submit them for analysis to a reputable laboratory, and determine that phosphorus application is required only if the tissue nitrogen is above 4% and the tissue phosphorus is less than 0.5%. If the tissue nitrogen is less than 4%, increase nitrogen fertilizer before worrying about any other problems.

• Bicarbonates in soil do not cause structural problems or sealing, nor are they bound to the soil colloid. High bicarbonate levels in a saturated paste extract are simply an indication that sodium is likely present. Why is this? Simple chemistry. Calcium or magnesium carbonates and bicarbonates are relatively insoluble (thus, they precipitate from solution). Sodium or potassium carbonates and bicarbonates are quite soluble (thus, they dissolve in water). Electroneutrality must be maintained in soils and in solutions, so the negative charge from anions such as bicarbonate must be balanced by positive charge from cations. High bicarbonate levels in a saturated paste extract indicate that sodium is the cation which balances the negative charge of the bicarbonate. That sodium can cause dispersion of soil particles. If high levels of bicarbonate are found in a saturated paste test, I would check the sodium adsorption ratio (SAR) of my irrigation water and take steps to address that problem.

• Use the saturated paste test to assess nutrient relationships in the soil. In general, I find it much more useful to look at soil test data as an indicator of available nutrients but to use tissue analysis as a means to detect nutrient deficiencies. Roots actually see a flux of nutrients, but current soil analysis methods measure a nutrient concentration, not a flux. Tissue tests tell us what the plant has, so there are no questions about whether a certain nutrient is available or not, deficient or not, or sufficiently mobile or not. In the tissue there are either adequate amounts or there are not. Final answer.

• Keep in mind that we do not have any data that correlates water extractable nutrient levels with turfgrass quality. Think carefully before making fertilizer applications based on soil test data. As a former golf course superintendent myself, I am aware of (and guilty of) the desire to apply a suite of nutrients to ensure a high quality playing surface.

• If fertilizers are necessary, the saturated paste test is not an ideal method for determining the nutrient requirement.

• With all that said, if one wishes to get the best commercially available approximation of soil solution, run a saturated paste on your soil samples.

A Final Thought

Unfortunately, the relationship between soil nutrients and turfgrass functional quality is not yet clear. Ongoing research at Cornell and other universities is addressing this issue and I am optimistic that it will soon be possible to interpret turfgrass soil tests with more clarity.

Micah Woods

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As a former golf course superintendent myself, I am aware of (and guilty of) the desire to apply a suite of nutrients to ensure a high quality playing surface.

Putting Green Mowers

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Plots were rated for turf quality on a scale of 1 to 9, where 1 = excellent quality, 9 = poor quality, and 6 = acceptable quality. Plots were also rated on two dates (July 25 and August 21) for % basal crown rot anthracnose (*Colletotrichum graminicola*).

There were significant differences in turf quality depending on the mower. Table 3 presents the overall turf quality means for the 4 mowers when averaged over frequency treatment.

Table 3. Overall turf quality means for the 4 studied mowers.

Mower	Turf Quality
Jake Float	7.3 a
Jake Fixed	7.2 a
Toro Flex	6.7 b
Toro Fixed	5.5 c

Means followed by the same letter are not significantly different (p=0.05) according to the LSD test.

There were also significant differences among the 3 mowing frequencies. Turf quality means for each frequency are shown in Table 4 when averaged over mower type.

Table 4. Turf quality means related to mowing frequency.

Frequency	Turf Quality
7 d single	7.2 a
5 d single + 2 d double	6.8 b
4 d single + 3 d double	6.1 c

Means followed by the same letter are not significantly different (p=0.05) according to the LSD test.

The interaction effect between mower and frequency was not significant (p=0.05).

Plots were rated twice for anthracnose percentage. The treatment means in Table 5 show that the Toro Fixed mower had a significantly higher incidence of anthracnose than the other three mowers when averaged over frequency treatment.

Table 5. Percentage incidence of anthracnose related to mower type.

Mower	Percentage Anthracnose
Toro Fixed	21.7 a
Toro Flex	10.6 b
Jake Fixed	6.7 bc
Jake Float	2.8 c

Means followed by the same letter are not significantly different (p=0.05) according to the LSD test.

Not surprisingly, plots receiving the most severe mowing regimen also had the highest incidence of disease, as shown in Table 6.

Table 6. Incidence of disease related to mowing regimen.

Frequency	Percentage Anthracnose
4 d single + 3 d double	18.1 a
5 d single + 2 d double	8.8 b
7 d single	4.4 c

Means followed by the same letter are not significantly different (p=0.05) according to the LSD test.

Frank S. Rossi and Mary C. Thurn

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Need your irrigation water tested?

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HORTICULTURE Elemental/Nutrient Analytical LABORATORY

The Horticulture Elemental/Nutrient Analytical Laboratory is one of a small number of university laboratories nationwide dedicated to assisting growers and homeowners in evaluating the nutritional and environmental status of their plants, water and soil.

The lab has been performing plant nutrient analyses for growers and researchers since the 1950s. Cornell faculty work closely with lab personnel to provide fertilizer recommendations and consultations on growers' specific problems. Soil or plant samples may also be submitted for total carbon/nitrogen ratios.

In the last decade, lab services have expanded to include environmental testing of water, plants, amended soil, and sewage sludge. This provides homeowners, turf managers and municipalities with levels of potentially toxic heavy metals so that they can evaluate the safety of their environment. State-of-the-art plasma emission technology is used to provide simultaneous elemental analysis of 30 elements.

The Horticulture Elemental/Nutrient Analytical Laboratory is committed to quality data, and the operation is tested quarterly through the North American Proficiency Testing Service. Please contact the lab for more information on sample preparation, available services and prices. The Horticulture Elemental/Nutrient Analytical Laboratory, 20 Plant Science, Cornell University, Ithaca, NY 14853-5908; (607) 255-1785; www. hort.cornell.edu/department/facilities/icp/index.html.

Energy Management

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Food and Pests

During the mid-1970s, the price of ammonia used for fertilization more than doubled. As a result, fertilizer prices also increased. In fact, fertilizers might have twice the energy per dollar value as the equipment used to manage a golf course. Even though much less is spent on fertilizers compared to a $25,000 mower, the energy needed to produce the fertilizer based on what you pay for it is considerably higher than the energy that the equipment consumes.

Clearly, reducing the use of fertilizer has direct energy savings, but also indirect savings by reducing turf growth that would require additional mowing. Also, proper timing of application to promote color, and turf health without stimulating top growth, is an important energy-saving measure that would include the use of iron for improved turf color.

Pesticide manufacturing is the highest energy-consuming practice on a weight basis of all agricultural inputs. In fact, the energy for production is two to four times greater than that for fertilizers. This includes the production of the active ingredient and the energy used for formulating the product, often with a petroleum-based formulant.

However, the high level of activity at low amounts of active ingredient needed to get the desired results and benefit of selectivity (killing pests, but not grass) provide other benefits that could reduce energy use, such as for weed control that would require enormous amounts of labor and energy.

Crucial in the pesticide and energy-use discussion are intensive preventive strategies, especially for insecticide use. This argues strongly for a more Integrated Pest Management approach to soil insect control, one that emphasizes cure rather than prevention. This effort alone could save substantial energy on many courses with the increased use of preventive materials such as imidacloprid (Merit).

Energy Conservation

Very little research has been conducted on energy-conserving turfgrass management. We are generally engaged in pest control and other measures that produce improved turfgrass quality and aesthetics. In the industry, how many turf managers take the time to review annual maintenance for fuel/energy use?

Records like this might reveal how much energy use has increased over the years as more golfers are on the course. At this point, the additional cost for energy might not be prohibitive. But at some point it might.

Audubon International includes energy efficiency as a component of its Cooperative Sanctuary and Signature Programs. These programs not only look at the golf course, but at the entire facility management. This is an important clarification when viewing energy costs and evaluating efficiency in budgets between the clubhouse and the course. Nevertheless, there are significant challenges and opportunities ahead in the area of energy efficiency.

Frank S. Rossi, Ph.D.

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A Healthy Ecosystem

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Energy Management Fuels Efficiency

Increasing fuel prices are causing me to reflect on how the future of our industry is intimately linked to fuel prices. A 1980 National Academy of Science committee report suggests that world production of oil and gas is expected to peak by the end of the 20th century (Hubberts Peak), followed by increased prices and strained reserves.

Environmentally, there are additional costs associated with carbon emissions from gas-powered equipment. Ten years ago, scientists from around the world gathered at the Intergovernmental Panel on Climate Change and concluded that the earth's temperature will increase a few degrees in the next decade. This point of view was initially considered controversial without significant scientific support. However, a host of recent measurements have supported the conclusion that the earth is warming.

For these reasons, the turf industry should be aware of the economic and environmental aspects of fuel consumption.

An Energy Sink

A chapter in the 1992 *Turfgrass Monograph* from the American Society of Agronomy reviewed the issue of energy use and turfgrass maintenance. The authors suggest that the excesses of having to fertilize and spray turfgrass for lush green carpets and the futility of having to mow weekly to maintain such conditions are only one side of the fuel issue.

The contention is there is a great need for the industry to always strive to reduce the use of nonrenewable energy (fuel), improve the public's understanding of the benefits of turf, and recognize that little information exists on the costs and benefits of turf.

Technological advances in the areas of mowing, fertilization, irrigation, and pest control have been emphasized, though without recognizing the energy associated with each practice. In the last several decades, mowing equipment has been used more extensively and more frequently, including mowing putting greens seven days a week, sometimes twice or three times per day. Petroleum-based synthetic pesticides and fertilizers as well as plastic irrigation equipment are common and enable us to have higher quality turf.

A Florida study from 1974, published in the *Journal of Environmental Systems*, found that compared with all other managed turfgrass areas (sports fields, home lawns, corporate parks, airports), golf courses have the highest costs per unit area from both an economic and energy perspective. This was confirmed in a California study published in the journal *Ecology*, where energy costs were determined. In that study, the total energy use was similar to the Florida study, however, almost 70 percent of all the energy used for turf management was for irrigation.

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CORNELL Turfgrass

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